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International Comparison of Real R & D Expenditures and Purchasing Power Parities

(Summary)

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1. Introduction <A7

The expanding world-wide competition in research and development is giving rise to numerous attempts by a range of organizations to compare research and development expenditure among various countries. If expenditure is calculated on an exchange rate basis, figures over the past few years are greatly affected by fluctuating exchange rates. Another problem is that since exchange rates do not always correspond to price-level ratios on a national currency base, the result of conversions do not necessarily reflect the actual amount of material or services that can be purchased with the R&D expenditure, that is, the purchasing power of the amount spent on research and development **(Note 1)**.

Purchasing power parities have been developed as a currency conversion rate that could adjust such price level differences between countries, but they cannot be applied in all cases (hereinafter, purchasing power parities will refer to OECD purchasing power parities unless otherwise indicated). There is some doubt as to whether the current purchasing power parities, which were calculated based on consumption goods, are in fact effective enough to be used for R&D expenditure. In this report we have clarified the key points that must be noted when using purchasing power parities for R&D expenditure by itemizing R&D expenditure and examining the price level for each expenditure item. We have also calculated the real conversion rate of R&D expenditure between the United States and Japan to determine the price level of each R&D expenditure item.

In this report we have used the 1985 estimated purchasing power parities based on the Geary Khamis Method.

<C7 (Note 1) In comparing R&D expenditure, we should take note of the differences among countries in what they mean by research and development and what it covers. And when comparing the monetary amount of R&D expenditure over a set period, we must also consider differences in the price inflation rate among countries. We shall not touch on these points in this report.

2. OECD Purchasing Power Parities

After discussing changes in and calculation methods for purchasing power parities, we shall cover the points that must be looked at when using purchasing power parities to convert R&D expenditure.

2.1 Purchasing Power Parities

Every five years OECD conducts a major survey to calculate purchasing power parities. Parities used in recent years are those calculated in 1985. The 1985 survey gives the purchasing power parity values for that year, while values for other years are adjusted using the difference between various countries and the United States in the price inflation rate based on the 1985 purchasing power parities. On the other hand, the exchange rate has fluctuated considerably over the past few years, partly because of currency speculation, and for this reason, purchasing power parities show a much more gradual move than the IMF exchange rate (Figure 1). Figures for all countries at times displayed a substantial gap between the purchasing power parity and the exchange rate.

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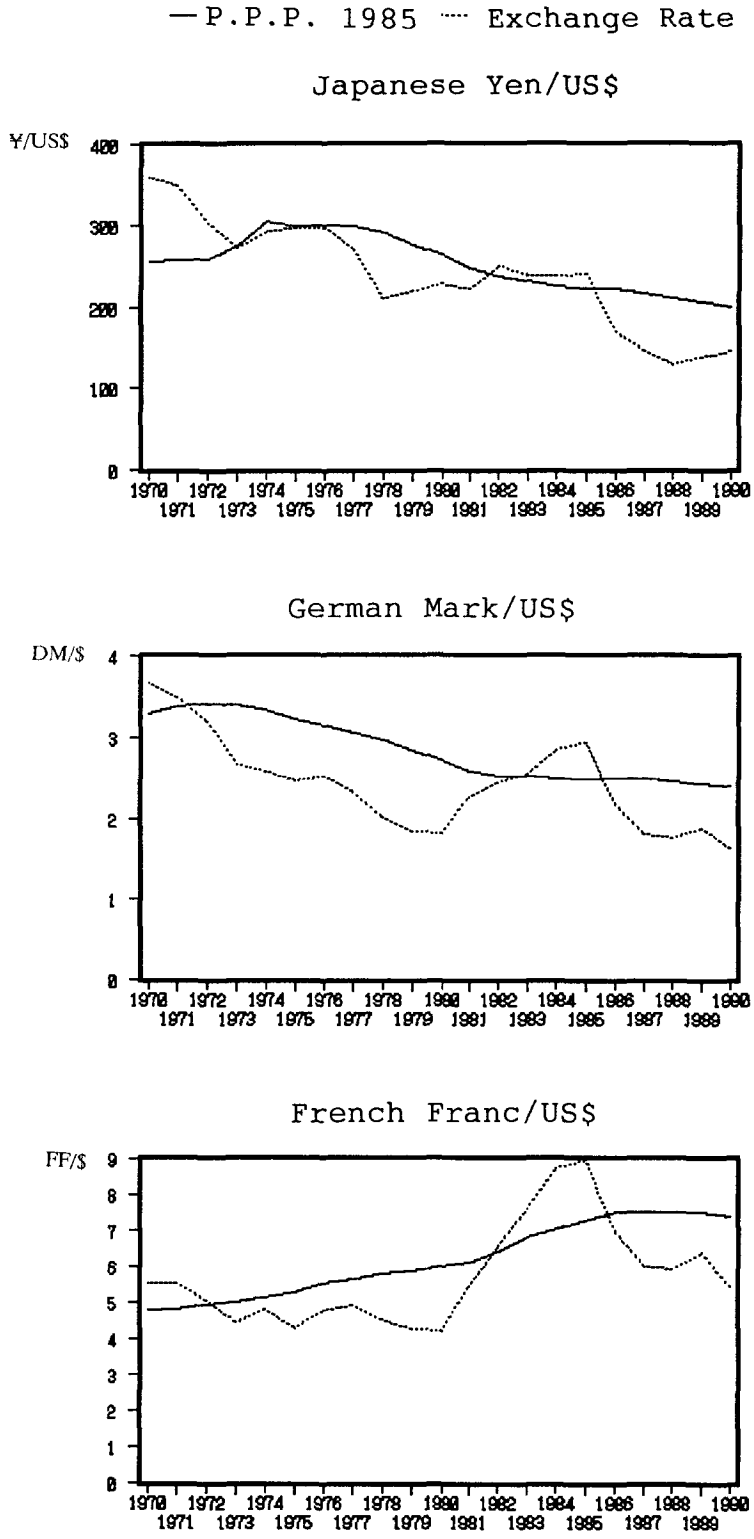
Japan's 1992 white paper on science and technology contained graphs showing R&D expenditure by the major industrialized countries calculated using purchasing power parities (Figure 2). Comparing figures for the United States and Japan, we can see that between 1970 and 1986 R&D expenditure rose much more sharply in the United States than in Japan. On a purchasing power parity conversion, R&D expenditure by the United States in 1991 was about 2.4 times as great as that by Japan (Japan's R&D expenditure is for the natural sciences only). On an exchange rate basis, however, it is only about 1.6 times as great.

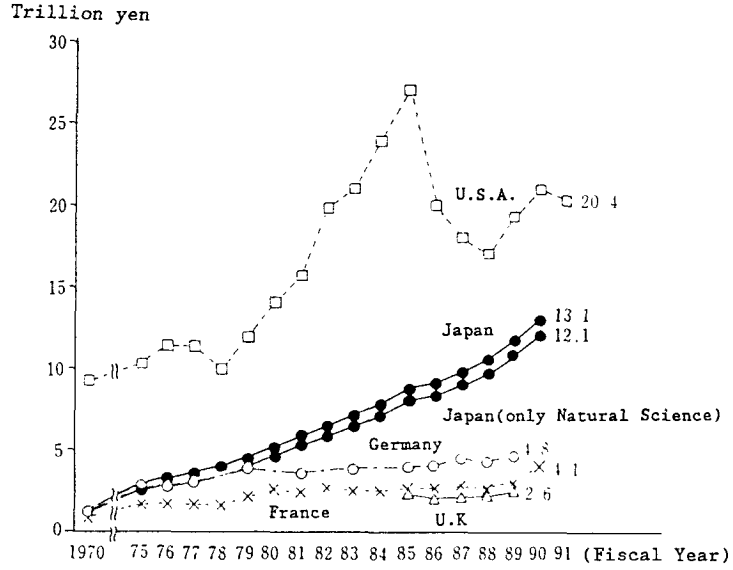
Figure 1 Purchasing Power Parities and Exchange Rates of Major Countries



Source:OECD, 'Purchasing Power Parities and Real Expenditures'

Figure 2 Yen Conversion of R&D Expenditure in Major Countries Based on Exchange Rate and Purchasing Power Parities

IMF Exchange Rate



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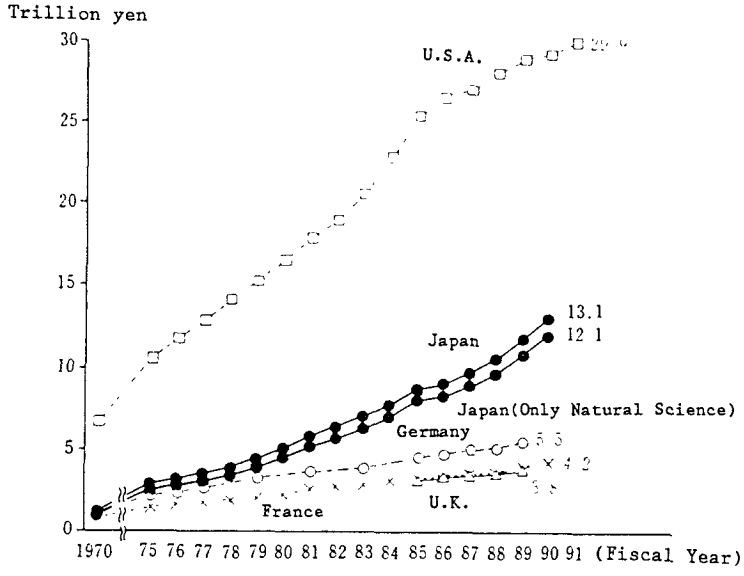


Source: White Paper on Science & Technology in 1992

2.2 Calculating OECD Purchasing Power Parities

In calculations of overall GDP purchasing power parities, price levels of the various GDP expenditure items will affect the proportion of GDP of each item, depending on the characteristics of the calculation methods described later. In 1985 end consumption by the private sector accounted for about 60% of GDP in each country. The major items of private sector consumption included food, medical care, housing, clothing, personal accessories and education. Government end consumption accounted for 10-20%, and gross fixed capital formation accounted for 20-30% in each country. Thus we can say that price levels of consumption goods greatly influences the calculation of purchasing power parities against GDP.

For the 1985 estimations, the OECD gathered data on the prices of about 3,000 kinds of goods and services that have a significant effect on the cost of living (2,500 kinds of consumption goods or services, 30 kinds of government programs and welfare services, and 250 kinds of machinery and equipment) and the monetary value of detailed GDP items that correspond to these goods and services from each country, and used these data as the basis for calculating purchasing power parities.

The Geary Khamis Method is the main methodology of purchasing power parity calculations[1][2][3]. The Geary Khamis Method is one which aims at securing transitivity in calculations of price ratios among countries, and its special feature is that to secure transitivity it estimates an international price for each product or service. Broadly speaking, the purchasing power parities for each country is indicated as a ratio of domestic price to international price of the same product or service.

Below is the Geary Khamis Method calculation formula. In the formula, i = product, j = country, P = product price (currency

base), Q = product quantity, and PPP = purchasing power parity.

$$PPP_j = \sum_i (P_{ij} \cdot Q_{ij}) \;/\; \sum_i (P_i \cdot Q_{ij})$$

The purchasing power parity is obtained by dividing the total monetary value of the various products in country j ($\Sigma(P_{ij} \cdot Q_{ij})$ currency base of country j) by the real value of the products ($\Sigma(P_i \cdot Q_{ij})$ standard national currency base) based on international prices π_i. The international price for product i is obtained by the following formula.

$$\pi_i = \sum_j \{P_{ij}/PPP_j \cdot (Q_{ij}/\Sigma Q_{ij})\}$$

An international price for product i is calculated by first obtaining the ratio of the price of product i to the purchasing power parity for each country, then converting this price ratio to a weighted average using the quantum weight for each country ($Q_{ij}/\Sigma Q_{ij}$). Thus purchasing power parities depend on international prices, and vice versa, and are calculated by solving simultaneous equations.

In the actual calculations, we first calculate the prices for the basic headings (the smallest items whose monetary value can be obtained from GDP data), each of which consists of similar products, from the product prices. We then calculate GDP purchasing power parities from the prices and monetary values of the basic headings using the Geary Khamis Method. Purchasing power parities are calculated not just for GDP as a whole, but for each GDP expenditure item as well **(Note 2)**. This has monetary value which indicates real use value as real value, and monetary value

which corresponds to $\Sigma(P \cdot Q)$ as nominal value (refer to columns (1) and (2) in Table 1). [3]

(Note 2) GDP purchasing power parities calculated as described above are on a United States basis (the purchasing power parity of the dollar is set at exactly one dollar). However this is not the case for the purchasing power parity of each GDP item, so the following additional calculation is required to bring it to a U.S. basis. Here, N = Japan, and A = United States.

Individual item's purchasing power parity on a U.S. dollar basis

$$= \frac{\text{Nominal value of fields of Japanese GDP expenditure / Real value of fields of Japanese GDP expenditure}}{\text{Nominal value of fields of U.S. GDP expenditure / Real value of fields of U.S. GDP expenditure}}$$

$$= \frac{\Sigma_i (P_{Ni} \cdot Q_{Ni}) / \Sigma_i (\pi_{Ni} \cdot Q_{Ni})}{\Sigma_i (P_{Ai} \cdot Q_{Ai}) / \Sigma_i (\pi_{Ai} \cdot Q_{Ai})}$$

Table 1-1 Japan's Nominal GDP, Real GDP and Purchasing Power Parities (1985 Estimation) in 1985

Item No.	GDP Expenditure Items	① Nominal Value (Billion¥)	② Real Value (Million$)	③ Ratio (Nominal Basis)	④ Ratio (Real Basis)	⑤ P.P.P. (¥/$)
1	PRIVATE FINAL CONSUMPTION EXPENDITURE	184428	859779	58.3%	60.4%	218
2	FOOD, BEVERAGES AND TOBACCO	41390	152235	13.1%	10.7%	294
3	Food	33275	122019	10.5%	8.6%	297
4	Bread and Cereals	6881	25396	2.2%	1.8%	260
5	Meat	4279	11492	1.4%	0.8%	465
6	Fish	7057	29963	2.2%	2.1%	277
7	Milk, cheese and eggs	2060	7464	0.7%	0.5%	299
8	Oils and fats	399	1203	0.1%	0.1%	335
9	Fruits, vegetables and potatoes	5797	19047	1.8%	1.3%	302
10	Other food	6803	27454	2.2%	1.9%	264
11	Beverages	5194	15424	1.6%	1.1%	326
12	Non-alcoholic beverages	1429	5231	0.5%	0.4%	256
13	Alcoholic beverages	3765	10193	1.2%	0.7%	363
14	Tabacco	2920	14792	0.9%	1.0%	234
15	CLOTHING AND FOOTWEAR	11766	53675	3.7%	3.8%	238
16	Clothing including repairs	10555	47588	3.3%	3.3%	243
17	Footwear including repairs	1211	6087	0.4%	0.4%	207
18	GROSS RENT FUEL AND POWER	34756	189859	11.0%	13.3%	157
19	Gross rent and water charges	28787	167664	9.1%	11.8%	133
20	Fuel and power	5969	22195	1.9%	1.6%	319
21	HOUSEHOLD EQUIPMENT AND OPERATION	10282	45558	3.3%	3.2%	246
22	Furniture, floor coverings & repairs	943	2300	0.3%	0.2%	487
23	Household textiles & repairs	1457	6478	0.5%	0.5%	204
24	Household appliances & repairs	2814	13591	0.9%	1.0%	210
25	Other household goods & services	5069	23189	1.6%	1.6%	239
26	MEDICAL AND HEALTH CARE	19012	137088	6.0%	9.6%	107
27	Medical and pharmaceutical Products	1231	7147	0.4%	0.5%	120
28	Medical and health services	17781	129941	5.6%	9.1%	107
29	TRANSPORT AND COMMUNICATION	17411	73649	5.5%	5.2%	280
30	Personal transport equipment	2862	16070	0.9%	1.1%	187
31	Operation of transport equipment	5921	14056	1.9%	1.0%	598
32	Purchased transport services	6849	32861	2.2%	2.3%	165
33	Communication	1779	10662	0.6%	0.7%	154
34	EDUCATION, RECREATION AND CULTURE	17244	67094	5.5%	4.7%	290
35	Recreational equipment and repairs	5258	25557	1.7%	1.8%	222
36	Recreational and cultural services	6720	31991	2.1%	2.2%	225
37	Books, magazines and newspapers	1808	7604	0.6%	0.5%	285
38	Education	3459	1942	1.1%	0.1%	2224
39	MISCELLANEOUS GOODS AND SERVICES	31655	136370	10.0%	9.6%	253
40	Restaurants, cafes and hotels	14191	45468	4.5%	3.2%	375
41	Other goods and services	17463	90902	5.5%	6.4%	196
42	NET PURCHASES ABROAD	912	4251	0.3%	0.3%	218
43	GOVERNMENT FINAL CONSUMPTION EXPENDITURE	30747	159431	9.7%	11.2%	171
44	COLLECTIVE GOVERNMENT SERVICES	15938	80599	5.0%	5.7%	179
45	INDIVIDUAL GOVERNMENT SERVICES	14809	78832	4.7%	5.5%	160
46	GROSS FIXED CAPITAL FORMATION	87624	342493	27.7%	24.0%	275
47	CONSTRUCTION	54111	197403	17.1%	13.9%	297
48	Residential buildings	15446	45270	4.9%	3.2%	403
49	Non-residential buildings	15189	58547	4.8%	4.1%	271
50	Civil engineering works	23476	93586	7.4%	6.6%	236
51	MACHINERY AND EQUIPMENT	33517	145090	10.6%	10.2%	246
52	Transport equipment	7148	35196	2.3%	2.5%	211
53	Non-electrical equipment	17993	74411	5.7%	5.2%	270
54	Electrical equipment	8376	35483	2.6%	2.5%	212
55	INCREASE IN STOCKS	2540	9372	0.8%	0.7%	297
56	BALANCE OF EXPORTS AND IMPORTS	10775	53259	3.4%	3.7%	237
57	GROSS DOMESTIC PRODUCT	316114	1424333	100.0%	100.0%	222

Source:Purchasing Power Parties and Real Expenditure in OECD, OECD

Table 1-2 U.S.A.'s Nominal GDP, Real GDP and Purchasing Power Parities (1985 Estimation)in 1985

Item No.	GDP Expenditure Items	① Nominal Value (Billion¥)	② Real Value (Million$)	③ Ratio (Nominal Basis)	④ Ratio (Real Basis)	⑤ P.P.P. (¥/$)
1	PRIVATE FINAL CONSUMPTION EXPENDITURE	2584275	2627501	65.5%	66.6%	1
2	FOOD, BEVERAGES AND TOBACCO	359248	388254	9.1%	9.8%	1
3	Food	278108	302820	7.0%	7.7%	1
4	Bread and Cereals	42395	40694	1.1%	1.0%	1
5	Meat	76639	95653	1.9%	2.4%	1
6	Fish	5970	7024	0.2%	0.2%	1
7	Milk, cheese and eggs	46128	49975	1.2%	1.3%	1
8	Oils and fats	5135	5185	0.1%	0.1%	1
9	Fruits, vegetables and potatoes	59652	59265	1.5%	1.5%	1
10	Other food	42189	45024	1.1%	1.1%	1
11	Beverages	49318	47695	1.2%	1.2%	1
12	Non-alcoholic beverages	16244	15234	0.4%	0.4%	1
13	Alcoholic beverages	33074	32461	0.8%	0.8%	1
14	Tabacco	31822	37739	0.8%	1.0%	1
15	CLOTHING AND FOOTWEAR	167351	181705	4.2%	4.6%	1
16	Clothing including repairs	141847	155154	3.6%	3.9%	1
17	Footwear including repairs	25504	26551	0.6%	0.7%	1
18	GROSS RENT FUEL AND POWER	514752	442787	13.0%	11.2%	1
19	Gross rent and water charges	409120	317602	10.4%	8.0%	1
20	Fuel and power	105632	125185	2.7%	3.2%	1
21	HOUSEHOLD EQUIPMENT AND OPERATION	148532	162134	3.8%	4.1%	1
22	Furniture, floor coverings & repairs	51159	60752	1.3%	1.5%	1
23	Household textiles & repairs	15796	14332	0.4%	0.4%	1
24	Household appliances & repairs	25408	25748	0.6%	0.7%	1
25	Other household goods & services	56169	61302	1.4%	1.6%	1
26	MEDICAL AND HEALTH CARE	356628	274930	9.0%	7.0%	1
27	Medical and pharmaceutical Products	45918	31993	1.2%	0.8%	1
28	Medical and health services	310710	242937	7.9%	6.2%	1
29	TRANSPORT AND COMMUNICATION	406227	480447	10.3%	12.2%	1
30	Personal transport equipment	150479	158212	3.8%	4.0%	1
31	Operation of transport equipment	181135	257161	4.6%	6.5%	1
32	Purchased transport services	28191	22284	0.7%	0.6%	1
33	Communication	46422	42790	1.2%	1.1%	1
34	EDUCATION, RECREATION AND CULTURE	228472	258126	5.8%	6.5%	1
35	Recreational equipment and repairs	96810	104312	2.5%	2.6%	1
36	Recreational and cultural services	54255	58242	1.4%	1.5%	1
37	Books, magazines and newspapers	22574	27109	0.6%	0.7%	1
38	Education	54833	68463	1.4%	1.7%	1
39	MISCELLANEOUS GOODS AND SERVICES	389219	425041	9.9%	10.8%	1
40	Restaurants, cafes and hotels	154549	185580	3.9%	4.7%	1
41	Other goods and services	234670	239461	5.9%	6.1%	1
42	NET PURCHASES ABROAD	13846	14077	0.4%	0.4%	1
43	GOVERNMENT FINAL CONSUMPTION EXPENDITURE	722659	641757	18.3%	16.3%	1
44	COLLECTIVE GOVERNMENT SERVICES	483966	438260	12.3%	11.1%	1
45	INDIVIDUAL GOVERNMENT SERVICES	238693	203497	6.0%	5.2%	1
46	GROSS FIXED CAPITAL FORMATION	735534	791211	18.6%	20.0%	1
47	CONSTRUCTION	405373	439260	10.3%	11.1%	1
48	Residential buildings	189189	223371	4.8%	5.7%	1
49	Non-residential buildings	116418	121833	2.9%	3.1%	1
50	Civil engineering works	99766	94056	2.5%	2.4%	1
51	MACHINERY AND EQUIPMENT	330161	351951	8.4%	8.9%	1
52	Transport equipment	79602	82748	2.0%	2.1%	1
53	Non-electrical equipment	202170	225779	5.1%	5.7%	1
54	Electrical equipment	48389	43424	1.2%	1.1%	1
55	INCREASE IN STOCKS	24123	26464	0.6%	0.7%	1
56	BALANCE OF EXPORTS AND IMPORTS	-119976	-140319	-3.0%	-3.6%	1
57	GROSS DOMESTIC PRODUCT	3946615	3946615	100.0%	100.0%	1

Source:Purchasing Power Parties and Real Expenditure in OECD, OECD

2.3 Points for Examination

We shall examine a breakdown of R&D expenditure from the following points to determine whether it is appropriate to use purchasing power parities for R&D expenditure.

(1) The ratios of the R&D expenditure items that are the same or similar to GDP expenditure items.

(2) International price levels of R&D expenditure items that are not included in (1).

(3) From (1) and (2), we can analyze the gap between the price level of final demand, which is a calculation standard for OECD purchasing power parities, and the price level of R&D expenditure items. We then calculate the conversion rate appropriate to R&D expenditure, using the calculation method for OECD purchasing power parities, to tie together the price levels of the various items.

3. Composition of R&D Expenditure Items and Price Levels

3.1 Comparison of Japan's R&D Expenditure Items and GDP Expenditure Items

We shall now look at a breakdown of Japan's R&D expenditure from the Report of the Survey on Research and Development by the Management and Coordination Agency. The purchasing power parities we are examining in this report are 1985 estimations, so we shall look at 1985 data. The research expenditure by all research institutions in Japan in 1985 amounted to about 8,116.4 billion yen (natural sciences only), of which personnel expenditure accounted for 42.3%, raw material expenditure 18.1%, expenditure for tangible fixed assets purchase 18.1%, and miscellaneous expenditure 21.5%. Expenditure for tangible fixed asset purchase can be further broken down into land and buildings (3.5%); machinery, instruments and equipment (11.8%); and other assets (2.8%).

Next we shall examine the differences between R&D expenditure items and their corresponding items from among Japan's GDP expenditure items, which are the standard for calculating purchasing power parities **(Note 3)**.

(1) Personnel Expenditure and Raw Material Expenditure

Personnel expenditure, which accounts for more than 40% of R&D expenditure, is different in character from GDP expenditure, which has its basis in goods and services transactions. As for raw material expenditure, which accounts for about 18%, there is no specific breakdown of this expenditure item, but a literal interpretation of the term raw material expenditure would seem to indicate that there is no corresponding item of GDP expenditure.

(2) Expenditure for Tangible Fixed Asset Purchase

Expenditure for tangible fixed assets purchase can be broken down into land and buildings; machinery, instruments and equipment; and other assets.

i) "Machinery, instruments and equipment" accounted for 11.8% of Japan's R&D expenditure, while its corresponding GDP item, "machinery and equipment" within GDP gross fixed capital formation, accounted for 10.6% of Japan's nominal GDP (Item 51, Column 3, Table 1-1).

(Note 3) To explain the positioning of R&D expenditure in national economic calculations: corporate research and development is looked upon as a kind of support activity for production, so goods used in research and development are regarded as intermediate goods. From an economic viewpoint, it may seem incongruous to use purchasing power parity values, which are calculated on the basis of end demand, for R&D expenditure. Nevertheless, if consumption items classified under individual end consumption in GDP and R&D expenditure items are alike, we have the key to estimating international price levels for R&D expenditure based on purchasing power parities. Of course, there is a price difference amounting to the intermediate margin, but we have overlooked this difference in this paper for the sake of simplification. In this report, price levels for R&D expenditure items are expressed as purchasing power parities.

ii) "Land and buildings" includes expenditure for construction of research institutions and land purchase. Of these, expenditure for construction of research institutions is included in gross fixed capital formation within GDP. If we exclude expenditure for land purchase, "land and buildings" corresponds to "non-residential building construction" expenditure (Item 49, Table 1-1) within GDP gross fixed capital formation.

iii) Conversely, the fields of "residential building construction" and "civil engineering", which are included in calculations for purchasing power parities concerning fixed assets, have little connection with research and development.

iv) From i) and ii) above, we can see that if we exclude land purchase expenditure, expenditure for tangible fixed assets purchase generally corresponds to GDP gross fixed capital formation. Expenditure for tangible fixed assets purchase accounts for 18.1% of R&D expenditure, while gross fixed capital formation accounts for 27.7% of GDP (Item 46, Column 3, Table 1-1). So the percentage of fixed asset expenditure within R&D expenditure is lower than the purchasing power parity calculation.

(3) Miscellaneous Expenditure

"Miscellaneous expenditure" includes expenditure on such items as light and heat, communication, transport, books and magazines, land rent and conferences. Of these, expenditure on light and heat, communication, transport, books and magazines, official trips, land rent and conferences are regarded as corresponding to GDP expenditure. Thus many items within "miscellaneous expenditure" correspond to individual end consumption. On the other hand, GDP expenditure items connected with general life, such as food, clothing, medical care, education and entertainment are rarely used in research and development. In research and development, there is considerable expenditure in such infrastructure items as light, heat and water, and transport and communications.

This relationship is shown in Figure 3.

3.2 Price Levels of Personnel Expenditure and Raw Materials

3.2.1 Personnel Expenditure for Researchers

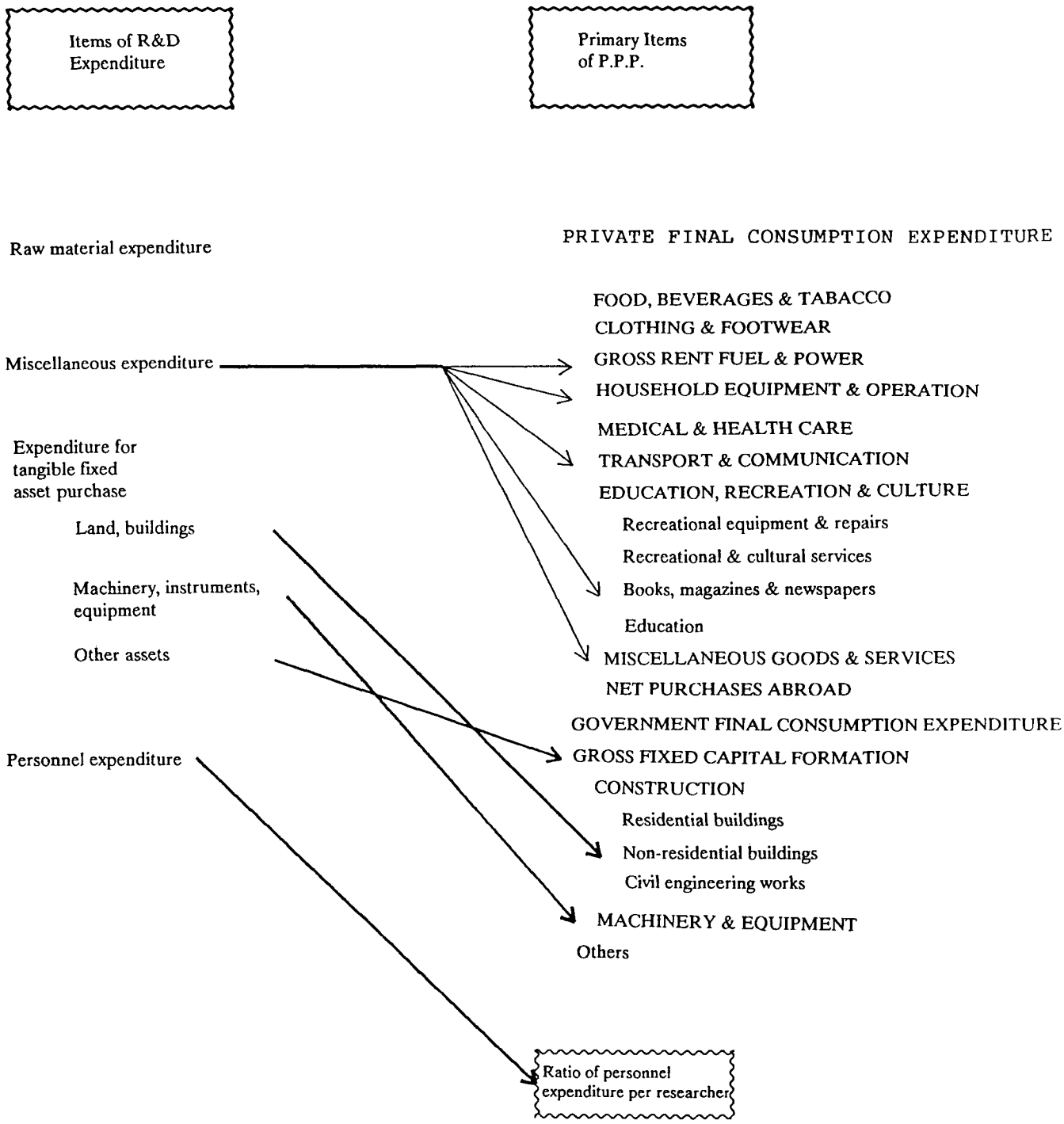
Personnel expenditure in research and development does not correspond to any purchasing power parity item **(Note 4)**. How, then, can we compare the price level of personnel expenditure, which accounts for more than 40% of R&D expenditure, among different countries. There is scope for detailed discussion, but here we shall look at a simple method of comparison.

For this, we can consider the "ratio of the annual average personnel expenditure per researcher" index. The average personnel expenditure can be obtained from the personnel expenditure related to research and development and the total number of researchers.

(Note 4) Personnel expenditure throughout Japan roughly equates to employee income on the distribution side in GDP. On the other hand, purchasing power parity bases price calculation on the expenditure side. Therefore the price level of personnel expenditure is not directly represented by purchasing power parity.
If we represent the price ratio of personnel expenditure on the analogy of the various purchasing power parity items, the purchasing power parity of individual consumption indicates the price level of researchers' cost of living. That is, we can think of it as indicating the price level of personnel expenditure for researchers. However, we must be careful when taking this view. The price level of personnel expenditure we are discussing here is the price level of expenditure that arises when companies and universities employ researchers, and not the price level of general spending by researchers. Researchers are likely to receive different standards of treatment in different countries. This idea holds true only when researchers in every country spend the entire amount of their wages, and the spending is of the same quality and quantity. In reality, however, the lifestyles and living standards of researchers in the various countries differ, so the quality and quantity of spending is different. The household savings rate is also different. We have therefore avoided using purchasing power parities of individual consumption for personnel expenditure.

Figure 3 Corresponding Tables for R&D Expenditure and Purchasing Power Parities

The figure shows the corresponding relationship between the R&D expenditure items and the Purchasing power parity items that represent their price levels. Personnel expenditure corresponds to the personnel expenditure Ratio and not purchasing power parities.



If we take the United States and Japan as an example, Japan's average personnel expenditure (yen base) / the United States average personnel expenditure (dollar base) show the personnel expenditure ratio **(Note 5)**.

(Note 5) Here we have assumed that the ratio between the United States and Japan for personnel expenditure for the research work-force per unit represents the purchasing power parity of personnel expenditure. Setting the number of hours worked by researchers in one year as a unit, we then worked out personnel expenditure per researcher. Statistically, research and development personnel expenditure is not just personnel expenditure for researchers, but personnel expenditure for all people engaged in research and development, including research assistants and technicians. Therefore, strictly speaking, to obtain the average amount of personnel expenditure per person, it is better to have as the denominator the total number of persons engaged in research and development, not just the number of researchers. However, since we do not have data on the number of persons engaged in research and development in the United States, here we shall use the number of researchers. The following points still require consideration.

First, as for having the number of persons engaged in R&D as the research and development work-force unit (the number of persons engaged in R&D is set as the denominator); by calculating with the number of researchers as the denominator, as we are doing here, we are assuming that the ratio of the number of persons engaged in R&D to the number of researchers is identical in both the United States and Japan.

Second, even if we use the number of researchers as the denominator, there is a problem as to whether we can represent personnel expenditure for researchers in the United States and Japan by a simple average value. If there are major differences between the United States and Japan in the age, gender and field distribution among researchers, certain statistical considerations to accommodate these differences will be necessary. We also believe that differences in the promotion and salary structure based on capability and seniority will give rise to differences in wage distribution among researchers.

Third, purchasing power parity is an index which shows the difference in price of a product or service of exactly the same quality, and there is some doubt as to whether we can regard Japanese researchers and American researchers as having the same value. That is, if the researchers of one country are more capable than researchers of the other, then it is quite natural for the more capable researchers to receive higher wages. Compared to products, researchers have a much lower level of mobility across national boundaries, so gaps between countries can exist. In our calculations, however, we have not worried about any qualitative comparison, rather, we have assumed that Japanese and American researchers are at the same level.

However, there are quite strong restrictions regarding information about personnel expenditure in the United States, so we have not been able to obtain comprehensive and reliable data. A U.S. National Science Foundation (NSF) report contains a breakdown of research and development expenditure by industry in 1983 [4]. According to this, wages of R&D personnel accounted for 45.6% of the total research and development expenditure by industry in 1983. From this, we have estimated that personnel expenditure in the natural science fields at universities, national research institutions and all other research and development establishments in the United States in 1983 amounted to 38,729,620,000 dollars. The full-time equivalent (FTE) number of natural science researchers in the United States in the same year was 630,153, so from this, personnel expenditure per researcher in the natural science fields amounted to 61,461 dollars **(Note 6)**.

(Note 6) We obtained the figure for personnel expenditure in the natural science fields within the overall research and development expenditure of all research institutions in the United States by assuming that the "the percentage that research and development expenditure in the natural science fields accounts for within the overall research and development expenditure by all research institutions" and the "ratio between the percentage that personnel expenditure accounts for within the overall research and development expenditure of industry and the percentage that personnel expenditure accounts for within the research and development expenditure only in the natural science fields at research institutions" obtained for Japan are the same for the United States. We also assumed that, similarly, the percentage of researchers in the natural science fields at all research institutions is the same in the United States as it is in Japan.

In Japan, according to a survey by the Management and Coordination Agency, personnel expenditure (natural sciences only) by all research institutions in 1983 amounted to 2,895,104,000,000 yen, and the FTE number of researchers was 305,422 **(Note 7)**. Therefore personnel expenditure per researcher in the natural science fields amounted to 9,479,045 yen.

If we adjust these figures using the real wage index and the consumer price index, in 1985 personnel expenditure per researcher was 66,474 dollars in the United States and 10,319,054 yen in Japan. Thus if we compare the annual average personnel expenditure per researcher in Japan and in the United States, it is the equivalent of one dollar to 155.2 yen.

3.2.2 Raw Materials and Land and Buildings

It is not clear exactly what the raw materials used in research and development are. We can think of metal and silicon for use in IC development, mice and other animals used in biological experiments, and the various reagents used in chemical experiments. However the economic character of such a diverse range of things and their international price levels are not clear. They are used in research so we can generally assume that most have a high degree of purity. And their specifications will differ depending on the user. From this we can think of them as sophisticated industrial goods (although mice are not industrial goods, we can say that they are technology-intensive creatures that are subject to sophisticated quality control). We therefore cannot regard them simply as raw materials for industrial goods. It is difficult to uncover the key to specifying the price level of the raw materials.

(Note 7) The number of researchers for the United States was worked out on the full-time equivalent basis, so we had to do the same to work out the number of researchers in Japan. Here we have followed the OECD calculations and halved the number of researchers at Japanese universities.

R&D expenditure includes expenditure to purchase land for research institutions and experimental stations, however, since the use value of the land will not drop in the future, it is illogical to include expenditure for land purchase in research and development costs without some form of adjustment.

3.3 Results of Chapter 3 Examinations

The following are the major points coming from the discussions above.

(1) There is a considerable difference in what is included in purchasing power parity items and R&D expenditure items, so purchasing power parity does not accurately reflect the international price level of R&D expenditure.

1) Among the R&D expenditure items, personnel expenditure (42% of overall R&D expenditure) and raw material expenditure (18%) do not have any corresponding purchasing power parity items.

2) In contrast to 1) above, although there is virtually nothing in R&D expenditure that corresponds to residential building construction, civil engineering and many expenditure items within individual consumption (food, medical care, etc.), these items are included in purchasing power parity calculations.

3) Even when R&D expenditure items and purchasing power parity expenditure items do correspond, the weight given to the corresponding items varies substantially. One example of this is expenditure for purchasing tangible fixed assets, which is about 18% of R&D expenditure, and gross fixed capital formation, which is about 28% of GDP.

(2) We estimated the price ratio between the United States and Japan for personnel expenditure within R&D expenditure. We calculated that the annual average personnel expenditure per researcher in the United States and Japan in 1985 was the equivalent of one dollar to 155.2 yen.

4. Calculating the Real Conversion Rate for R&D Expenditure in the United States and in Japan

4.1 Basic Idea

(1) Outline

We calculated the U.S. dollar to Japanese yen conversion rate for R&D expenditure to represent the results of analysis in Chapter 3 in broad terms. To collect data and calculate similar conversion rates among other countries would be very time-consuming, so for the time being we have focused on R&D expenditure in the United States and Japan, both of which account for a significant proportion of the world's R&D expenditure.

Taking advantage of the fact that the OECD purchasing power parities are classified into 56 items, we multiplied the purchasing power parity for each item **(Note 8)** by its percentage of overall R&D expenditure in fiscal 1985. The sum total of these calculations is the real conversion rate for R&D expenditure. For personnel expenditure related to research and development, we used the ratio of the average personnel expenditure per researcher and not the purchasing power parity.

There are hardly any examples of purchasing power parity calculations for specific fields such as these.

(Note 8) Strictly speaking, the value which represents the research and development price level and which is used in calculating the real conversion rate is not the purchasing power parity, but the ratio of the nominal value to the real value, which is close to the purchasing power parity value (the ratio of the nominal value to the real value is the purchasing power parity expressed in international prices; we have referred to it as the ratio of the nominal value to the real value and represented it by the letter K in this report to distinguish it from purchasing power parity expressed on a dollar base). If the real value (dollar base) of each GDP item = R, and the nominal value (national currency base) of each GDP item = N, then K = N/R. The words "real" and "nominal" here have a different meaning from those used when looking at economic indicators over an extended period of time in which the real value is found by dividing the nominal value by the price inflation rate. A value for K is found for each item (refer to examples 1 and 2 in Table 2).
The value of K is close to the purchasing power parity. In these calculations K is a postulate.

(2) Important Points

i) These calculations assume that the value for each purchasing power parity item represents the price level of its corresponding R&D expenditure item. Purchasing power parity is based on the price of products and the sale proceeds in each country, so if we attempt to calculate the purchasing power parities for R&D expenditure among different countries using the same method, we are in effect calculating purchasing power parities by obtaining international prices based on data about the price of and sale proceeds from products and services used in research and development in each country. In reality, however, it is not easy to survey price levels for products and services used in research and development in each country.

Therefore we decided to represent the price levels of R&D expenditure by the value of purchasing power parities that correspond to R&D expenditure items. We thought that if we used the suitable figures from among those for the 56 GDP items rather than the purchasing power parity value for GDP as a whole, we would obtain appropriate results for R&D expenditure. However, even though GDP is itemized, these items do not completely represent the price levels of R&D expenditure. It must be said that purchasing power parity values we have used here are not accurate indicators of price levels, so of the figures for price levels which can be used at present, we chose those that most closely resemble price levels for R&D expenditure.

ii) Since nothing in purchasing power parities corresponds to personnel expenditure, we used the ratio of personnel expenditure per researcher between the United States and Japan **(Note 9)**.

(Note 9) If we consider research activities carried out by researchers to be a kind of product, then it follows that personnel expenditure per researcher represents product price. The ratio of personnel expenditure per researcher in the United States and Japan represents the product price ratio between the two countries. In principle, the product price ratio is the purchasing power parity between the two countries for a specific product. So for personnel expenditure, we have added the ratio of the annual average personnel expenditure per researcher in the United States and in Japan to the weighted average.

Table 2 The Ratio of Prices to International Prices of GDP Items in U.S.A. and Japan (K)

Item No.	GDP Expenditure Items	Calculation of (K) ① Japan's K Nominal Value/Real Value in Table 1-1 ①/② (¥/$)	② U.S.A.'s K Nominal Value/Real Value in Table 1-2 ①/② ($/$)	③ Reference OECD P.P.P ¥/$	④ Reference Calculated P.P.P ¥/$ (①／②)
1	PRIVATE FINAL CONSUMPTION EXPENDITURE	214.5	0.984	218	218.1
2	FOOD, BEVERAGES AND TOBACCO	271.9	0.925	294	293.8
3	Food	272.7	0.918	297	296.9
4	Bread and Cereals	270.9	1.042	260	260.1
5	Meat	372.3	0.801	465	464.7
6	Fish	235.5	0.850	277	277.1
7	Milk, cheese and eggs	276.0	0.923	299	299.0
8	Oils and fats	331.7	0.990	335	334.9
9	Fruits, vegetables and potatoes	304.4	1.007	302	302.4
10	Other food	247.8	0.937	264	264.4
11	Beverages	336.7	1.034	326	325.7
12	Non-alcoholic beverages	273.2	1.066	256	256.2
13	Alcoholic beverages	369.4	1.019	363	362.5
14	Tabacco	197.4	0.843	234	234.1
15	CLOTHING AND FOOTWEAR	219.2	0.921	238	238.0
16	Clothing including repairs	221.8	0.914	243	242.6
17	Footwear including repairs	198.9	0.961	207	207.1
18	GROSS RENT FUEL AND POWER	183.1	1.163	157	157.5
19	Gross rent and water charges	171.7	1.288	133	133.3
20	Fuel and power	268.9	0.844	319	318.7
21	HOUSEHOLD EQUIPMENT AND OPERATION	225.7	0.916	246	246.4
22	Furniture, floor coverings & repairs	410.0	0.842	487	486.9
23	Household textiles & repairs	224.9	1.102	204	204.1
24	Household appliances & repairs	207.0	0.987	210	209.8
25	Other household goods & services	218.6	0.916	239	238.6
26	MEDICAL AND HEALTH CARE	138.7	1.297	107	106.9
27	Medical and pharmaceutical Products	172.2	1.435	120	120.0
28	Medical and health services	136.8	1.279	107	107.0
29	TRANSPORT AND COMMUNICATION	236.4	0.846	280	279.6
30	Personal transport equipment	178.1	0.951	187	187.2
31	Operation of transport equipment	421.2	0.704	598	598.0
32	Purchased transport services	208.4	1.265	165	164.8
33	Communication	166.9	1.085	154	153.8
34	EDUCATION, RECREATION AND CULTURE	257.0	0.885	290	290.4
35	Recreational equipment and repairs	205.7	0.928	222	221.7
36	Recreational and cultural services	210.1	0.932	225	225.5
37	Books, magazines and newspapers	237.8	0.833	285	285.5
38	Education	1781.2	0.801	2224	2223.9
39	MISCELLANEOUS GOODS AND SERVICES	232.1	0.916	253	253.5
40	Restaurants, cafes and hotels	312.1	0.833	375	374.8
41	Other goods and services	192.1	0.980	196	196.0
42	NET PURCHASES ABROAD	214.5	0.984	218	218.1
43	GOVERNMENT FINAL CONSUMPTION EXPENDITURE	192.9	1.126	171	171.3
44	COLLECTIVE GOVERNMENT SERVICES	197.7	1.104	179	179.1
45	INDIVIDUAL GOVERNMENT SERVICES	187.9	1.173	160	160.2
46	GROSS FIXED CAPITAL FORMATION	255.8	0.930	275	275.2
47	CONSTRUCTION	274.1	0.923	297	297.0
48	Residential buildings	341.2	0.847	403	402.8
49	Non-residential buildings	259.4	0.956	271	271.5
50	Civil engineering works	250.8	1.061	236	236.5
51	MACHINERY AND EQUIPMENT	231.0	0.938	246	246.3
52	Transport equipment	203.1	0.962	211	211.1
53	Non-electrical equipment	241.8	0.895	270	270.0
54	Electrical equipment	236.1	1.114	212	211.8
55	INCREASE IN STOCKS	271.0	0.912	297	297.3
56	BALANCE OF EXPORTS AND IMPORTS	202.3	0.855	237	236.6
57	GROSS DOMESTIC PRODUCT	221.9	1.000	222	221.9

K is obtained by dividing the nominal value of each GDP item by its real value.
Source:Purchasing Power Parties and Real Expenditure in OECD, OECD

Expenditure for raw materials used in research and development is not included in the calculations.

iii) These calculations show Japan's real R&D expenditure by determining a suitable conversion rate for research and development. However, as mentioned above, the calculation method is not the same as that used in OECD purchasing power parities, so to avoid misunderstanding, we do not refer to the conversion rates as purchasing power parities for R&D expenditure. Instead, we have called it the real conversion rate for R&D expenditure in the United States and Japan.

4.2 Calculation Method

4.2.1 Weighted Average of Purchasing Power Parities

The basic idea behind these calculations is that the structure of the OECD purchasing power parities can show the purchasing power parities of the different groupings by combining the purchasing power parity of each item within the grouping, so if we can estimate the purchasing power parity which corresponds to each R&D expenditure item, we are able to calculate the purchasing power parities for R&D expenditure as a whole by bringing them to their weighted averages.

Of the values listed in the OECD reference ([1] of the bibliography), if we bring the "ratio of the nominal value (national currency base) to the real value (dollar base) (expressed as K; Note 8)" for any GDP item to its weighted average, giving weight to the real value, we can obtain a value for K for all GDP items (Table 2). Through this method we can obtain K for Japan's overall R&D expenditure by bringing K which corresponds to the R&D expenditure items to a weighted average, giving weight to the real value of each of Japan's R&D expenditure items. This

weighted averaging is carried out for both Japan and the United States. We can obtain the real conversion rate by obtaining the ratio of K for the overall R&D expenditure in Japan and in the United States.

This is shown by the following formulae.
The amount of the R&D expenditure items is X_1, X_2,$\cdots X_m$.
The ratio of R&D expenditure items is W_1, W_2,$\cdots W_m$ (m= number of items).
The ratio of nominal value to real value of the purchasing power parity items that correspond to R&D expenditure items is K_1, K_2, $\cdots K_m$.
The ratio of nominal value to real value of the overall R&D expenditure is $K\sigma$.

We bring K to its weighted average by the real value of R&D expenditure (X/K), so:

$$K\sigma = \frac{K_1(X_1/K_1) + K_2(X_2/K_2) + \cdots K_m(X_m/K_m)}{(X_1/K_1) + (X_2/K_2) + \cdots (X_m/K_m)}$$

$$= \frac{X_1 + X_2 + \cdots X_m}{(X_1/K_1) + (X_2/K_2) + \cdots (X_m/K_m)}$$

Thus far we have represented each R&D expenditure item in the form of a percentage of overall R&D expenditure, so we shall change the formula. The amount of each expenditure item is represented by $X_1 = \Sigma X_i \cdot W_1$; therefore we shall incorporate this into the above formula.

$$K\sigma = \frac{W_1 + W_2 + \cdots W_m}{(W_1/K_1) + (W_2/K_2) + \cdots (W_m/K_m)} \quad \text{(Formula 1)}$$

Furthermore, if, as mentioned in Note 2, the K for Japan's overall R&D expenditure is K_N, and the K for the United States' overall R&D expenditure is K_A, then the real conversion rate STPPP (yen/dollar) is obtained by dividing the Japanese figure (K_N) by the American figure (K_A).

$$STPPP = K_N/K_A \quad \text{(Formula 2)}$$

4.2.2 Assumptions Regarding Price Levels for R&D Expenditure Items

From the points mentioned in Chapter 3 about personnel expenditure, raw materials, machinery, instruments and equipment, land and buildings, and other expenditure, we have made the following assumptions regarding price levels in the United States and Japan.

Assumption 1: The ratio of personnel expenditure per researcher represents the purchasing power parities between the United States and Japan.

Assumption 2: It is difficult to estimate the price levels for raw materials so this has been excluded from calculations.

Assumption 3: The purchasing power parities for machinery and equipment within gross fixed capital formation represent the price levels of machinery, instruments and equipment; and the purchasing power parities for non-residential buildings within gross fixed capital formation represent the price levels of land and building.

Assumption 4: Many items falling under miscellaneous expenditure (items of R&D expenditure other than personnel expenditure, raw material expenditure, and expenditure for tangible fixed assets purchase) correspond to individual consumption. However, purchasing power parity items within individual consumption are quite diverse, and some have very little connection with R&D expenditure. Therefore, items of individual consumption that have little connection with research and development should be excluded. Specifically, food, medical care and entertainment have nothing to do with research and development and should therefore be excluded. Moreover, only a part of clothing and miscellaneous goods and services should be taken into account. From these we combine the purchasing power parities of the individual consumption items that correspond to miscellaneous expenditure items to calculate the appropriate purchasing power parities, and these represent the price levels of miscellaneous expenditure.

4.2.3 Calculation Formula

(1) We established the following variables (K is obtained by dividing the nominal value of each GDP item by its real value; Note 8).

Variables which represent price levels of expenditure items:

Ratio of personnel expenditure per researcher --- KS
K of corrected individual consumption on the basis of research and development characteristics --- KIC
K of gross fixed capital formation (non-residential buildings) --- KFCON
K of gross fixed capital formation (machinery and equipment) --- KFM
K of gross fixed capital formation (major headings) --- KFA

Percentage of overall expenditure:

Personal expenditure	--- WP
Raw materials	--- WM
Expenditure for tangible fixed assets purchase:	
Land and buildings	--- WCON
Machinery, instruments and equipment	--- WMA
Other assets	--- WX
Miscellaneous expenditure	--- WO

(The sum of these items is 1)

(2) The following formula give the K for Japan's overall R&D expenditure (K_N).

K_N = (1-WM)/(WP/KS+WO/KIC+WCON/KFCON+WMA/KFM+WX/KFA)

(3) Using the same formula, we can obtain the K for the United States' overall R&D expenditure (K_A) **(Note 10)**.

(4) We can obtain the real conversion rate for research and development using Formula 2.

(5) Annual Real Conversion Rate

We followed the OECD method of estimating purchasing power parities for the years after 1985. OECD estimates the annual value by multiplying the 1985 purchasing power parity values by the price inflation rate of each country. In this report, we have multiplied the 1985 real conversion rate by the ratio of the GDP deflators in Japan and the United States (the ratio of the figure obtained after dividing the value of the Japanese deflator based on 1985 by that of the United States).

(Note 10) The breakdown of R&D expenditure which form the basis of calculations for the United States is itself based on available data. These data classify R&D expenditure by United States industry into personnel expenditure, raw material expenditure and indirect expenses. We estimated the breakdown of indirect expenses (expenditure for tangible assets purchase and miscellaneous expenditure) by using the same ratio as Japan's R&D expenditure items.

4.3 Calculation Results

Table 3 shows the various K values, and Table 4 shows the real conversion rates. The conversion rate for 1985 as calculated by us is 185.5 yen/dollar, and this is a 16.4% higher value for the yen than the OECD's purchasing power parities against overall GDP of 222 yen/dollar.

We converted R&D expenditure by the United States into yen by using the real conversion rates obtained here (Figure 4). For comparison, we have included conversions of United States R&D expenditure into yen based on purchasing power parities and IMF exchange rates, and also R&D expenditure by Japan (natural sciences only).

5. Conclusion

(1) Purchasing power parity is premised on the final demand structure of the overall economy, while on the other hand, R&D expenditure is centered on personnel expenditure for researchers and expenditure for the purchase of fixed assets used in research. Therefore, the calculation base for purchasing power parities is not entirely suitable for research and development. At the very least, we should be well aware that using purchasing power parities for research and development will contain a considerable error.

(2) We calculated the real conversion rate for R&D expenditure between the United States and Japan based on the structure of R&D expenditure. Our calculations put the value of the yen in the real conversion rate for R&D expenditure about 16% higher than in purchasing power parities. This is not a precise calculation for data was limited, rough assumptions were made regarding price levels of R&D expenditure, and, in particular, raw material

Table 3-1 Calculating Table for K of Japan's R&D Expenditure

Factors for calculation of K / Year	1985
Reference:PPP for GDP (¥/$)	222
KIC: K of corrected individual consumption on the basis of R&D characteristics	210.4
KFCON: K of gross fixed capital formation(non-residential buildings)	259.4
KFM: K of gross fixed capital formation(machinery & equipment)	231
KFA: K of gross fixed capital formation(major headings)	255.8
KS: Ratio of personnel expenditure per researcher	155.2
WP: Personnel expenditure	42.3%
WM: Raw material expenditure	18.1%
Expenditure for tangible fixed asset purchase	18.1%
WCON: Land, buildings	3.5%
WMA: Machinery, instruments, equipment	11.8%
WX: Other assets	2.8%
WO: Miscellaneous expenditure	21.5%
1-WM: Total except raw material expenditure	81.9%
KN: K of Japan's total R&D expenditure	181.9

Table 3-2 Calculating Table for K of the United States R&D Expenditure

Factors for calculation of K / Year	1985
Reference:PPP for GDP (¥/$)	1.0000
KIC: K of corrected individual consumption on the basis of R&D characteristics	0.9677
KFCON: K of gross fixed capital formation(non-residential buildings)	0.9555
KFM: K of gross fixed capital formation(machinery & equipment)	0.9380
KFA: K of gross fixed capital formation(major headings)	0.9296
KS: Ratio of personnel expenditure per researcher	1.0000
WP: Personnel Expenditure	45.6%
WM: Raw Material Expenditure	17.0%
Expenditure for Tangible Fixed Asset Purchase	17.1%
WCON: Land, Buildings	3.3%
WMA: Machinery, instruments, equipment	11.1%
WX: Other Assets	2.6%
WO: Miscellaneous Expenditure	20.3%
1-WM: Total Except Raw Material Expenditure	83.0%
KA: K of the U.S. total R&D expenditure	0.98033

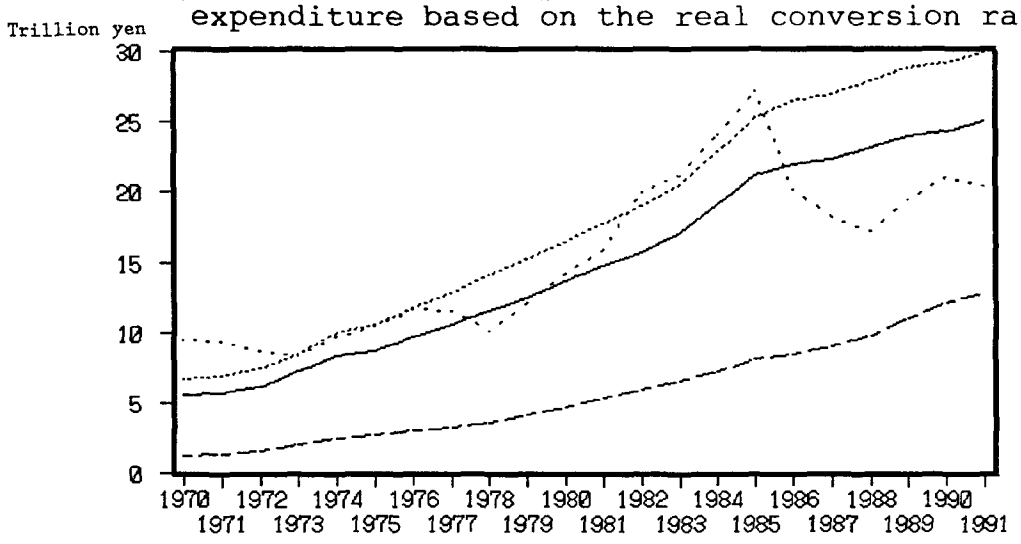
KN=(1-WM)/(WP/KS+WO/KIC+WCON/KFCON+WMA/KFM+WX/KFA)

Table 4 Real Conversion Rate for R&D, Purchasing Power Parities and Exchange Rate (Yen/US$)

Year	Real Conversion Rate for R&D	Purchasing Power Parities	Exchange Rate
1970	211.7	256	358.1
1971	210.2	257	349.3
1972	214.7	259	303.2
1973	232.6	274	271.7
1974	253.0	304	292.1
1975	244.0	298	296.8
1976	248.0	300	296.6
1977	246.5	298	268.5
1978	239.8	291	210.4
1979	225.7	275	219.1
1980	218.3	262	226.7
1981	204.9	247	220.5
1982	195.2	236	249.1
1983	190.9	230	237.5
1984	188.2	225	237.5
1985	185.5	222	238.5
1986	183.6	221	168.5
1987	177.9	215	144.6
1988	172.9	209	128.2
1989	170.0	205	138.0
1990	166.4	200	144.8
1991	164.9	197	134.7

Figure 4 Yen Conversion of R&D Expenditure by United States

(Solid line is the yen conversion of U.S. R&D expenditure based on the real conversion rate)



— Yen Conversion of U.S. R&D Expenditure (Real Conversion Rate Basis)

..... Yen Conversion of U.S. R&D Expenditure (P.P.P. Basis)

... Yen Conversion of U.S. R&D Expenditure (Exchange Rate Basis)

-- Reference: Japan's R&D Expenditure

expenditure was not included in calculations. Nevertheless, our estimation that the value of the yen in the real conversion rate for R&D expenditure is higher than in purchasing power parities probably holds true.

(3) The significance of our calculating the real conversion rate is that we have presented a method of measuring the real quantity of research and development in each country.

The basic idea of purchasing power parity is to grasp economic activities on a real quantity base and not as a nominal value. In line with this view, the real conversion rate in this research applies purchasing power parity methods to the various research and development fields. If these calculations can be carried for each country, we shall be able to ascertain real quantities for their respective research and development, and this, in turn, will influence discussions on international science and technology policy. This kind of calculation method is considered to be extremely effective when the exchange rate is fluctuating wildly. It is also thought to be of benefit in analyzing R&D expenditure in developing countries and the countries of the former communist bloc, where price levels and research and development structures are quite different.

This calculation method is not simply limited to research and development, but can also be applied to calculating the real conversion rates in other specific fields. Provided we know the breakdown of expenditure items and rough price levels, we are able to calculate the real conversion rate.

6. Points Requiring Further Discussion

(1) Examination of statistical values

In this report we have calculated the real conversion rate for

R&D expenditure assuming certain R&D expenditure characteristics on the basis of purchasing power parities. A more accurate calculation would require detailed data on R&D expenditure and analysis of each item's price level in Japan and overseas. The following are the key points requiring examination.

i) A breakdown of R&D expenditure; personnel expenditure for researchers, which is the largest expenditure item; and especially the precise number of researchers and people engaged in research and their wage levels in the United States.
ii) The capability- or seniority-based wage structure covering researchers in each country, and a calculation of the international average personnel expenditure.
iii) The price levels of raw material expenditure.

(2) Analysis of expenditure by individual data
In addition to the examination of statistical values at (1) above, we can consider analyses of expenditure at individual research institutions or of the international price margin in research-related equipment and material.

(3) Examination of estimated purchasing power parities for 1990

(4) Examination of the real conversion rate for countries other than the United States and Japan

(5) From the above, we can expect accurate calculations of the real conversion rate for various countries. And we can tie in the calculation results to the various analyses covering research and development. For example, analyzing the institutional factors in each country which may influence the R&D expenditure items, or using the results as basic data for research on the effect of research and development on the economy.

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Reference Table 1: Ratio of U.S. R&D Expenditure Items

U.S. R&D Expenditure Items	1983 U.S. Statistical Value	1985 U.S. Estimated Value
Personnel Expenditures	45.6%	45.6%
Materials	17.0%	17.0%
Indirect Cost	37.4%	37.4%
Tangible Fixed Assets Exp.		17.1%*
(Land, Buildings, etc)		3.3%*
(Machinery & Instruments etc)		11.1%*
(Others)		2.6%*
Other Expenses		20.3%*
Total	100.0%	100.0%

NSF reference:
1985 figures marked with an asterisk * are estimated from the ratio of Japan's R&D expenditure items. These are a breakdown of indirect expenditure so they are not included in the total.

Reference Table 2: Yen Conversion of R&D Expenditure by the United States (in multiples with Japan's R&D expenditure set at 1)

Year	Yen Conversion on Real Conversion Rt	Yen Conversion on PPP Basis	Yen Conversion on Exchange Rate	(Reference) Japan's R&D Exp.
1970	4.63	5.60	7.83	1
1971	4.17	5.09	6.92	1
1972	3.85	4.65	5.44	1
1973	3.61	4.25	4.21	1
1974	3.43	4.13	3.96	1
1975	3.28	4.00	3.99	1
1976	3.29	3.98	3.93	1
1977	3.26	3.94	3.55	1
1978	3.23	3.92	2.84	1
1979	3.05	3.72	2.96	1
1980	2.92	3.50	3.03	1
1981	2.74	3.31	2.95	1
1982	2.66	3.21	3.39	1
1983	2.62	3.15	3.26	1
1984	2.65	3.17	3.35	1
1985	2.60	3.11	3.34	1
1986	2.61	3.14	2.39	1
1987	2.47	2.99	2.01	1
1988	2.36	2.86	1.75	1
1989	2.19	2.64	1.78	1
1990	2.00	2.41	1.74	1
1991	1.97	2.35	1.61	1