

Civilian and Defense Research and Development Funding in Six Major Economies

Thomas L. Powers and Ricardo P. Leal

The economic performance of a country is based in part on its ability to develop technology to create products that will be demanded in the global marketplace. The development of technology in turn depends on the nature and level of the funding provided for such efforts. This paper examines this important issue through a review of the expenditures and sources of funding for research and development in France, Germany, Japan, the European Union, the United Kingdom, and the United States. The trends in the data indicate that Japan has the greatest relative investment in civilian research and development. This trend can no longer be explained by Japan "catching up" with the U.S. Based on present trends, Japan's gross research and development expenditures per capita will exceed those of the United States in 1997.

I. INTRODUCTION

A great deal of discussion has occurred regarding the importance of research and development (R&D) funding and its impacts; however, the precise status of this area remains to be determined (Glismann and Horn [10]; Kitamura [15]). An examination of recent trends in international research and development expenditures is helpful to assess future implications. There are many factors associated with the overall performance of competing economies; a very significant one is the level of research and development activity (Chakrabarti, Feinman, and Fuentivilla [5]). The relative economic performance of countries is related to their consistent creation of technology that contributes to successful products in the global marketplace (Franko [9]). Technology development is in turn directly related to expenditures for that purpose (Namatame [18]).

This paper reports research and development funding and trends for Japan,

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France, Germany, the United Kingdom, the United States, and the European Union based on the Organization for Economic Cooperation and Development (OECD) data for the period 1981 through 1994. Our contribution is to report on these trends and to estimate the level of total civilian R&D expenditures that is not reported by the OECD. We believe that this variable is the most relevant in assessing the impact of R&D funding. Our purpose is to report the status of this area, as opposed to making policy recommendations. We report that, based on present trends, Japan is the only country analyzed able to realistically catch up with the U.S. in the funding of gross research and development expenditures per capita. Maintaining the current growth trends, Japan would catch up with the U.S. in 1997. Japan has already overtaken the U.S. when only civilian R&D expenditures are considered relative to the GDP or on a per capita basis. It can be safely said that in relative terms, Japan is the country that invests the most in non-defense-oriented research and development. The paper is organized as follows. First, background material related to research and development funding and how it may contribute to firm and national competitiveness is presented. The specific objectives of the research are detailed; results are presented, and implications based on our findings are discussed.

II. BACKGROUND

The global economy of the 21st century will see many new challenges facing the world's major economies. Among these challenges will be the need for funding and development of new products and processes. Countries and companies that were industry leaders in the post World War II period may find them at risk as the world evolves into a more unified and integrated economic framework (Behrman [2]; Terpstra [25]). The triad regions of Asia, North America, and Europe will constitute major markets as well as business threats to one another in the 21st century. Japan and the United States have been considered the most competitive economies in the world, and their commercial confrontation is a constant in the international media (The Economist [26]). From the perspective of U.S. business organizations, many that have previously been industry leaders may find themselves unable to keep up with increasingly innovative competitors from abroad (Dertouzos, Lester, and Solow [6]). Increased innovation by competing nations has and will continue to threaten the leadership position of the U.S. (Ryan and Bonham-Yeaman [22]; Dertouzos et

al. [6]).

The impact of innovation on economic performance has been recognized for several years (Ross and Kami [21]; Parkinson [19]; Kantrow [12]), and has been viewed as a major threat to U.S. firms (Kim and Mauborgne [14]). In the period following World War II, U.S. firms were leaders in new product development and innovation. In recent years, however, European and Japanese companies have become very visible in their technological progress (Glismann and Horn [10]). Technology's impact on products in global markets is believed to be a source of Japan's economic strength (Chakrabarti [4]; Powers and Leal [20]). Although Japan has been the most visible global player in innovative product development activity, there is also evidence that the U.S. may be threatened in certain industries by European nations that are increasing their standing as a significant global force (Sorenson [24]; Scott [23]; Chakrabarti [4]).

Future events in the global market will be based, in part, on present innovative activities (Auriol and Pham [1]). Already, we see shorter product life cycles that force firms to increase investment in product design and manufacturing processes in order to remain competitive. As the global economy shifts to higher technology goods, the importance of research and development funding will increase further as these industries require relatively higher levels of expenditures than lower technology goods. During the 1980s, production of high-technology products in the Organization for Economic Co-Operation and Development (OECD) countries increased by 117% (Butler [3]).

Not only has foreign investment in technology been seen as a cause of decreased U.S. leadership, but also in some cases foreign countries have obtained a higher return on their investment in research and development. Japan has accomplished this through a greater emphasis on process technology, as opposed to basic research. This has enabled Japan to be faster and more efficient in producing and delivering products compared to the U.S. (Mansfield [17]). Japanese research and development spending is second in the world; only the U.S. being greater. Of particular interest is the fact that the growth of research and development spending in the Japanese private sector has widely surpassed that of the public sector (Kitamura [15]).

Funding of research and development activity is necessary for the

development of technology to foster subsequent technology (Dinopoulos, Oehmke, and Segerstrom [7]). The need for funding research and development exists at two levels, new innovations as well as continued improvements (Gomory [11]). Each of these aspects plays an important part in maintaining competitive advantage. The losses in global market shares of the United States and the United Kingdom relative to Asian and European competitors over the past 20 years have been due in part to a lower level of investment in technology (Franko [9]). The U.S. still holds the largest market share in high-technology industries. However, the maintenance of this position will be in part based on its ability to fund research and development activity and to realize a sufficient technological and competitive return from this investment.

Research and development expenditures are a viable government policy element that is also controlled by individual firms. Although governments may play a major role in research and development funding, both the funding level and the direction of the research that is conducted is often dependent on the actions of individual firms. The consistency of research and development expenditures over time is also important, in addition to the level of expenditures. Research and development must be funded in slow economic periods, as well as during times of greater economic and business growth (Macharzina [16]). Our research examined the recent trends in this funding, emphasizing the total civilian research and development expenses and its trends. Specifically how R&D and inventive activities impact competitiveness is beyond the scope of this paper and remains an important issue for future research.

III. RESEARCH OBJECTIVE AND METHOD

The specific objectives of the present research are to address the following questions for the countries examined: 1) What are the levels of research and development expenditures and how have those expenditures changed since the early 1980s? 2) What is the relative level of research and development funding between industry and government, and what proportion of government funding is devoted to defense? 3) What is the subsequent total net level of civilian research and development funding? 4) How long would it take for the economies analyzed to catch up with the U.S. given the current trends?

In order to address these research questions, data were obtained from the

Organization for Economic Cooperation and Development (OECD). The OECD is an international organization of the industrialized, market-economy countries. The OECD was established in 1961 as a successor to the Organization for European Economic Cooperation that administered the Marshall Plan.

Research and development expenditures resulting in the creation of technology can be a usable measure of innovative activity (Van der Eerden and Saelens [27]; Glismann and Horn [10]; Chakrabarti, Feinman, and Fuentivilla [5]). In this study we used several measures of research and development expenditures that aid in the identification of sources and trends over time. The OECD measures used in this research were 1) gross domestic expenditures¹ on research and development; 2) gross domestic expenditures on research and development as a percentage of gross domestic product; 3) gross domestic expenditures on research and development per capita; 4) percentage of gross domestic research and development financed by industry, government, other national sources (higher education institutions and private non-profit organizations), and from abroad; 5) government expenditures on research and development; 6) government civil and defense research and development expenditures as a percentage of government research and development expenditures. Each of these variables were obtained for the most recent years of available OECD data in the period 1981-1994.

IV. RESEARCH FINDINGS

A. Total Research and Development Expenditures

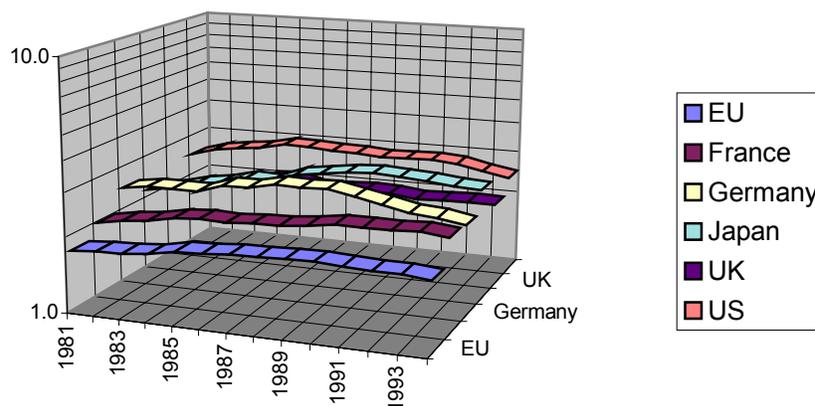
Table 1 shows total research and development expenditures, expenditures per capita, and expenditures as a percent of GDP. The U.S. spent an average of \$129.2 billion over the 1981-1994 period, over double that of Japan with \$50.8 billion. Germany is third in expenditures, averaging \$27.4 billion, France fourth with \$19.5 billion, and the U.K. last with \$18.0 billion. The European Union countries combined spent an average total of \$88.4 billion, falling between the U.S. and Japan. When the growth trend is examined for total expenditures from 1981 in Table 5, the European Union countries spent 2.5 times more in 1994 compared to 1981. France and Germany spend 2.3 times more, Japan 3.2 times

more, and the U.S. spent 2.3 times more. Clearly, Japan's growth rate is much higher than the U.S. and the other countries examined².

On research and development expenditures per capita, the U.S. is the leader followed by Japan and Germany. The 1994 data revealed, however, that Japan is second to the U.S. and is quickly approaching the U.S. level of research and development expenditures per capita. Comparing the 1981 to 1994 trends of per capita expenditures, the European Union countries increased 2.1 times, France and Germany 2.3 times, Japan 3 times, the U.K. 1.8 times, and the U.S. 2 times. This again shows the still greater growth rate of Japan's research and development investment on a per capita basis compared to the other economies examined.

When the average research and development spending as a percent of GDP is examined, the U.S. leads, followed closely once more by Japan and Germany. The European Union countries on average remained last. When examined for 1994 only, Japan has the highest expenditure level as a percentage of the GDP, followed by the U.S. and Germany. As seen in Figure 1, comparing research and development expenditures as a percentage of GDP over time, the United States trended slightly down, while at the same time Japan has trended upward with the exception of the most recent years. Germany has trended down and recently fell below France.

Figure 1
Research and development expenditures as a % of GDP, 1981-1994



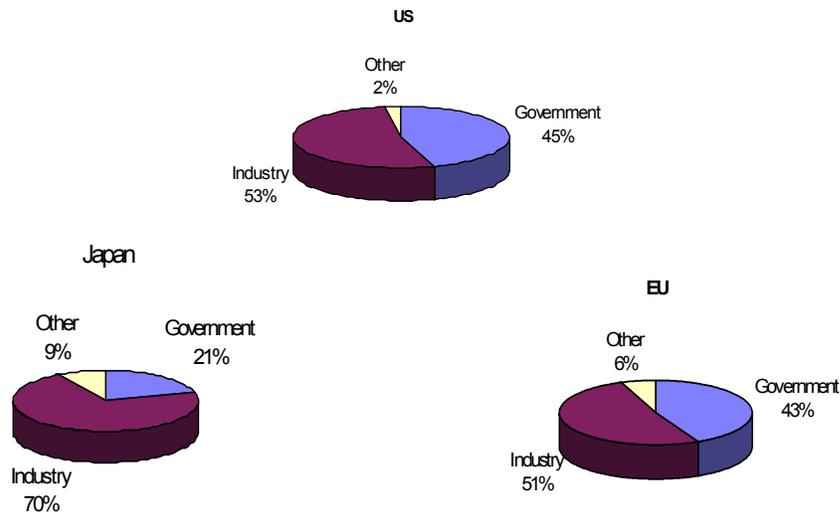
B. Sources of Research and Development Funding

When firms devote resources to research and development, as opposed to the government financing of research and development, the more likely the funding will be quickly utilized for product and process innovation (Glismann and Horn [10]). Also, the presence of funding by industry is indicative of individual firms' commitments to the success of long-term strategies that require major investments in technology (Dertouzos et al. [6]). As seen in Table 2, sources of funding of research and development were identified based on four sources for each country examined: Industry Funding, Government Funding, Other Domestic, and Funding from Abroad. "Other Domestic" is comprised of financing from higher education and private non-profit institutions.

Japan has a higher average industry financing level than the other economies examined by a wide margin. It averages 70.9% of funding from industry sources, followed by Germany with 61.4%. The United States, the U.K, and France follow with 52.5%, 47.8%, and 43.2% of funding from industry sources on average over the 1981-94 period, respectively. The European Union research and development expenditures are on average 51.3% financed by industry, falling behind Japan and Germany. Other domestic and funding sources from abroad do not vary widely, although the U.K. and France do have relatively higher percentages of funding from abroad. Figure 2 highlights the striking difference in the sources of R&D funding between Japan, the U.S., and the European Union.

France has the highest level of average government funding at 49.7%, followed by the United States, the U.K., and Germany. Japan has the lowest level of government funding of research and development at 20.6%. Overall, the funding sources are relatively stable over time. Japan's proportion financed by the government decreased from 24.9% in 1981 to a low of 18% in 1990 only to go back to 21.5% in 1994. The next section presents trends in defense and civilian R&D expenditures.

Figure 2
Average research and development financing, 1981-1994



C. Government Expenditures: Civilian vs. Defense

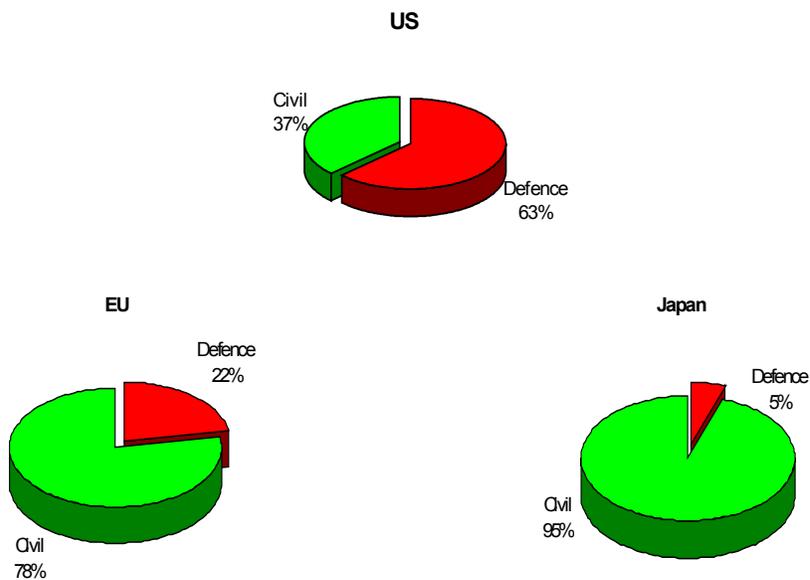
Table 3 shows government expenditures in billions of U.S. dollars and the breakdown of government expenditures on civilian compared to defense research and development. The U.S. government spends the largest nominal amount by far. However, Japan has overtaken the U.S. in government expenditures in R&D growth recently. The U.S. growth rate in government R&D expenditures was 2 times versus 2.2 times for Japan and around 2 times for most of the other countries from 1981 to 1994.

The U.S. has the highest percent of government expenditures on research and development for defense at 62.9% on average, followed by the U.K. at 44.5%. The other economies spend far less in this, with Japan having the lowest, but fastest growing, percentage spent on defense at 5.1% average. Japan in 1994 spent 6.0% of government expenditures on defense research and development. All the other economies are spending much less in defense as a proportion of total government expenditures. In 1994, the U.S. government

spent 55.3% in defense R&D from a peak of 69.3% in 1986. The same seems to be happening in the other European countries.

As seen in Figure 3, the disparity between the U.S., Japan, and the European Union in government expenditures on defense related research and development is substantial. This may put Japan at an advantage since its research and development funding is devoted almost exclusively to civilian purposes, which can enhance its position in the global market. The trend of government funded defense research and development shows an increase for Japan and a decrease in the other economies. Nevertheless, the disparities are substantial for this to equalize in the short-run.

Figure 3
Average civil and defence government expenditures on research and development, 1981-1994



D. Estimated Total Level of Civilian Research and Development

Given the importance of civilian research and development activity to market competitiveness, total civilian expenditures were estimated as shown in Table 4. By deducting government funded defense expenditures from the total expenditures, the total civilian research and development expenditure level was obtained. This was then expressed as a percent of gross expenditures, as a percent of GDP, and on a per capita basis.

It must be kept in mind when examining business expenditures on research and development that part of this expense may be dedicated to defense. However, the OECD data did not allow us to verify this and thus pure civil expenditures may be overestimated. On the other hand, defense expenditures may eventually yield civil innovations as an offsetting effect. The results, if civil expenses are overestimated, would show the U.S. to have an even lower business research and development expenditure level.

The results in Table 4 are revealing. Although the U.S. led dramatically in total research and development expenditures compared to Japan (see Table 1; \$129.2 billion compared to \$50.8 billion on average), the difference between the two countries becomes smaller when one looks at civilian expenditures alone. On a total civilian expenditures basis, the U.S. leads Japan with \$86.9 billion compared to Japan's \$59.2 billion on average. Thus, Japan's expenditures in R&D are 68% of that of the U.S. In 1994, however, this ratio was 55%, reflecting the U.S. decreasing expenditures with defense.

Since there is no data for Japan before 1985, the growth rates for total civilian expenditures from 1985, as estimated from Table 4, reveal that Japan increased its expenditures by 1.95 times up to 1994. The U.S. civil expenditures increased by 1.7 times in the same period and the European Union by 1.8 times.

While Japan's civilian research and development expenditures are only slightly less than its total expenditures, the U.S. civilian expenditures are 29.6% less than the total expenditure level on average. As shown in Figure 4, when comparing total civilian research and development expenditures as a percent of GDP to total research and development expenditures as a percent of GDP (Figure 1), a much different pattern emerges. Japan is the leader in civilian research and development expenditures as a percentage of the GDP and on a per capita basis, having overtaken the U.S. in both measures. Germany was at a

comparable level as Japan but shows a sharp decline in the period following its efforts at reunification. The U.S., France, the U.K., and the European Union countries all are at a relatively stable and comparable rate, but below that of Japan and Germany.

V. DISCUSSION AND IMPLICATIONS

The findings of our research indicate that although the U.S. currently has a higher gross R&D expenditure level than the other economies examined, there are several factors that make this lead not as substantial as first appears. Upon closer examination of the data, Japan is funding research and development in a manner that makes it already a leader in research and development funding relative to the U.S. and the other economies examined. In fact, Japan already leads all other countries considering only civilian expenditures in research and development on a per capita and relative to the GDP basis.

Figure 4
Estimated civil research and development expenditures as a % of GDP

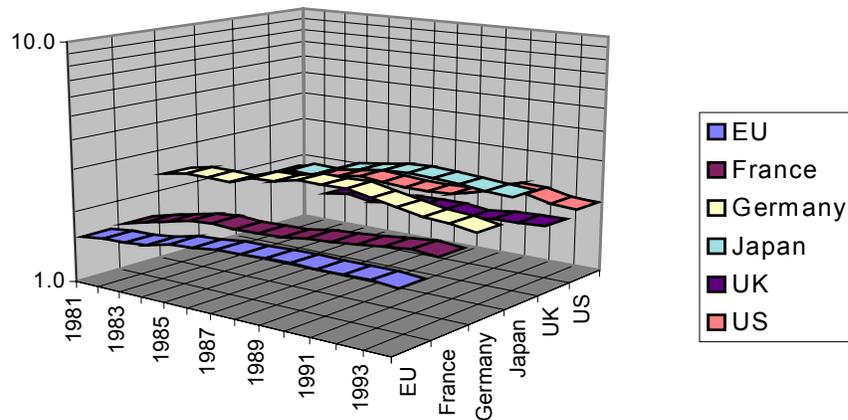


Table 5
Summary of trends in research and development funding, 1981-1994

Economy	Variable	1981	1994	14 Year Growth	Geometric Average Growth	Years To Catch Up With US
EU	Gross R&D Exp. US\$ Billion	51.3	126.0	145.5%	6.6%	57
	Gross R&D Exp. US\$ Per Capita	161.0	339.9	111.1%	5.5%	201
	Total Civil Exp. in US\$ Billion	45.4	117.2	157.8%	7.0%	54
	Total Civil Exp. Per Capita	142.6	316.1	121.7%	5.9%	816
France	Gross R&D Exp. US\$ Billion	11.4	26.4	130.8%	6.2%	2779
	Gross R&D Exp. US\$ Per Capita	211.1	456.9	116.4%	5.7%	70
	Total Civil Exp. in US\$ Billion	9.1	22.8	150.4%	6.8%	4670
	Total Civil Exp. Per Capita	167.8	394.0	134.8%	6.3%	57
Germany	Gross R&D Exp. US\$ Billion	16.6	37.4	125.1%	6.0%	Never
	Gross R&D Exp. US\$ Per Capita	269.3	459.4	70.6%	3.9%	Never
	Total Civil Exp. in US\$ Billion	16.0	36.2	126.1%	6.0%	Never
	Total Civil Exp. Per Capita	259.5	444.7	71.3%	3.9%	Never
Japan	Gross R&D Exp. US\$ Billion	23.3	75.1	222.1%	8.7%	33
	Gross R&D Exp. US\$ Per Capita	198.2	600.8	203.1%	8.2%	3
	Total Civil Exp. in US\$ Billion	38.0	74.1	154.4%	6.9%	387
	Total Civil Exp. Per Capita	325.1	593.0	132.0%	6.2%	Already Did
UK	Gross R&D Exp. US\$ Billion	12.3	22.6	84.4%	4.5%	Never
	Gross R&D Exp. US\$ Per Capita	217.3	387.4	78.3%	4.2%	Never
	Total Civil Exp. in US\$ Billion	9.5	19.8	108.6%	5.4%	Never
	Total Civil Exp. Per Capita	168.0	338.7	101.6%	5.1%	Never
US	Gross R&D Exp. US\$ Billion	73.7	168.5	128.7%	6.1%	
	Gross R&D Exp. US\$ Per Capita	320.2	646.4	101.9%	5.1%	
	Total Civil Exp. in US\$ Billion	53.9	134.1	149.0%	6.7%	
	Total Civil Exp. Per Capita	234.0	514.5	119.9%	5.8%	

The figures for Japanese total civil expenditure start in 1985. The growth rates have been adjusted accordingly.

A summary of our analysis is shown in Table 5. There are three major considerations that affect the current position of the U.S.: (1) the slightly lower, growth rates in total and civil research and development funding compared to other selected economies, notably Japan; (2) the relatively high level of government funding compared to industry funding of research and development; and (3) the relatively high level of research and development expenditures that are devoted to non-civilian applications. These factors in combination greatly favor Japan's leadership at the expense of the U.S. and the other economies examined. The superior performance of Japan in funding inventive activities, in particular, has been noted in earlier studies (Evenson [8]; Glismann and Horn [10]).

There is a wide disparity in the growth rates in total research and development expenditures between Japan and the other economies. Japan's expenditures have tripled while the other economies have slightly more than doubled. On a per capita and on a percentage of GDP basis these trends are even more dramatic. Not only has Japan surpassed the U.S. in total expenditures as a percent of GDP, Japan's relative increase in total expenditures as a percent of GDP from 1981 to 1994 is double that of the U.S. and France, the next two countries in expenditure as a percentage of GDP increase. On a per capita basis similar evidence supports the notion of Japan's superiority in this area. Japan's sources of research and development funding are also quite different than the other competing economies examined. Its relative level of industry funding is substantially greater than the other economies. Additionally, the loss of the U.S. leadership has been explained by Glismann and Horn [10] as a catching-up effect by other countries for earlier periods. But the most recent data still show a high growth rate in expenditures and in patents (Powers and Leal [20], which may indicate that the reduced, but still vigorous, U.S. inventive activity may not be simply explained by other economies catching up.

Although defense related research and development may in fact have civilian spin-offs, it is not generally considered to have the same impact on the development of consumer goods and on overall economic performance (Kennedy [13], Glismann and Horn [10]). The disparity between the U.S. and Japan in government expenditures on defense related research and development is substantial and may contribute to Japan's innovative capability so widely seen in recent years. If the trend that we have observed in the level of the U.S.

and Japan's gross R&D expenditures per capita were to continue into the future, Japan will overtake the U.S. in 1997. Japan already overtook the U.S. in total civilian expenditures per capita in 1987.

An additional consideration is the U.S. reducing its level of defense expenditures in the 1990s. At the same time Japan is increasing defense expenditures. This may tend to mitigate the wide disparity we have observed on total civilian research and development expenditures in the future. Germany's funding of research and development as a percentage of GDP was at the same level as that of Japan, but has declined recently. If the trend that we identified for Germany continues for several more years, it can have a negative impact on the European Union in total. In 1993 Japan was considered to be the world's most competitive economy (The Economist [26]). However, the U.S. regained the leadership in the 1995 and 1996 and, as our data show, has improved its figures for R&D funding recently while those of Japan stabilized. No doubt, Japan aside, the U.S. remains unchallenged.

VI. SUMMARY AND CONCLUSIONS

In this paper we have identified the levels and trend of research and development funding for Japan, France, Germany, Great Britain, the United States, and the European Union. Japan's performance is unique and superior relative to the other economies. We specifically call attention to the fact that virtually all of Japan's R&D expenditures are civilian in purpose and funded by industry. When total civilian research and development expenditures are examined, Japan's investment in technology is already superior and has overtaken the U.S. on both a per capita and a relative GDP basis. The results reported in this paper have profound competitive and policy ramifications that we believe are important to investigate and identify in future research.

NOTES

1. All currency figures are in U.S. dollars adjusted based on the purchasing power parity across countries.
2. These results are consistent for local currency expenditures and do not seem to be driven by foreign exchange rate changes.

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