The Importance of Innovation for Productivity

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✷ The views expressed in this paper are of the authors only and do not reflect in any way those of either Industry Canada or the Government of Canada.

1. INTRODUCTION

Rapid technological changes, the information revolution and increasing globalization of business activities have intensified competition among countries for export markets, capital, R&D, and skilled people. The competitive imperative is especially critical for Canada because it depends heavily on international trade and foreign capital and competes head on with the United States, the world's largest and the most dynamic economy, for capital, R&D, skilled people and high-value added activities.

In the 1990s, the growth rate of real per-capita income in Canada was significantly lower than in other OECD countries, particularly the U.S.. The most often cited reason for the phenomenal productivity performance in the U.S. economy is its dynamism and superior innovation record. If innovation is the key to improving growth in productivity and living standards, it is important to examine the key drivers of innovation and understand the nature and sources of Canada=s innovation gap.

Canada=s economic performance in the 1990's lagged far behind that of the U.S. B real incomes in Canada are currently about 30 percent below those in the U.S.. Although Canada has achieved a 10% annual growth in nominal merchandise exports over the1990's (from $152.1 billion in 1990 to $360.0 billion in 1999), this has been due largely to a buoyant U.S. economy and the real depreciation of the Canadian dollar. However, we cannot rely on the weak dollar and the strong US economy to improve the living standards and quality of life of Canadians. On the contrary, the depreciating currency may actually erode the living standards of Canadians. The reality is that 90% of the income gap between Canada and the U.S. is due to the productivity gap. Therefore, only superior productivity performance will improve Canada=s international cost competitiveness on a sustained basis, raise the standard of living and close the real income gap between Canada and the U.S..

The research to date strongly suggests that technical progress, the embodiment of innovation, is the fundamental determinant of longer-term productivity performance, hence international competitiveness, living standards and quality of life. The main objective of this paper is to analyze the linkages between innovation and productivity. Our paper hopes to shed some new light on the following four important research questions:

- What does the cross-country data show about the importance of innovation for productivity and living standards?

- How strongly is inter-industry variation in manufacturing sector productivity correlated with the key indicators of innovation activity in Canada and the United States?

- What are the major determinants of innovation?

- How does Canada compare with other G-7 countries in terms of the key drivers of innovation?

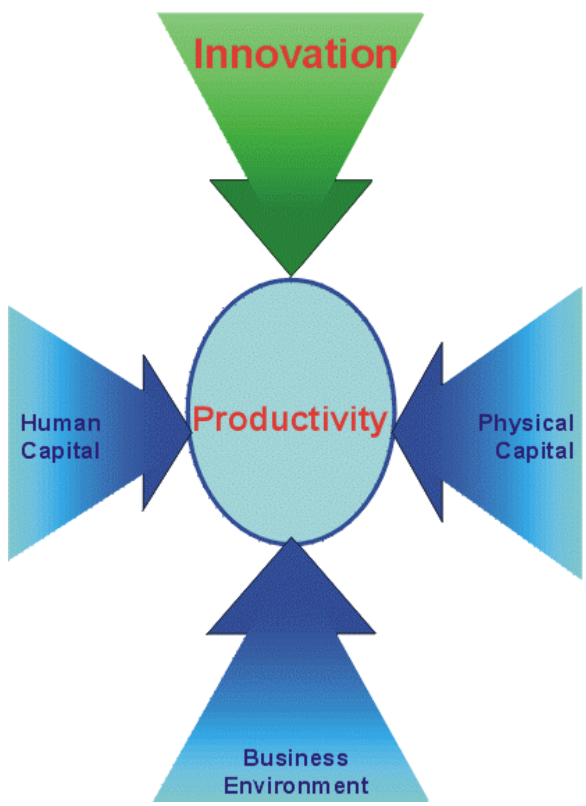
The next section (section 2) of the paper provides a conceptual framework on different dimensions of innovation, examines the theoretical linkages between innovation and productivity, and discusses the foundations of various forms of innovation. In section 3, he examines the relationship between productivity and the key indicators of innovation, both internationally and across Canadian and U.S. manufacturing industries. In section 4, we look at the international evidence on the major determinants of innovation. Then, we compare Canada's innovation record with that of other G-7 countries, in section 5. In the last section (section 6), we summarize the main results of our research and examine the implications of our findings.

2. CONCEPTUAL FRAMEWORK

Key Drivers of Productivity

Labour productivity levels and real wages are strongly positively correlated across developed and developing countries – i.e.; low wage countries such as India and Pakistan also have low labour productivity while high wage countries such as the United States and Canada exhibit high labour productivity (see Chart 1). This central role of productivity in determining living standards and quality of life has given rise to an extensive literature on the factors influencing its level and growth (see Stiroh (1999) and Elias (2000) for a survey of the literature).

Modern growth theory identifies three key determinants of productivity growth: accumulation of physical capital, accumulation of human capital, and rate of innovation and technological change. It is not appropriate, however, to consider them as separate factors, since they interact in complex ways and are complementary in nature. Advanced technologies are generally incorporated in the production process to improve productivity. But new investments in machinery and equipment, and skills development in



the labour force are also required to use state-of-the-art technologies effectively. In short, the quantity and quality of these three key factors, and the way in which they are organized, managed and utilized within a firm are what determine productivity performance.

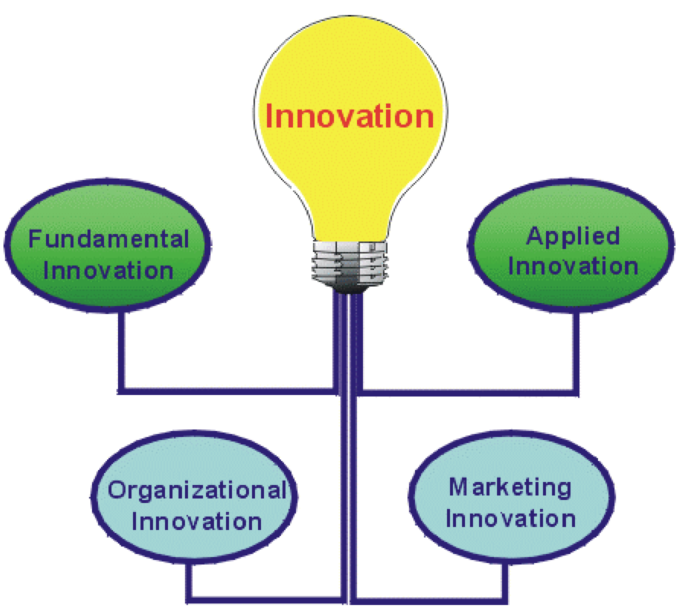
Aside from these three key determinants, a country's business environment also matters. In particular, framework conditions, such as openness to trade and investment, the degree of competition in the economy, the financial system, quality of management and intellectual property protection are important enabling factors for improving productivity. In particular, the degree of competition in a particular country or sector may be one of the key factors, since lack of competition reduces the pressures on firms to adopt and use advanced technologies, re-organize workplace, rationalize production and to improve productivity.

Several recent papers done for Industry Canada on productivity issues provide an overview of what economists know to date about productivity, and summarize what consensus that has emerged on the drivers of productivity growth and the special role played by innovation. Harris' (1999) literature survey identifies three key productivity drivers: investment in machinery and equipment; human capital; and openness to trade an investment, all within an overall framework where innovation creates the opportunities for growth. He also identifies several other factors, including: innovation and technology diffusion; and general purpose technologies, to name just two. Globerman (1999) focuses on literature dealing with technological change as a key driver of productivity growth. He observes that there is a growing perception that major technological developments in computing and telecommunications, including the emergence of the Internet will induce productivity growth. He identifies R&D expenditures and patent intensities as proxies for this type of technological change. He too emphasizes the importance of innovation for productivity. Morck and Yeung (1999), in their review of the economic determinants of innovation, identify several key factors, including, among others: intellectual property rights; the quality of corporate decision making; and a well-functioning financial system.

Innovation and Productivity

The link between innovation and productivity growth receives particular attention in the literature. In fact, innovation is often thought of as the "engine of growth" because of its lasting long-run effects on productivity. Although the conceptual links between innovation and productivity are strong and clear, the relationship between the two is complex.

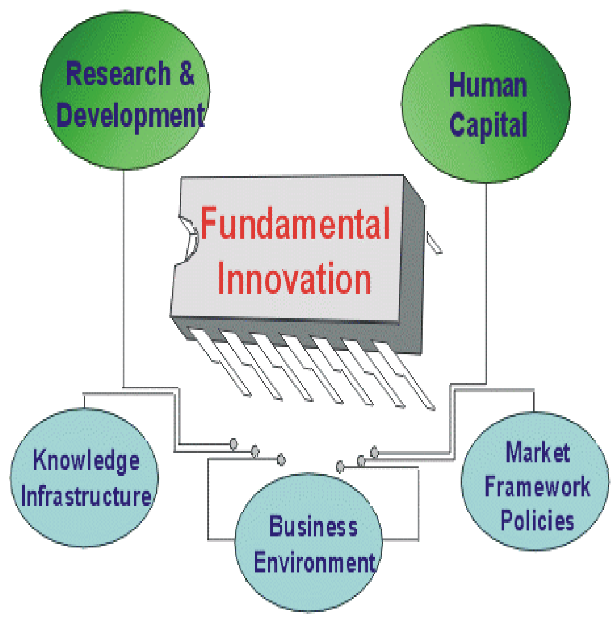
Innovation is a continuous process of discovery, learning and application of new technologies and techniques from many sources. Many of the techniques and processes are cumulative and interdependent, and the technological capacity of a firm may also be influenced by external factors such as the educational system, the research infrastructure and the functioning of the capital markets.



In this context, innovation includes

both fundamental and applied innovation. In addition, innovation can take the form of organizational and marketing changes which expands demands for products, support existing structures for new methods of production and increase the efficiency of the other types of innovative effort, leading to productivity improvements. Although these are potentially very important for increasing productivity, in this paper we will concentrate only on technological innovations, because of lack of data on these innovation activities and resource constraints.

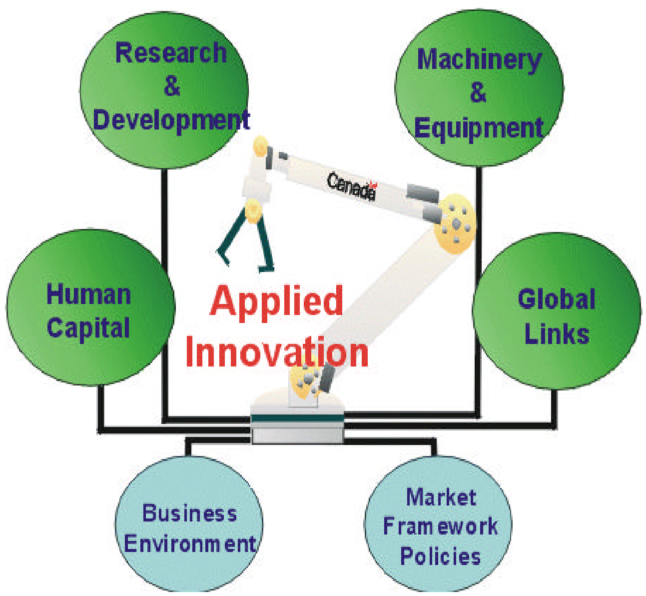
Fundamental innovation, often thought of as research proper, comprises the invention of new products and processes. It is a familiar concept, often measured by patents granted or active patents, sometimes adjusted for quality. The R&D intensity (the R&D/GPD ratio), an input measure, is also used by many as a proxy for fundamental innovation.



Investment in R&D and the accumulation of human capital, especially the share of scientists and engineers in total labour force, are crucial prerequisites for fostering fundamental innovation. Fundamental innovation also depends on the quality of supporting institutions such as the knowledge infrastructure (universities, government labs, etc.), a healthy business environment and sound market framework policies (competition and intellectual property protection, etc.). They provide a favourable environment for innovative activity.

Fundamental innovation, however, is only a small but important part of total innovative effort, especially for a small open economy like Canada. The greater part of innovation actually consists of applied innovation which occurs when new products or processes developed either in Canada or in other countries, especially the United States are utilized, or when existing technologies are used in a new context or in a new way.

Like fundamental innovation, applied innovation is also enhanced by investments in R&D and human capital. In addition, investments in M&E and strong global links are important for the adoption and diffusion of new innovative processes and techniques. Finally, supporting institutions provide positive feedback on the innovation process.



3. INNOVATION AND PRODUCTIVITY EMPIRICAL FINDINGS

International Evidence

The per capita real income and productivity levels vary a great deal across OECD countries. The interesting question is whether differences in fundamental innovation activity explain the differences in productivity and income levels among OECD countries. We used two measures of fundamental innovation in this context: per-capita patents granted in the United States and per-capita active patents. Since the United States is the largest and the most dynamic market in the world, the competition for obtaining a patent in the US is intense. Therefore, per-capita patents granted in the US is expected to be a good proxy for fundamental innovation. Similarly, active patents better reflect fundamental innovation than patent applications or patents granted.

As expected, labour productivity levels are positively correlated with patent activity across OECD countries (see Chart 2 and Table 1). Firstly, the gap between a country's labour productivity and the OECD average is positively correlated to the number of patents granted to nationals of that country within the U.S.. Further, U.S. patents granted explains about 40% of cross national variations in the productivity gap with the OECD, and a 10% increase in U.S. patents granted results in a 1.6% increase in the country's relative labour productivity. Secondly, GDP per capita is positively correlated with domestic patents in force. The per capita patents in force explains about 76% of the cross national variation in GDP, and a 10% increase in patents in force results in a 2.9% increase in GDP per capita.

We could not include developing countries in our sample because reliable data on labour productivity for these countries are not available. However, there is no reason to expect that the strong positive relationship observed for the OECD countries will not hold for a sample of OECD and developing countries.

The Canadian Evidence

In addition to the international evidence, we also examine the linkages between innovation and productivity across two-digit manufacturing industries in Canada and the United States. We restrict our analysis to only manufacturing industries, because productivity data for non-manufacturing industries suffer from serious measurement problems. Furthermore, these industries are much more heterogeneous than manufacturing industries. Since data on patents and adoption and use of advanced technologies for individual manufacturing industries are not available, based on the discussion in Section 2, we used R&D intensity, M&E intensity and human capital intensity as the key indicators of innovation activity. We use two measures of productivity: output per employed person and total factor productivity (TFP) growth.

As expected, all three indicators of innovation are positively correlated with the labour productivity level across Canadian manufacturing industries. Similarly, TFP growth is also significantly positively correlated with the three innovation measures (see Charts 3 to 5). However, when the three indicators of innovation are combined in regression analysis, the regression results are weak. (Table 2). While human capital, M&E intensity and R&D intensity are jointly significant determinants of average TFP growth across Canadian manufacturing industries, the adjusted R^2 is low (0.24) and none of the innovation indicators are individually significant regressors, although they are jointly significant at the 10% level. When the innovation measures are regressed on average labour productivity the adjusted R^2 is only 0.11 and none of the regressors are significant, individually or jointly. In addition, the coefficient on R&D intensity is negative, although this is inconclusive as the t-statistic is very low on this variable.

These results give qualified evidence on the relationship between innovation and productivity in Canada. While the innovation indicators do vary to a small degree in conjunction with both labour productivity levels and TFP growth in Canada, the relationship is weak. Nor does the available evidence from the regression analysis allow us to differentiate the independent effects of each type of innovative activity on productivity. This is particularly true for R&D intensity which is highly correlated with human capital in the regression on labour productivity levels. However the positive relationship between the innovation indicators and average TFP growth imply that a one-time level increase in the innovation activity may raise the productivity growth rate indefinitely.

The US Evidence

Like Canada, the correlation between the three innovation variables and labour productivity level across US manufacturing industries is highly positive and statistically significant, but significantly stronger than in Canadian industries (see Charts 6 to 8). On the other hand, the correlation between TFP growth and three innovation measures are significantly weaker for the US industries.

The discrepancy between the Canadian and U.S. results is even more pronounced when we turn to the regression results across U.S. manufacturing industries (Table 3). Again, average labour productivity levels and average TFP growth were regressed on the three indicators of innovative activity:

human capital, M&E intensity and R&D intensity. The adjusted R^2 for the innovation indicators, regressed on average labour productivity is 0.84, while the adjusted R^2 when the innovation indicators are regressed on TFP growth is -0.27. This important difference between the two countries is interesting but puzzling. Perhaps it reflects the fact that the US is the technological leader and relies more heavily on fundamental innovation to maintain productivity than Canada. If this is the case, then US TFP growth could depend more on the rate of *increase* in fundamental innovation rather than the level of innovation. At the same time Canada relies more heavily on the adoption and diffusion of new technologies and less on fundamental innovation.

The regression results also provide an indication of which innovative activities have the strongest effects on labour productivity levels across U.S. manufacturing industries. Again, in the U.S., like in Canada, the coefficient on R&D intensity is negative. However, the existence of multicollinearity between the variables, and the high correlation between R&D per employed person and average labour productivity, indicates that the effect of R&D intensity on labour productivity levels is not easily separated from other innovative activities. That said, it appears that M&E intensity has the strongest effects on labour productivity levels among the U.S. manufacturing industries. The regression coefficients indicate that a 10% increase in M&E intensity leads to a 4.3% increase in labour productivity, compared to only a 0.3% increase in labour productivity for a 10% increase in human capital, all else held equal. Thus, the most effective mechanism for increasing labour productivity across U.S. manufacturing industries is achieved through increasing M&E intensity.

In conclusion, both the international and the Canada and US evidence strongly suggest that innovation is a key driver of productivity, and that of the innovative activities examined, M&E investment has the strongest impact on productivity independent of the interactions of investment and productivity. In addition, for Canada, the results also suggest that a one-time boost to innovative activity could positively and permanently raise the productivity growth rate.

4. DETERMINANTS OF INNOVATION

The previous section has investigated the extent to which labour productivity is determined by innovative activity, both internationally, and across North American industries. This section now turns to an analysis of the determinants of innovation with the aim of investigating what conditions support innovative activity.

Fundamental Innovation

The creation of new technologies, products and processes can be measured by either the outputs of the process, or inputs into it. Output can be proxied by patents granted per capita, or by patents in force per capita. The most common input proxies are R&D intensity (the ratio of R&D to GDP) and the human capital engaged in research (the share of R&D personnel in the total population). While none of these measures are perfect indicators of fundamental innovation, there is a high degree of correlation between them (Chart 9). Countries with high R&D and human capital intensities, such as the US, Japan and Sweden, also have high per-capita fundamental innovation. On the other hand, countries with low R&D/GDP ratios and low human capital intensities, such as Hungary and Spain, exhibit low per-capital fundamental innovation. Canada ranks slightly below the middle of these two extremes.

Our conceptual framework also suggests that both fundamental and applied innovation are also positively influenced by a number of important factors in the business environment, some of which have a more concrete relationship with innovation than others. The first two examined here, intellectual property protection and the strength of the domestic economy directly affect the returns to innovative activity. The others; quality of financial services, openness of the domestic economy, quality of technological infrastructure and quality of management, have less direct effects on domestic innovation abilities.

The data on the quality of the business environment which has been used to investigate the relationship between innovative outputs and the quality of the business climate, with the exception of intellectual property rights, has come from the World Competitiveness Report (1999). The World Competitiveness Report rates the quality of specific conditions across 47 economies internationally, and uses the ratings to index and rank the economies on the general business conditions which support competitiveness in a number of ways. The index of intellectual property rights has been obtained from a study by Park and Ginarte (1997) which scores a countries patent protection based on characteristics of the national patent regime.

In our empirical analysis, we find that both the direct and indirect business conditions are positively and significantly correlated to fundamental innovation. Countries with strong intellectual property protection also have higher levels of R&D intensity (Chart 13) and patents in force per capital, as do countries with stronger domestic economies (Chart 14). Countries with better technological infrastructure, as ranked by the World Competitiveness Index, also have higher R&D intensity and more patents in force (Chart 17). Surprisingly, a more general infrastructure measure, which include both physical as well as environmental infrastructure, is more closely correlated with the two measure of fundamental innovation. The correlation between the general infrastructure indicator and R&D intensity is 0.72, and between general infrastructure and patents in force is 0.83 compared to only 0.70 and 0.68 respectively for the technology infrastructure ranking. The degree of internationalization or global links, is also positively correlated with the two indicators of fundamental innovation across developed and developing countries (see Chart 15). Countries with better capital market performance and higher quality financial institutions also have higher levels of R&D intensity and more patents in force (Chart 16). A more specific measure on the availability of adequate financial resources for technological development has a stronger relationship with R&D intensity: the correlation between R&D intensity and financial resources for technology is 0.74.

While little can be said about the relative magnitude of variations in the direct and indirect determinants of fundamental innovation, the cross-country regression analysis provides some indication of the relative importance of each. Table 4 indicates that the direct determinants are capable of explaining much more of the cross-country variation in fundamental innovation than are the less direct variables. The two indicators of fundamental innovation, patents in force per 100,000 population and R&D as a percentage of GDP, were each regressed on the direct determinants of innovation, (R&D personnel per capita, intellectual property protection and strength of the domestic economy), on the indirect determinants (internationalization, finance, technology infrastructure, and management), and on the direct and indirect determinants together.

In the all-encompassing equation (1a), the adjusted R^2 is 0.72, however only R&D personnel per capita and the strength of patent rights are significant determinants of patent activity. Additionally, the signs on strength of the domestic economy and internationalization are positive - the opposite of what is expected for a ranked variable - but the t-statistics on these variables are very low. Equation (1b) regresses R&D intensity on only the direct determinants of innovation; the adjusted R^2 is 0.74, higher than the all inclusive equation (1a). Again, only R&D personnel per capita and patent rights have are significant, however the sign on strength of the domestic economy is negative as expected. The explanatory power of the less direct business environmental factors as a group is significantly lower, the adjusted R^2 is only 0.47. Of these factors, only the strength of technology infrastructure is a significant determinant of R&D intensity.

Similar results are obtained when regressing on the other measure of fundamental innovation - patents in force per 100,000 population. The combined explanatory power of both the innovation specific factors and general business climate factors is high - the adjusted R^2 is 0.79, and again, only R&D personnel per capita and patent rights are significant determinants of fundamental innovation. When only the group of direct determinants is regressed upon, the adjusted R^2 does not fall significantly, and all three of the direct conditions affecting fundamental innovation are individually significant. However, when we regress patents in force on the indirect environmental conditions, the adjusted R^2 falls to 0.63. While this implies that the indirect factors are more important for the patent activity measure of fundamental innovation than for the R&D intensity measure, it also indicates that the indirect environmental conditions have much less explanatory power than the direct influencers of innovation. Within the group of business environmental factors, the only individually significant factor is, again, the strength of technological infrastructure.

The implication of these findings is that the improvement of Canada's fundamental innovation performance can be achieved, with the best results, by improving Canada's performance on innovative inputs and business environmental conditions directly related to innovation. The World competitiveness rankings indicate that Canada has plenty of scope for improvement in these areas. (Box 1)

Box 1

Business Environment Measures	**Canada's Ranking**
	(out of 47)
Internationalisation[1]	24th
R&D personnel per capita	16th
Technology infrastructure	6th
Finance	11th
Financial resources for technology improvement	14th
Strength of the Domestic Economy	12th
	(Out of 120)
Intellectual Property Rights	27th

Applied Innovation

Applied innovation is closely related to fundamental innovation. The two measures of fundamental innovation, use of specialized robots in manufacturing and Internet users per capita, are both positively correlated with R&D intensity across OECD countries (Chart 10). Countries that use more advanced technologies have also devoted more resources to R&D spending.

[1] In spite of Canada's high trade openness, Canada ranks low on the internationalization measure partly because of its poor export market diversification (the heavy reliance on the US market), the large current account deficit, lower share of trade in commercial services in total trade and slower growth in FDI relative to the other countries ranked.

Additionally, they also have stronger performance on other measures of innovation inputs. The use of both advanced technologies are also positively correlated with high levels of human capital measured by researchers in the labour force (Chart 11). Countries with a high proportion of researchers in the labour force also use more robots in manufacturing and have high Internet usage. Similarly, applied innovation is positively related to higher rates of physical investment in related capital (Chart 12). The use of specialized robots is high in countries where a high proportion of GDP is invested in machinery and equipment. Likewise, Internet usage is high in countries that invest a high proportion of GDP in information and communications technologies (ICT).

Further evidence on the relationship between applied innovation and the conditions for fundamental innovation across OECD countries can be obtained from the multiple regression analysis reported in Table 5. The log of internet users per 1000 population has been regressed on ICT investment intensity, researchers per capita and R&D intensity. The overall regression is significant, with an adjusted R^2 of 0.37. Of the innovation conditions, only ICT investment is a significant determinant of internet use independent of the other innovative inputs. Additional tests of joint significance (not reported) indicate that the number of researchers per capita also contribute to the explanation of internet use per capita, but that R&D intensity does not. This indicates that applied innovation is affected most strongly by innovative inputs which improve an economies ability to adopt an applied innovation, but that fundamental innovation in the form of R&D intensity does not play a large part in determining the use of applied innovation.

Finally, there is limited evidence for a relationship between applied innovation and our business environmental conditions. The quality of financial service industry is positively with the applied innovation measure of Internet use — with a the correlation coefficient of 0.52. The rank correlation between technological infrastructure and internet use is 0.59 and between technological infrastructure and use of robots is 0.31. Management quality is also positively associated with the applied innovation measure of Internet use, with a correlation of 0.72.

In short, innovation is driven by a number of important factors: R&D intensity, investment in M&E, human capital, technological infrastructure, intellectual property protection, strength of the domestic economy, quality of financial institutions and quality of management.

5. CANADA'S INNOVATION PERFORMANCE: G7 COMPARISONS

The level of innovation in Canada lags behind the United States on most of the key indicators, and lags behind other G7 economies on many. (Charts 19 to 25) Canada=s gross domestic expenditure on research and development is below all G7 countries, with the exception of Italy. Canadians have a much lower number of patents per capita in the US than either the Americans or Japanese. Similarly, Canada=s expenditure on M&E as a percentage of GDP is the lowest in the G7. However, Canada=s performance is better when investment in ICT as a percentage of GDP is compared across the G7; Canada ranks third on this measure, just below the U.S.. Further, Canada does have a higher proportion of R&D personnel than the US, but it still only ranks 4th among the G7.[2]

There is some evidence that Canada=s innovation levels are catching up with the U.S. and other G7 economies. The innovation gap measured by GERD/GDP has narrowed between 1990 and 1997; Canada=s R&D inensity grew at 1.4% per annum, while the other G7 economies experienced a decline. Similarly, the M&E intensity grew faster than all other G7 economies, excepting the U.S, and Canada tied with Italy with the fastest growing ICT intensity. Further Canada experienced the fastest average

[2] However, Canada ranks 6th out of the G7 for the total R&D personnel in business per capita, only ahead of the UK.

annual percentage growth in patents granted in the U.S. between 1992 and 1997. However, Canada ranked behind the U.S., France and Italy in the average annual percentage growth of R&D personnel per capita. Overall, the slow convergence of innovation indicators between Canada and the rest of the G7 bodes well for future productivity performance.

Another mitigating factor, is Canada=s openness to international trade and investment. With a lower capacity for domestic fundamental innovation than most of the G7, it is important that Canada be open to the diffusion of innovation and knowledge developed elsewhere. In this respect, Canada has the highest trade openness of any G7 country, and is second only to the US in FDI openness. However, Canada=s international linkages are dominated by its economic relations with the US. Further, Canada badly trails the US in all the key determinants of a healthy business climate: intellectual property protection, strength of the domestic economy, quality of financial institutions and quality of management.

6. CONCLUSION

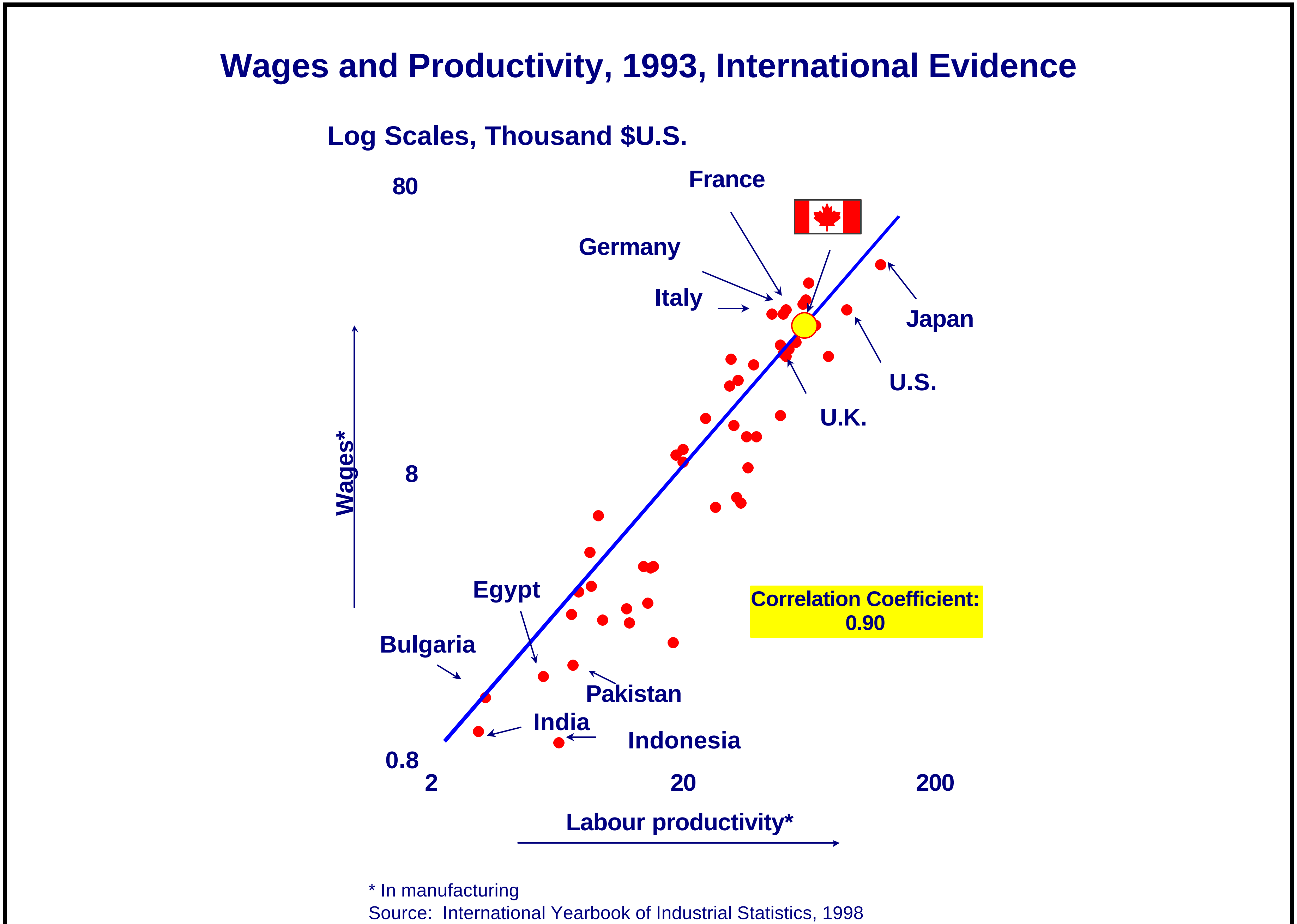
Our empirical findings suggest that innovative activity (as measured by patents granted) is highly positively related to productivity and per-capita income across developed and developing countries. Similarly, across manufacturing industries, productivity ***levels*** are positively correlated with three key drivers of innovation (R&D intensity, human capital intensity and M&E intensity) in Canada and the United States. However, productivity ***growth*** is not significantly correlated with these variables. Further, of the three key drivers of innovation, M&E investment intensity provides the strongest boost to productivity levels.

Across countries, fundamental innovation (measured by per-capita patents granted) is positively related to R&D spending and human capital. Similarly, applied innovation (proxied by the use of advanced technologies) is positively influenced by R&D spending and investments in human capital and machinery equipment. Both types of innovative activities are also determined by factors which shape the general business climate : intellectual property rights, macro-economic conditions, global links, adequacy of financial services infra-structure and the quality of management. However, it is determined that by far the most effective means of promoting innovation is to focus on the technology sector specific conditions that directly influence innovation.

Canada lags behind the US considerably, our largest trading partner and the main competitor for investment, R&D, skilled people and high-value added activities, in terms of the three key drivers of innovation : R&D; M&E and human capital. Canada also lags behind the US in all the key determinants of a healthy business climate. However, Canada has made significant progress in the 1990's in closing the R&D gap. Furthermore, Canada leads the US in terms of openness, an important pre-condition for an innovative economy (see Harris 2000).

These findings strongly suggest that to improve its competitive position and close the productivity and real income gaps, Canada needs to close the R&D, M&E and human capital gaps and improve the general business climate vis-à-vis the US.

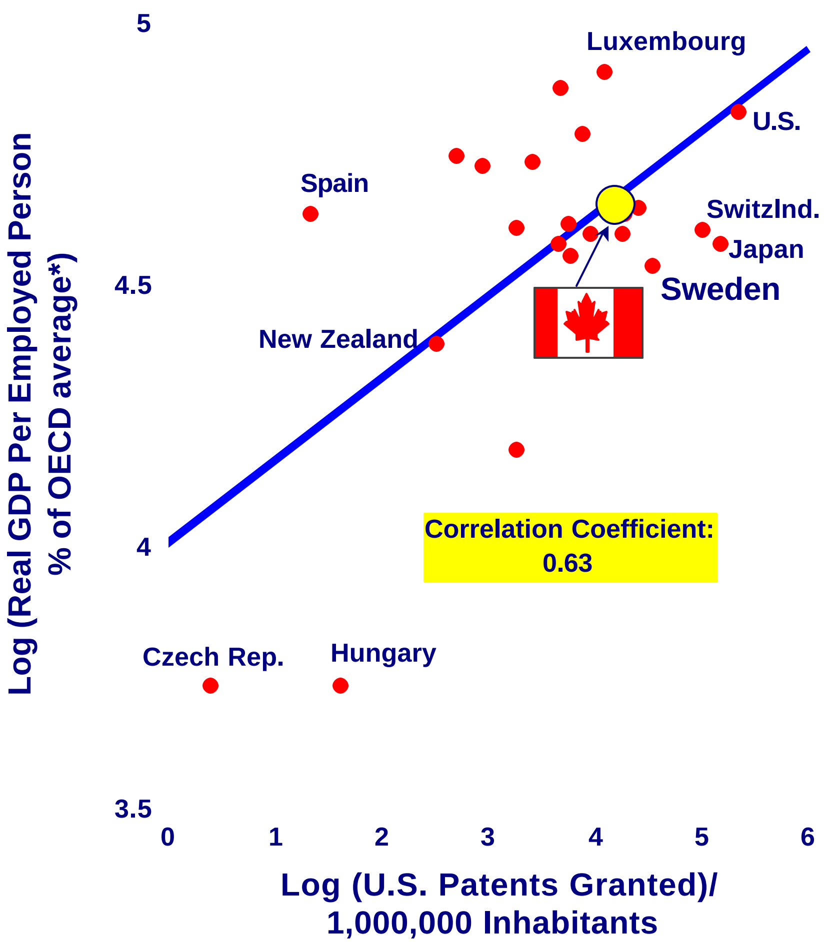
Chart 1



Wages and Productivity, 1993, International Evidence
Log Scales, Thousand $U.S.
80
8
0.8
Wages*
2
20
200
Labour productivity*
France
Germany
Italy
Japan
U.S.
U.K.
Egypt
Bulgaria
Pakistan
India
Indonesia
Correlation Coefficient:
0.90
* In manufacturing
Source: International Yearbook of Industrial Statistics, 1998

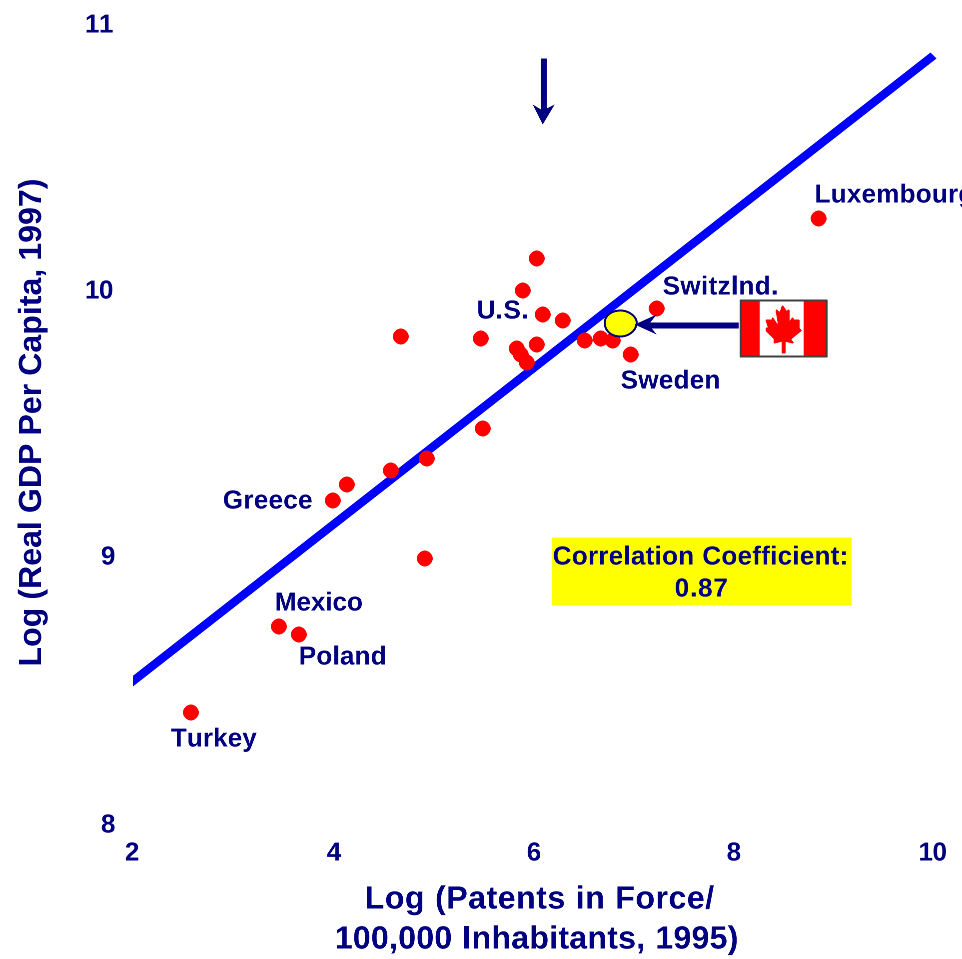
Chart 2

Real GDP Per Employed Person* and Patents Per Capita Granted in the U.S. for OECD Countries, 1995



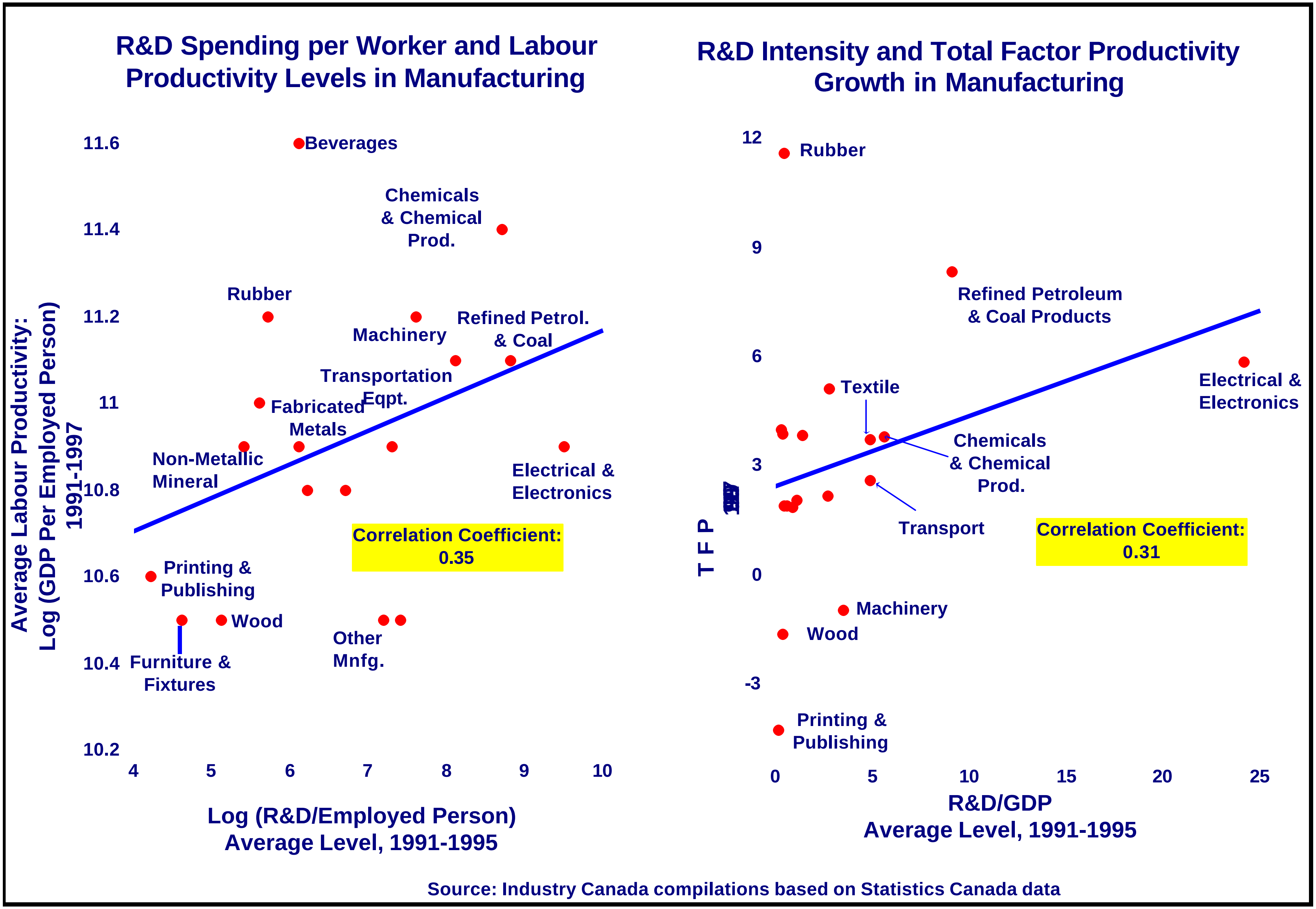
* OECD average is a weighted average based on 1996 PPPs.
Source: Industry Canada compilations based on data from OECD and U.S. Patent and Trademark Office.

Real GDP Per Capita* and Patent in Force Per Capita OECD Countries**



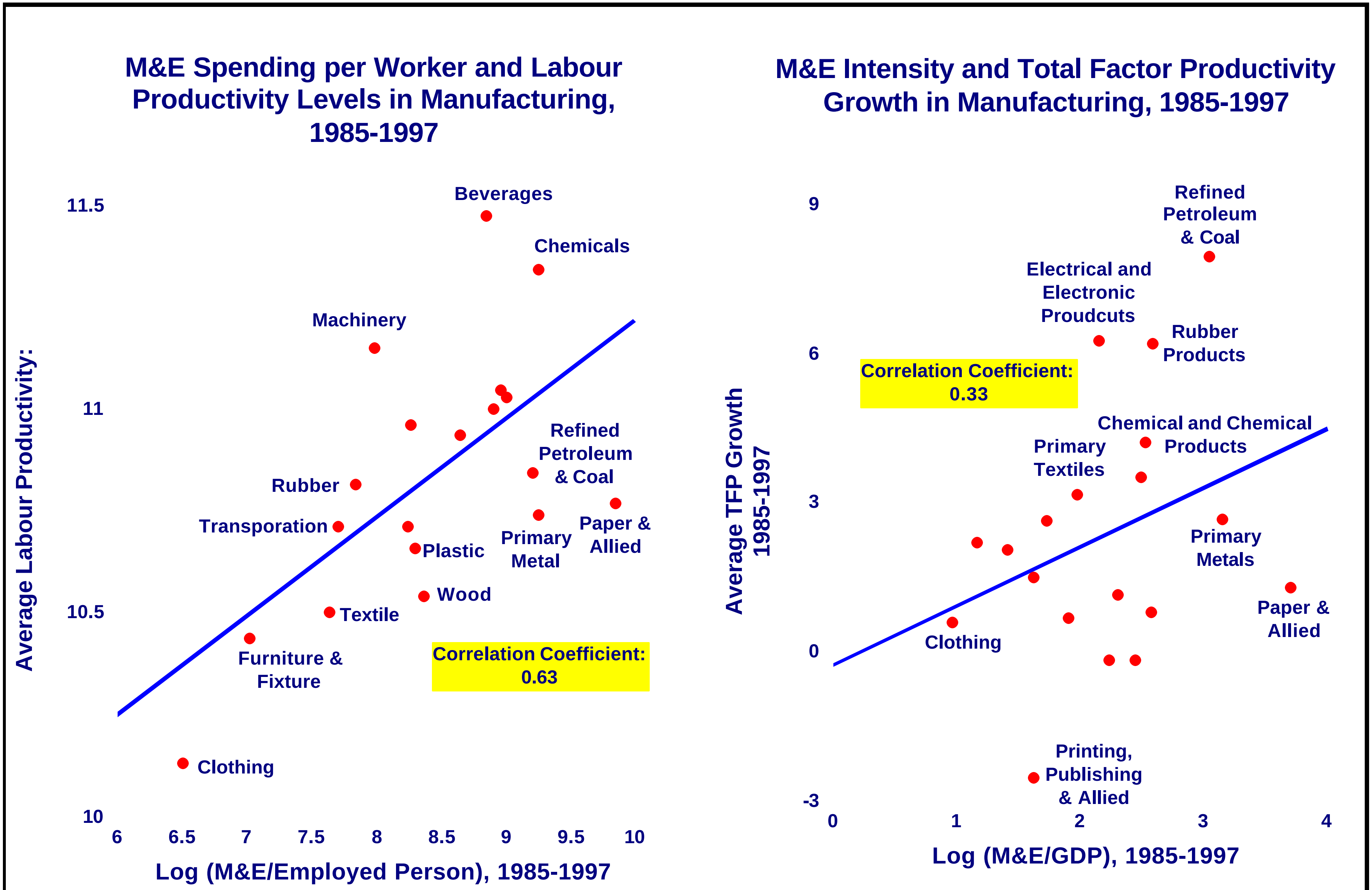
* In US$ based on prices and PPPs in 1990
** Excluding Italy and the U.K. for whom the data on patents in force are not available
Source: Industry Canada compilations based on data from U.N.

Chart 3



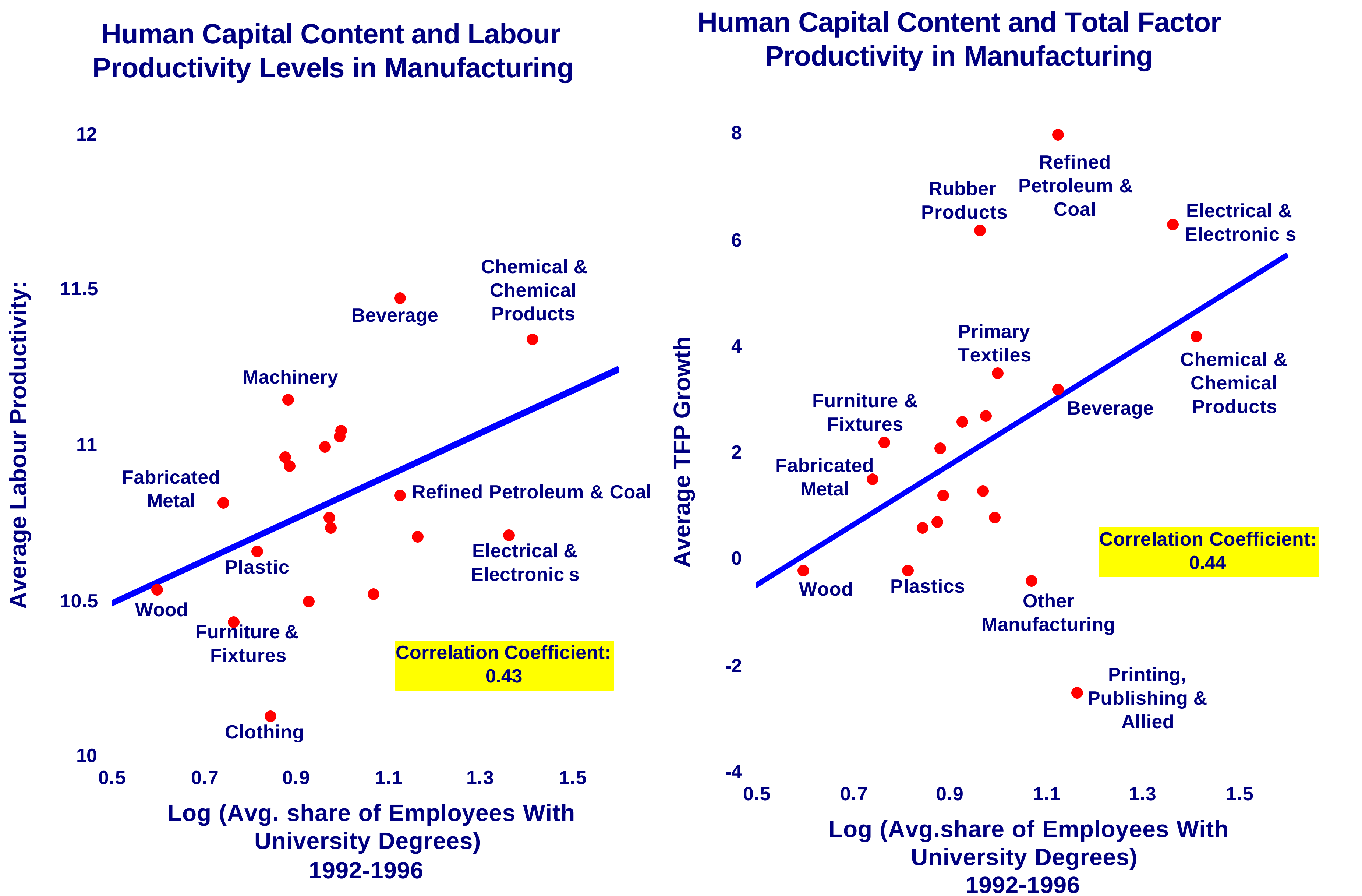
R&D Spending per Worker and Labour Productivity Levels in Manufacturing
Average Labour Productivity: Log (GDP Per Employed Person) 1991-1997
Log (R&D/Employed Person) Average Level, 1991-1995
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
4
5
6
7
8
9
10
Beverages
Chemicals & Chemical Prod.
Rubber
Machinery
Refined Petrol. & Coal
Transportation Eqpt.
Fabricated Metals
Non-Metallic Mineral
Electrical & Electronics
Correlation Coefficient: 0.35
Printing & Publishing
Wood
Furniture & Fixtures
Other Mnfg.
R&D Intensity and Total Factor Productivity Growth in Manufacturing
T F P
R&D/GDP Average Level, 1991-1995
12
9
6
3
0
-3
0
5
10
15
20
25
Rubber
Refined Petroleum & Coal Products
Textile
Electrical & Electronics
Chemicals & Chemical Prod.
Transport
Correlation Coefficient: 0.31
Machinery
Wood
Printing & Publishing
Source: Industry Canada compilations based on Statistics Canada data

Chart 4



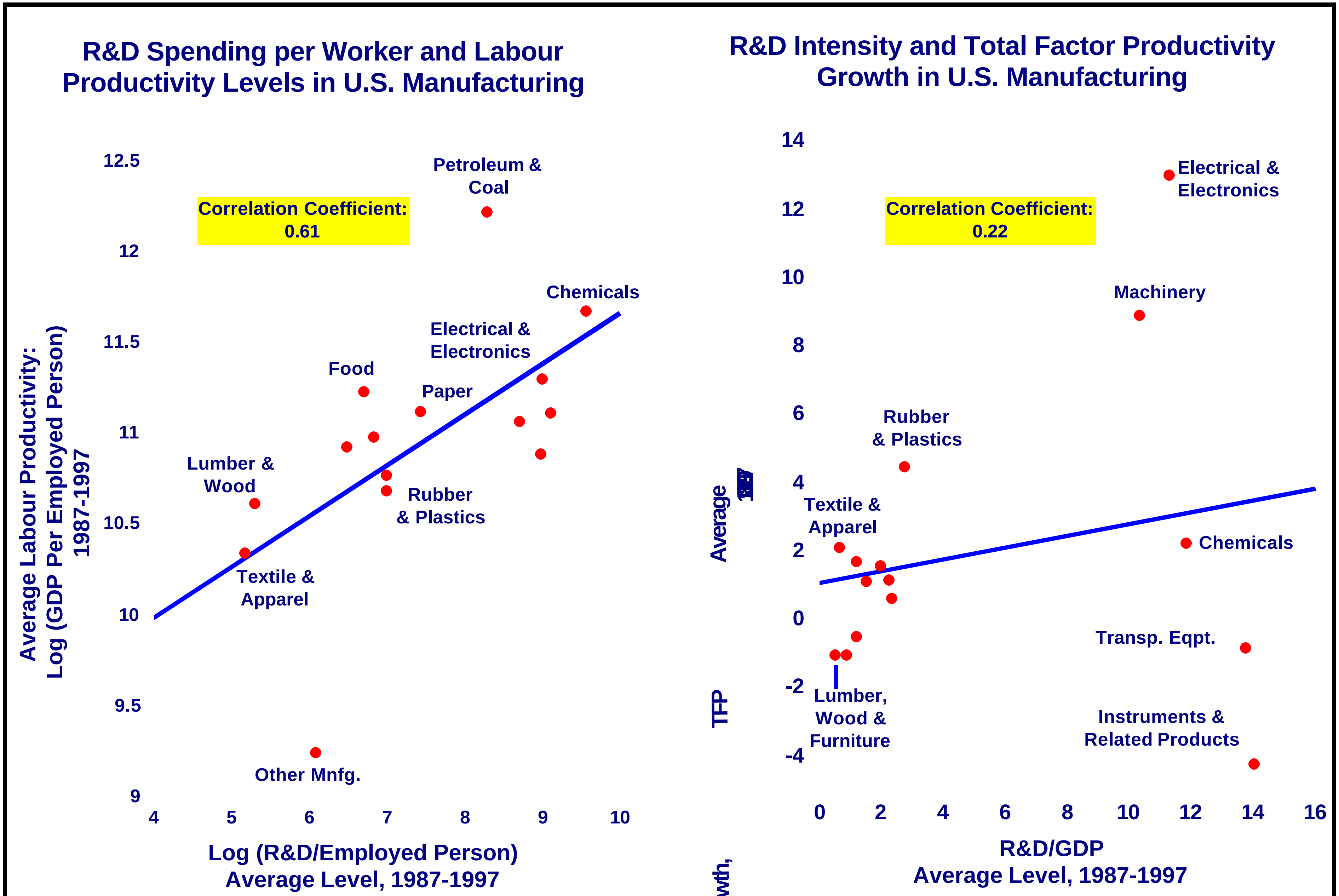
Source: Industry Canada compilations based on Statistics Canada data

Chart 5



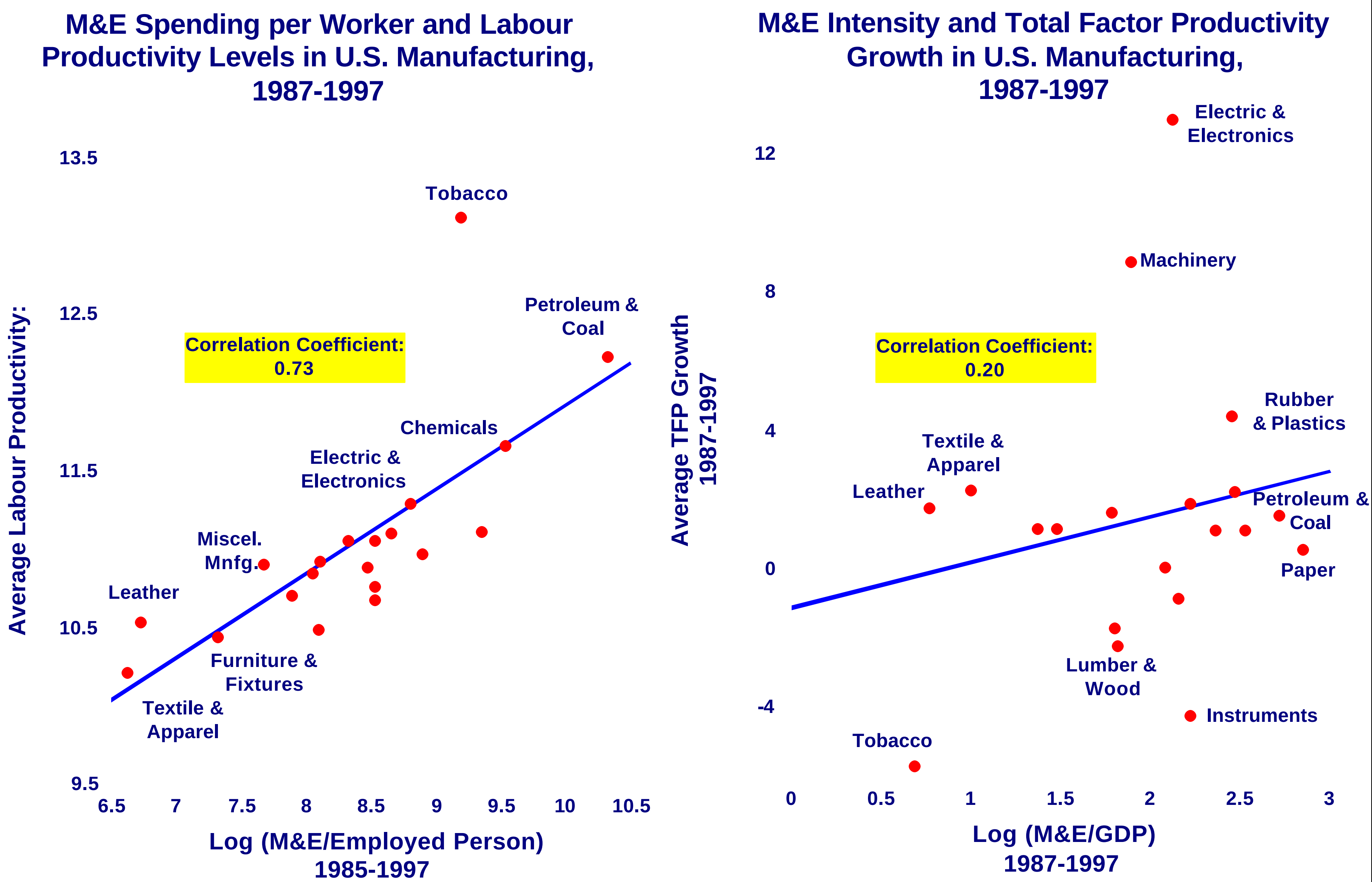
Source: Industry Canada compilations based on Statistics Canada data

Chart 6



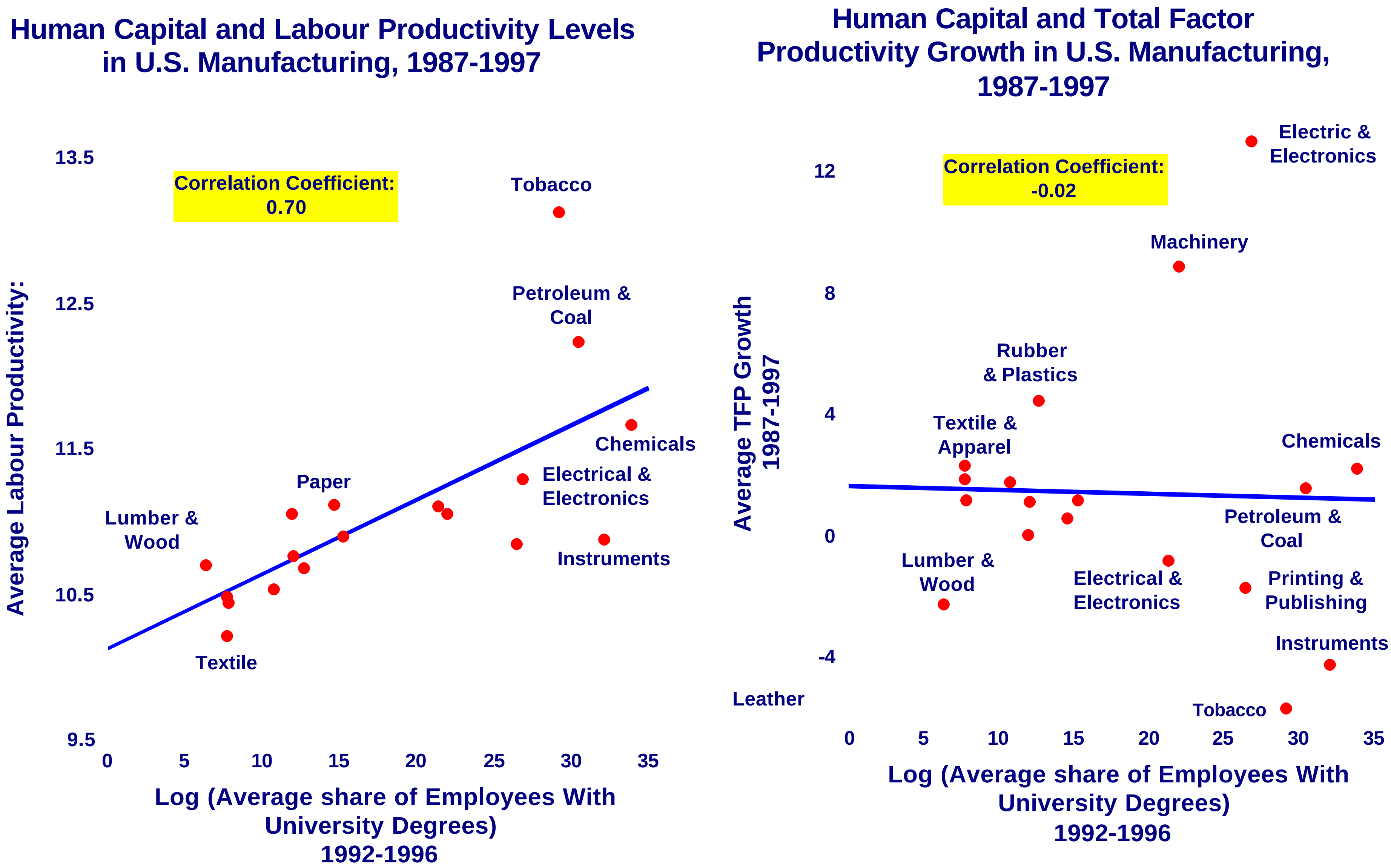
Source: Industry Canada compilations based on BEA data.

Chart 7



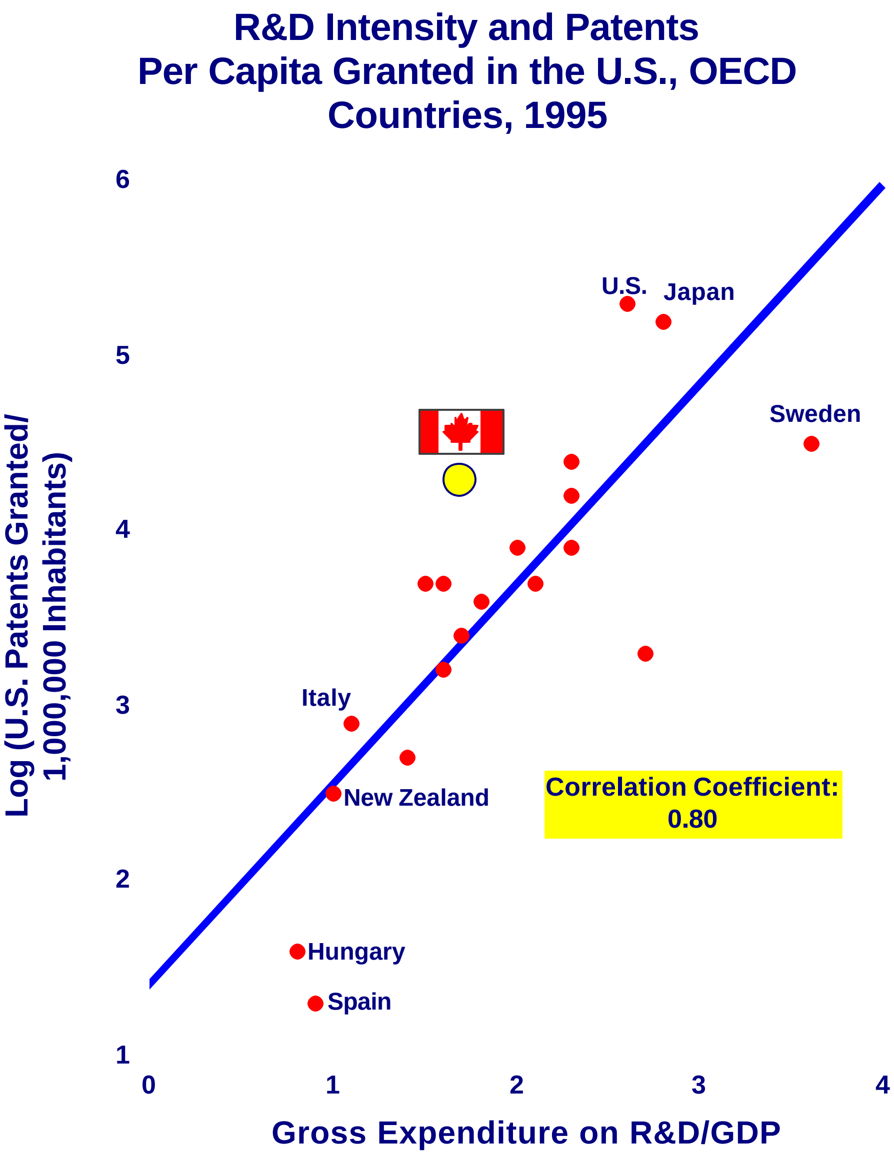
Source: Industry Canada compilations based on BEA data.

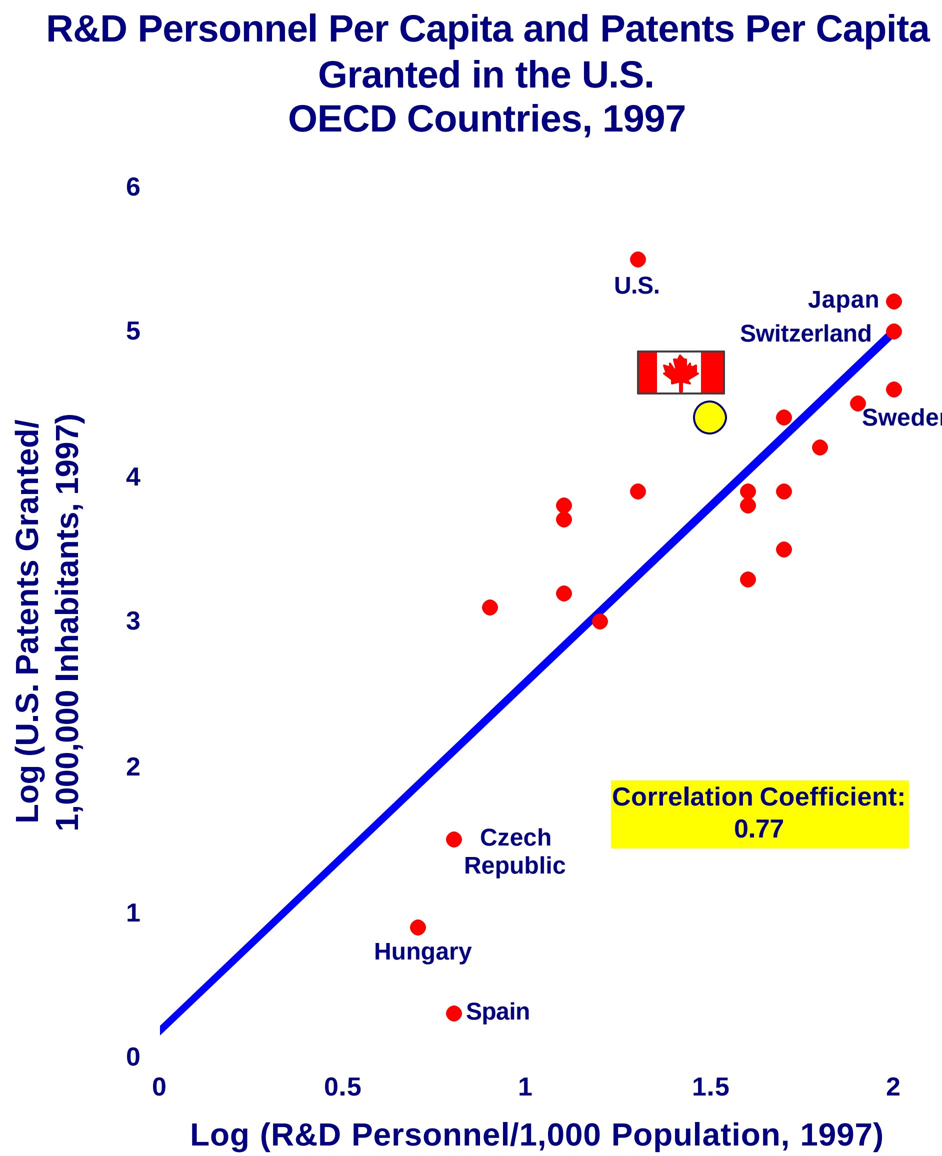
Chart 8



Source: Industry Canada compilations based on BEA data.

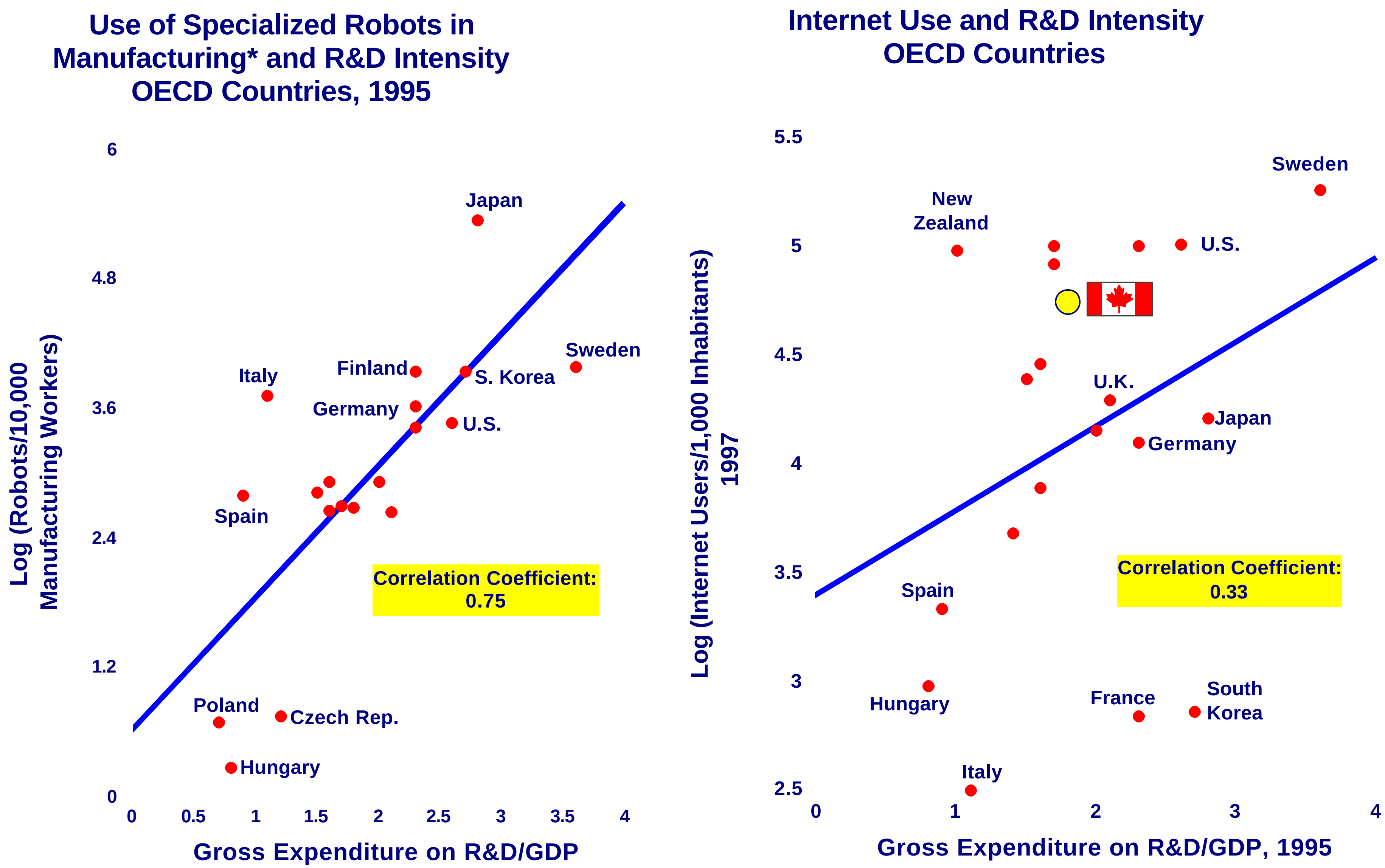
Chart 9





Source: Industry Canada compilations based on data from U.S. Patent and Trademark Office and OECD

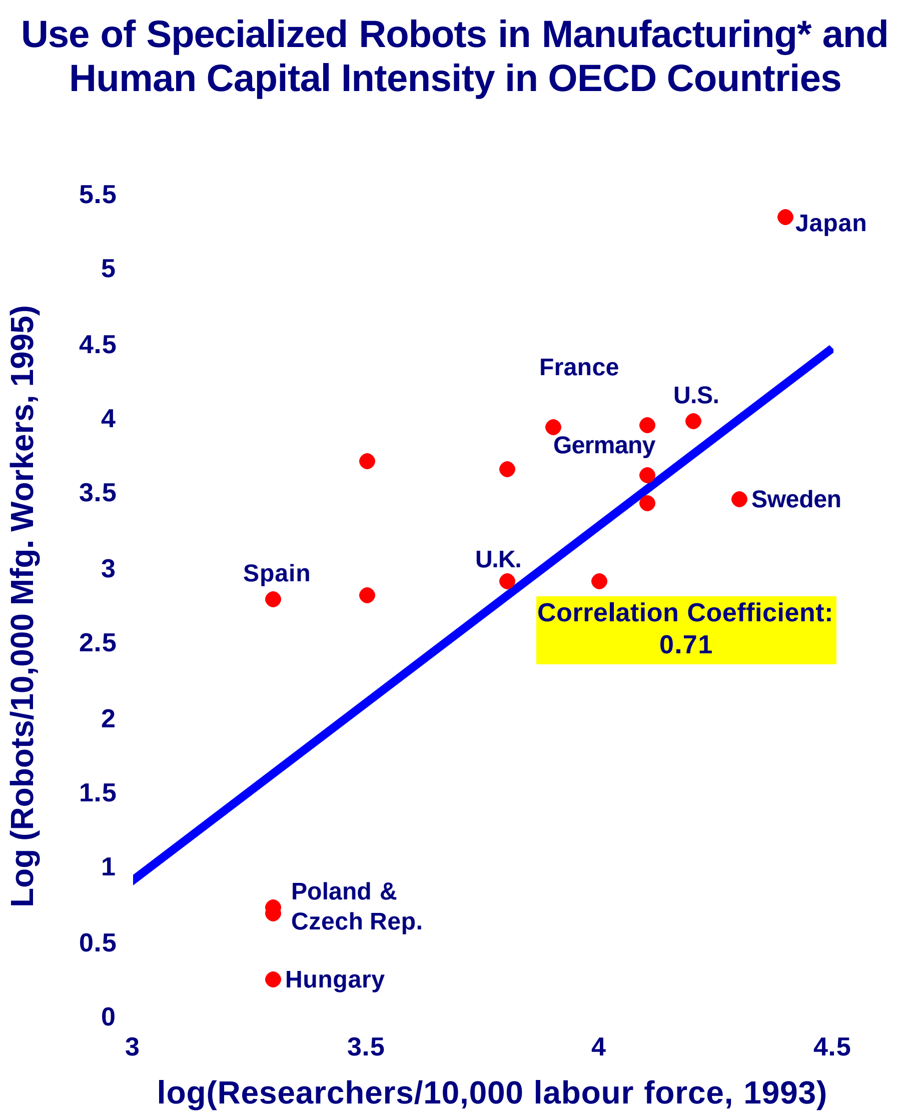
Chart 10

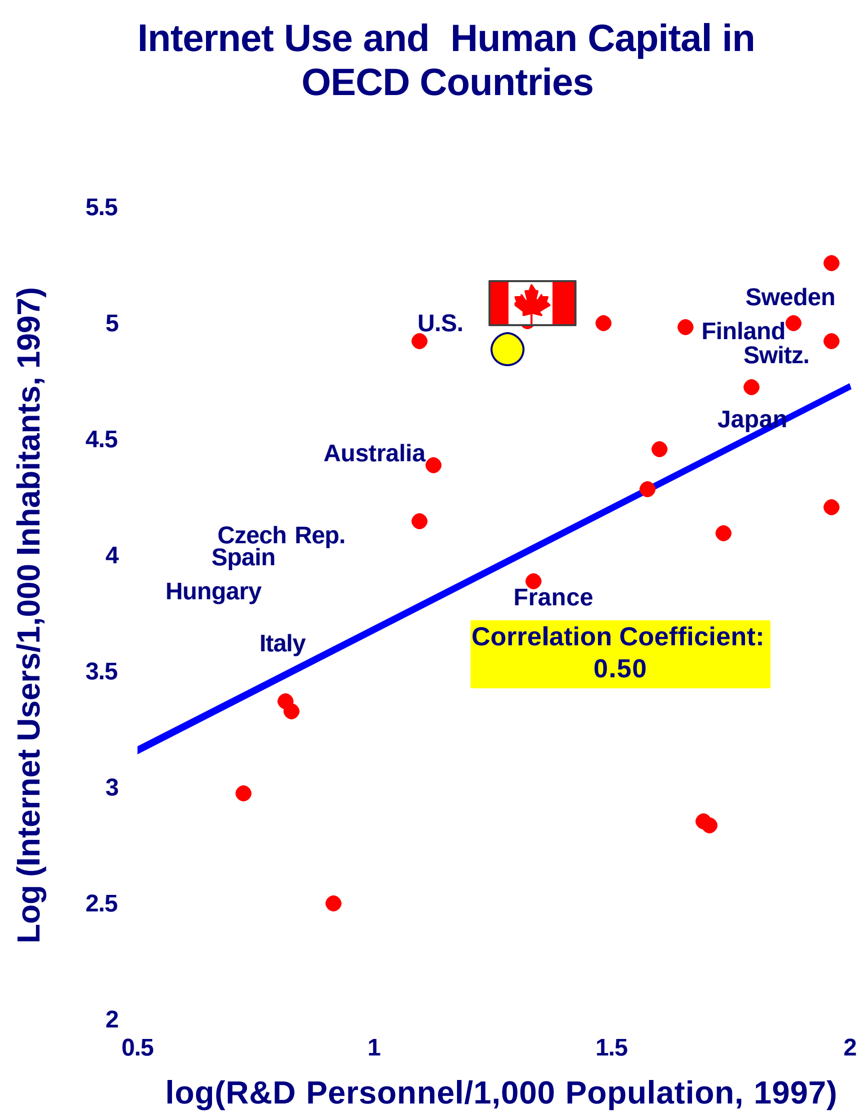


* Number of trajectory operated and adaptive robots.

Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996,* and International Telecommunication Union

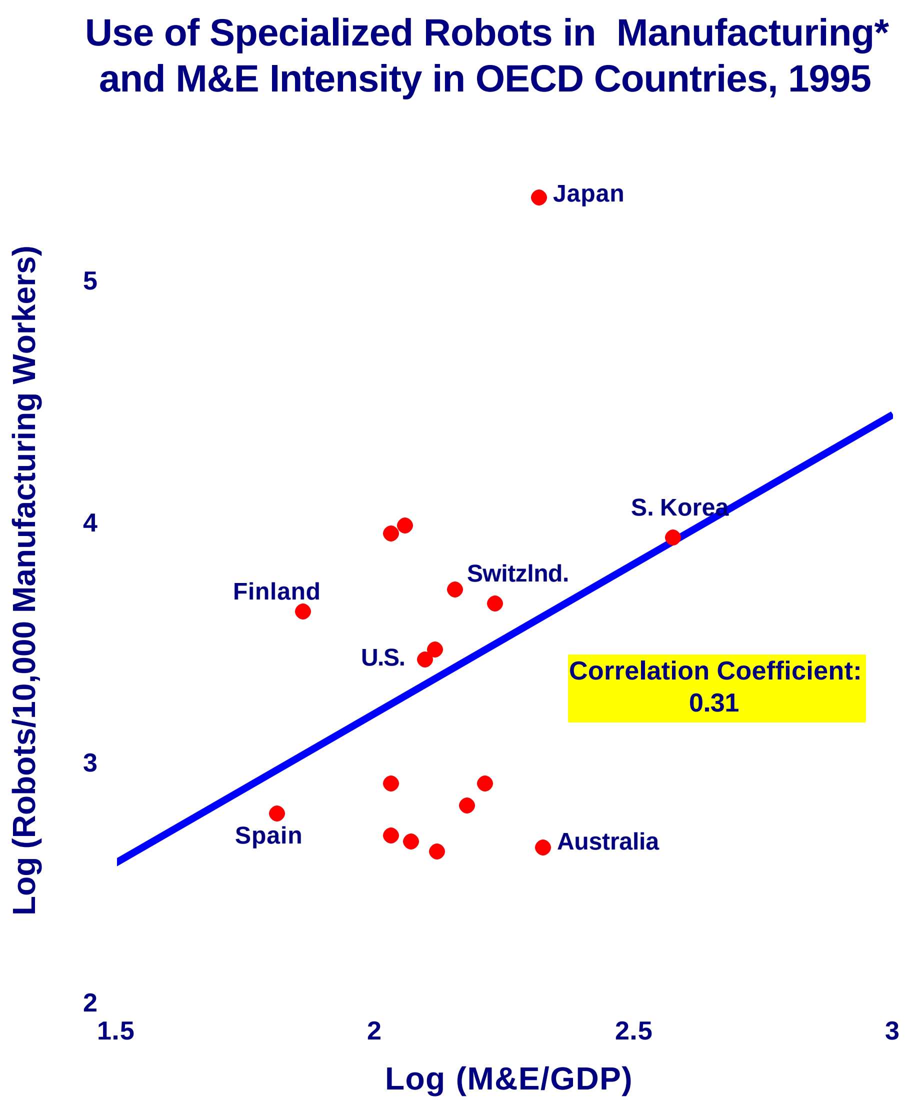
Chart 11

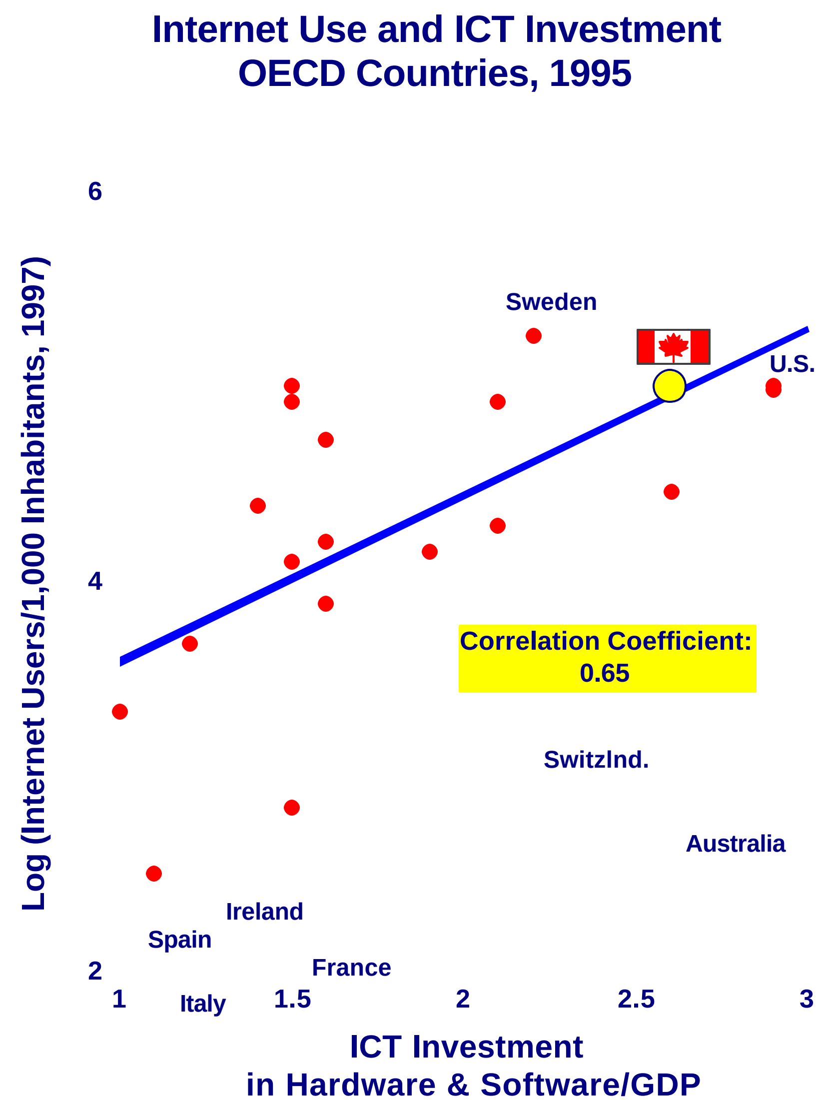




* Number of trajectory operated and adaptive robots.
Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996*, and International Telecommunication Union

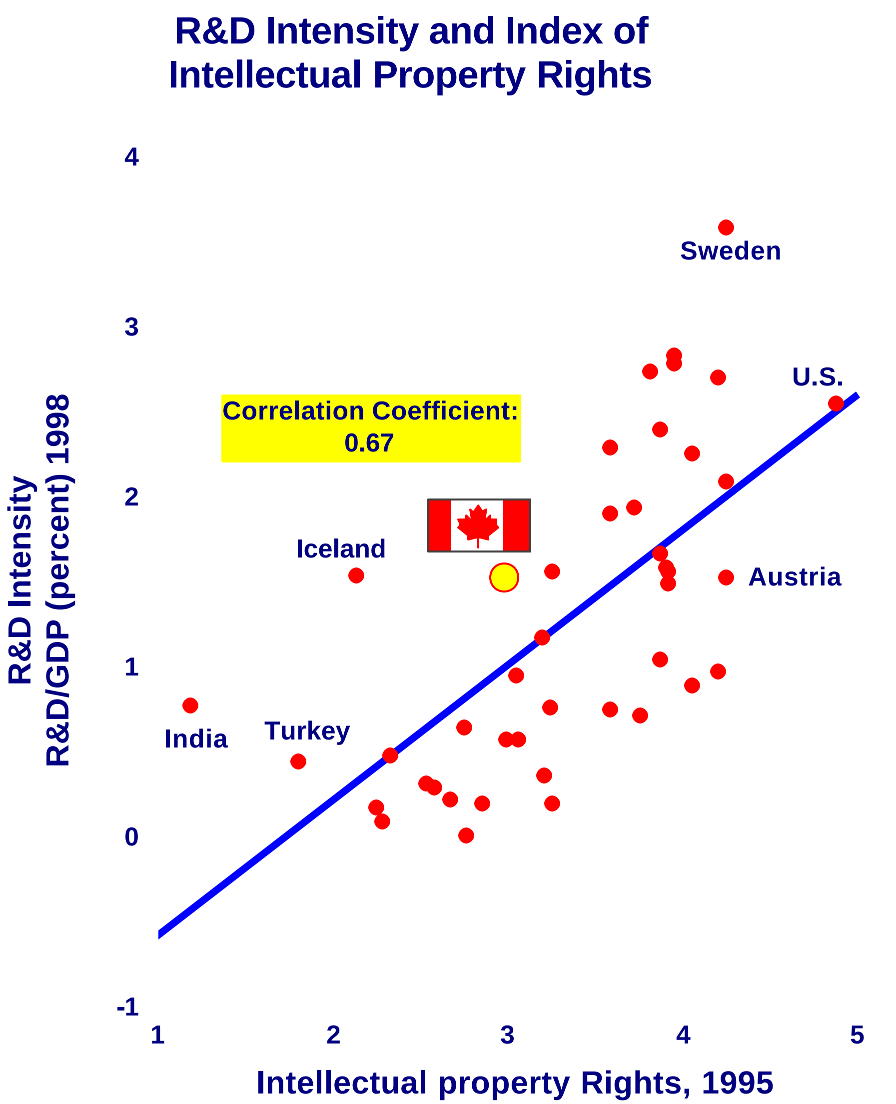
Chart 12

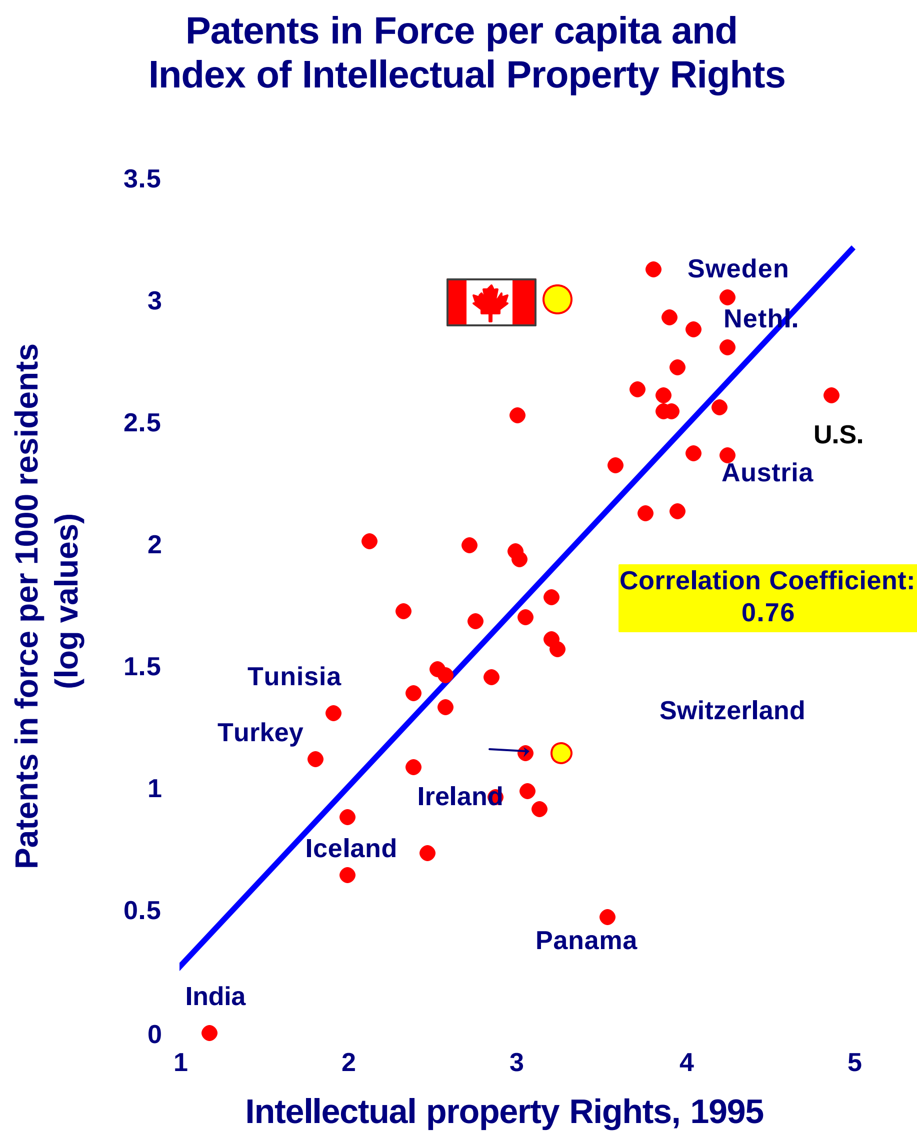




* Number of trajectory operated and adaptive robots.
Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996*, and International Telecommunication Union

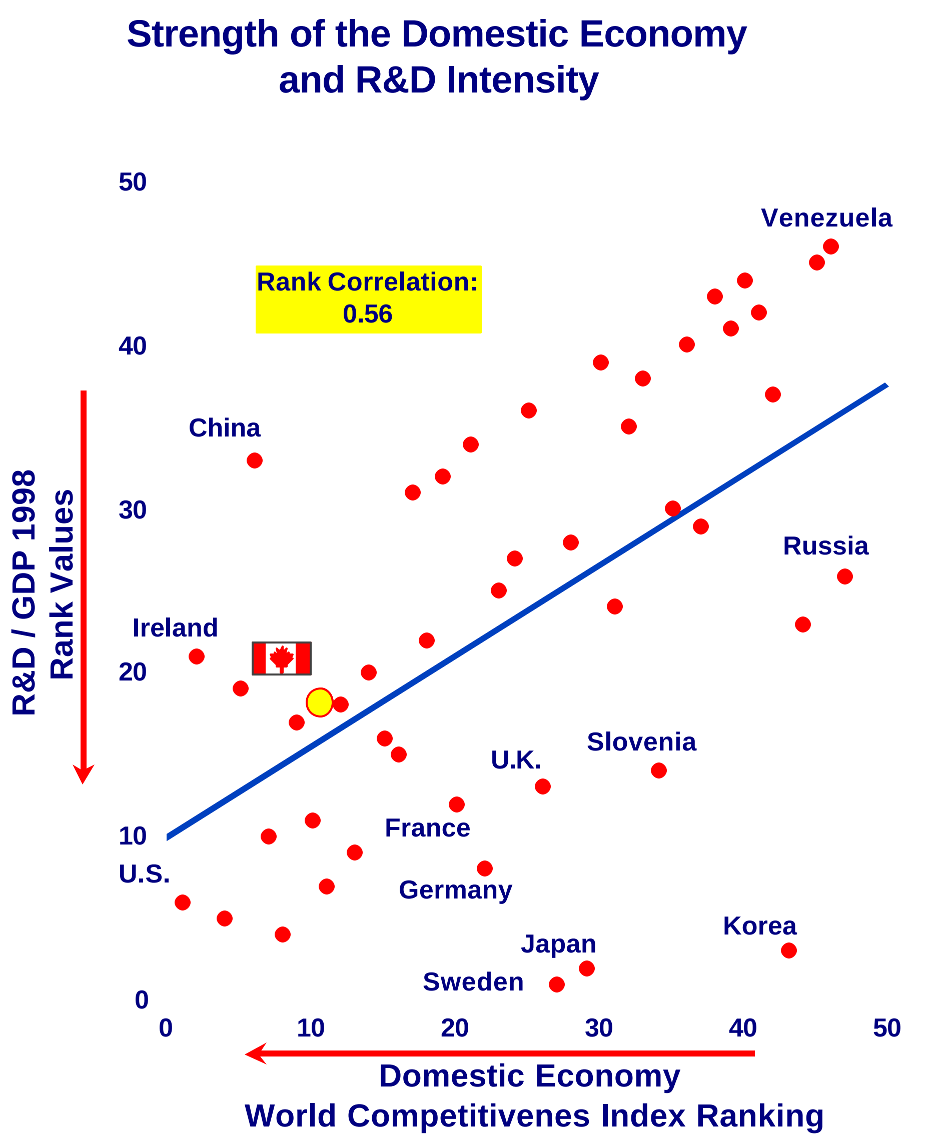
Chart 13

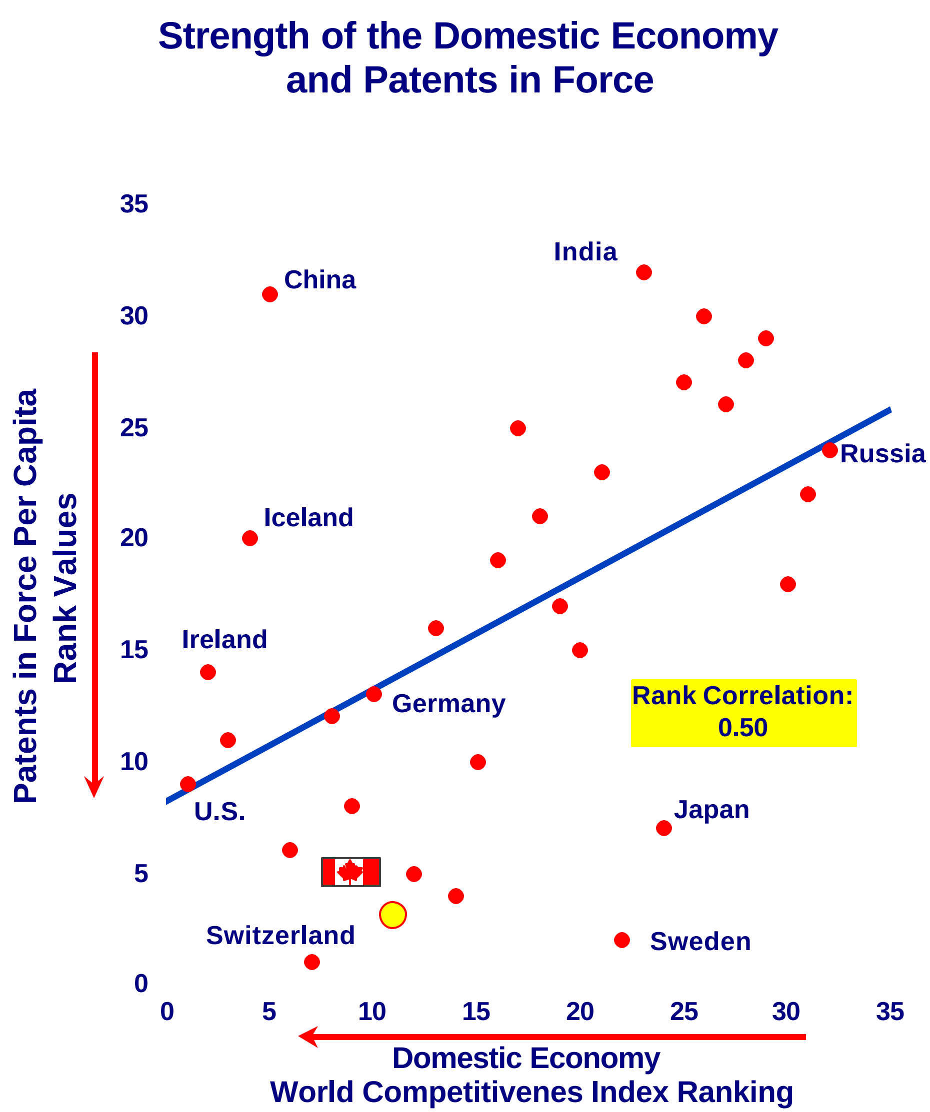




Source: World Competitiveness Yearbook, 1999 and Park and Ginarte (1997)

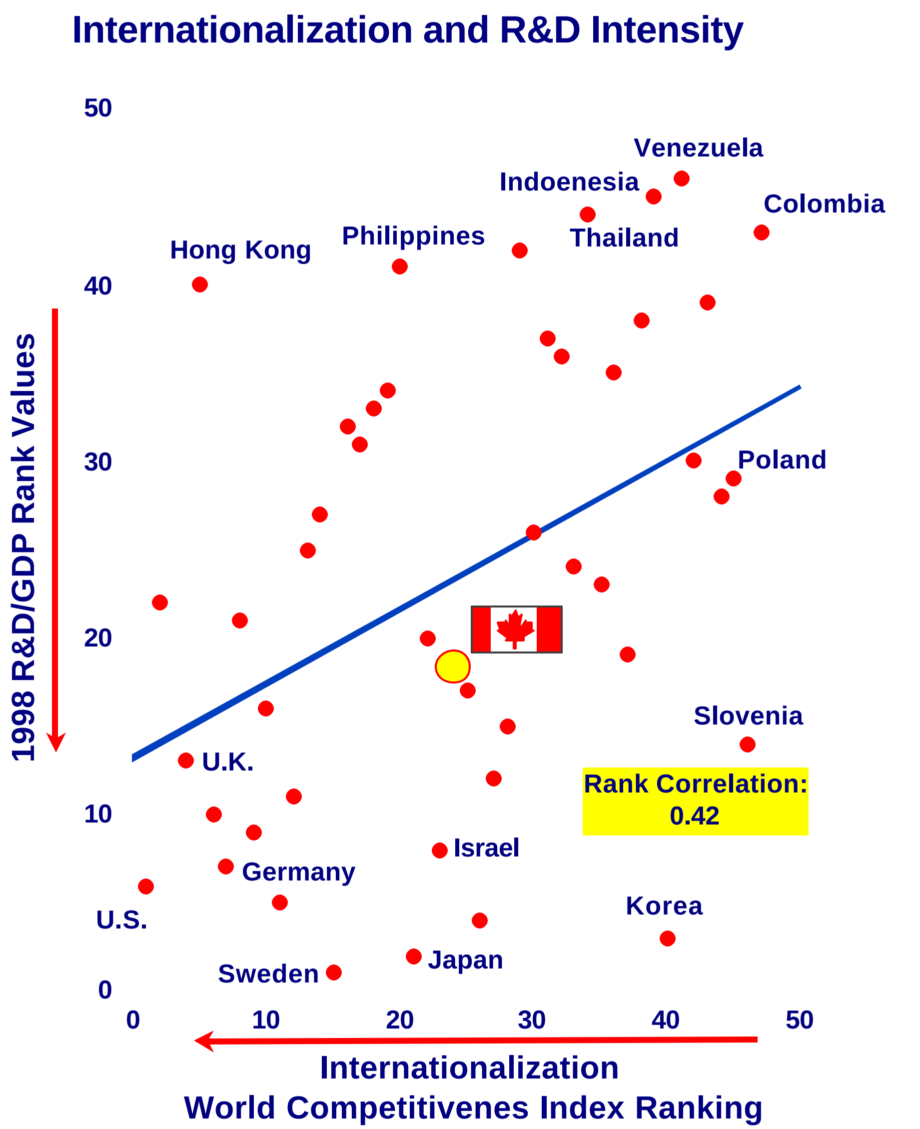
Chart 14

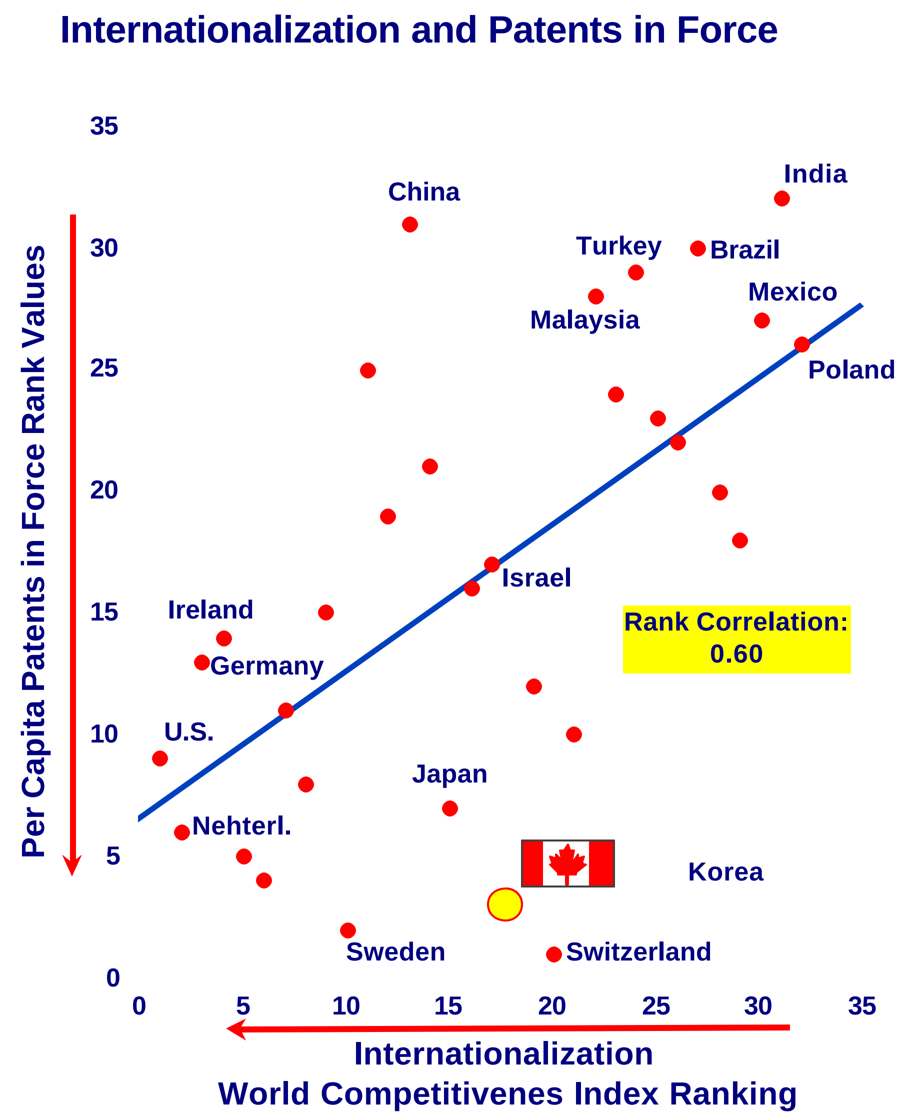




Source: World Competitiveness Yearbook, 1999

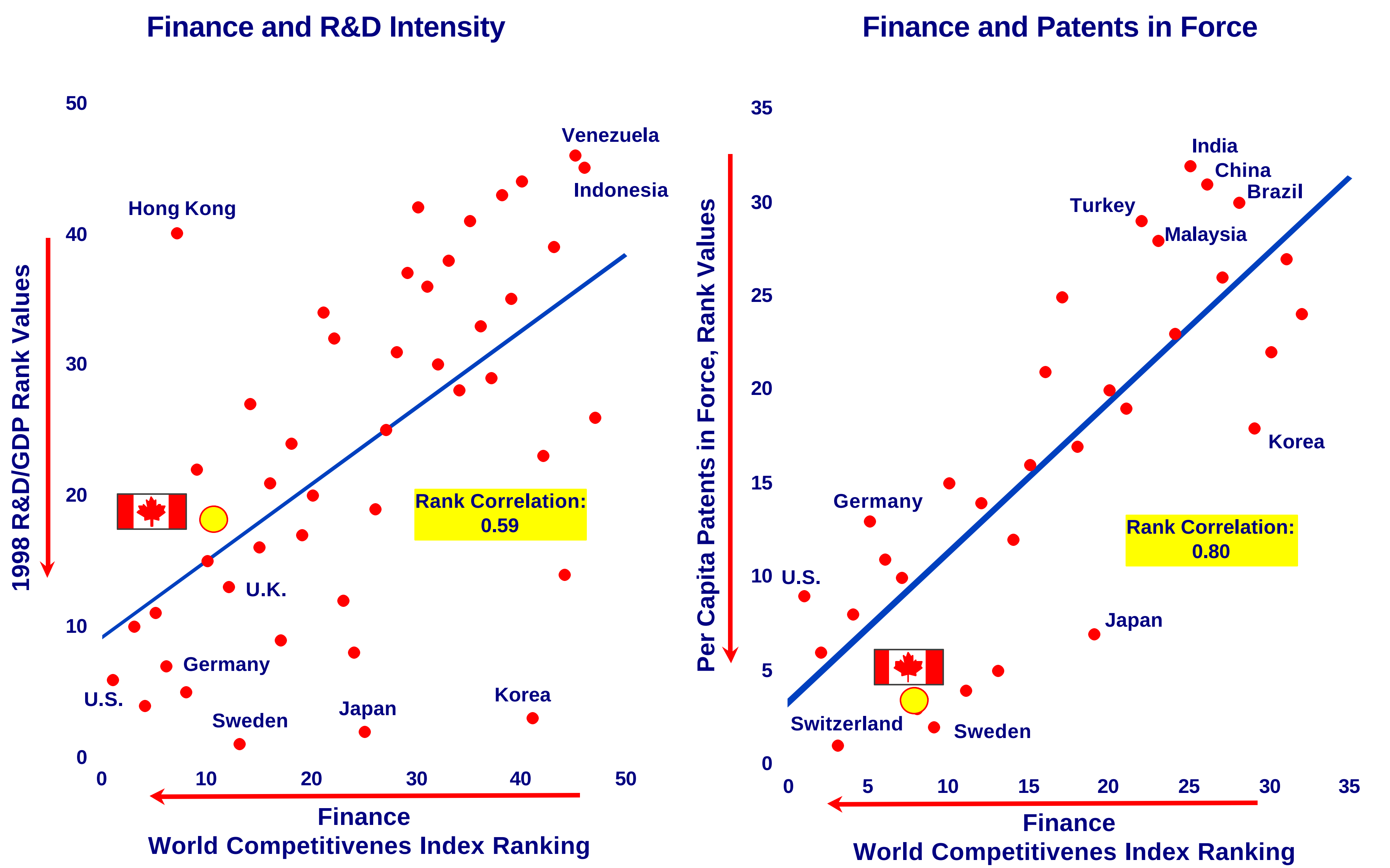
Chart 15





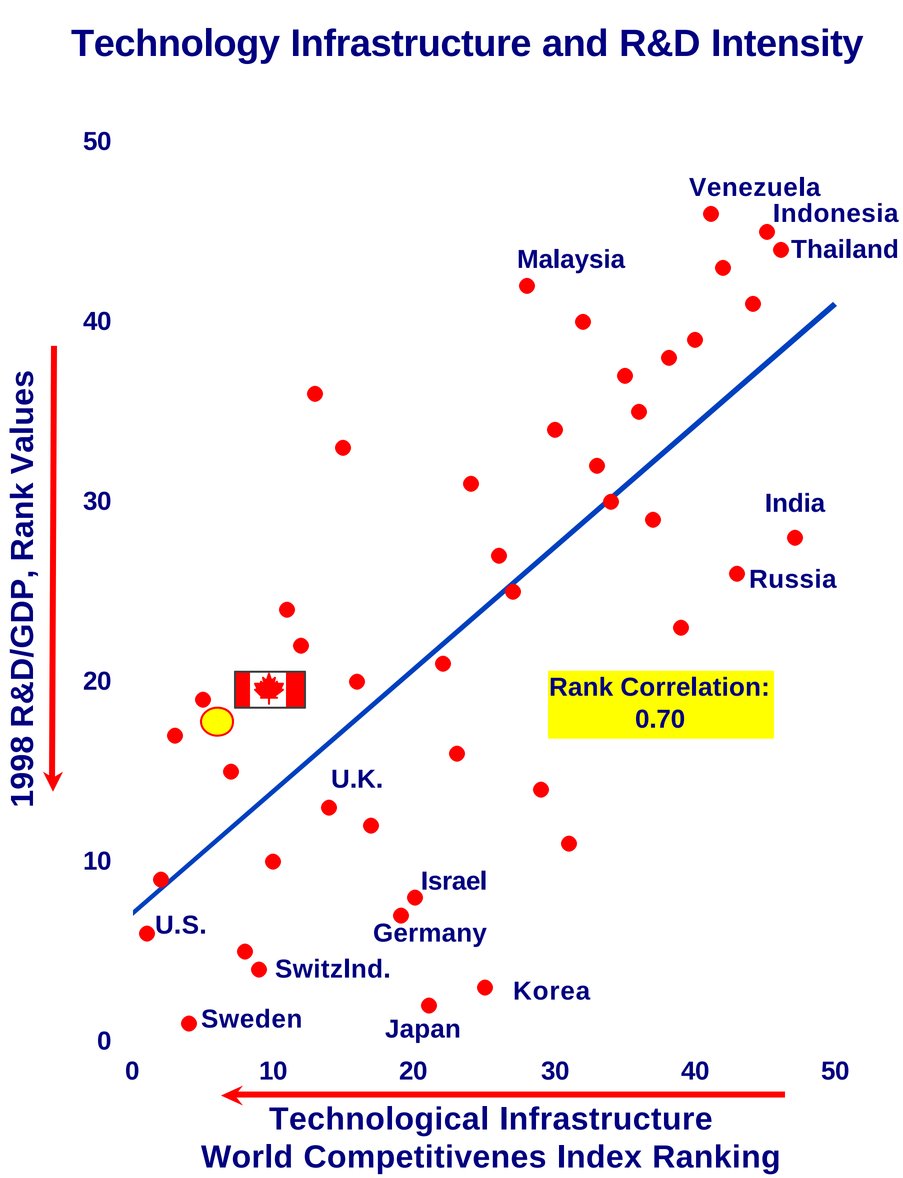
Source: World Competitiveness Yearbook, 1999

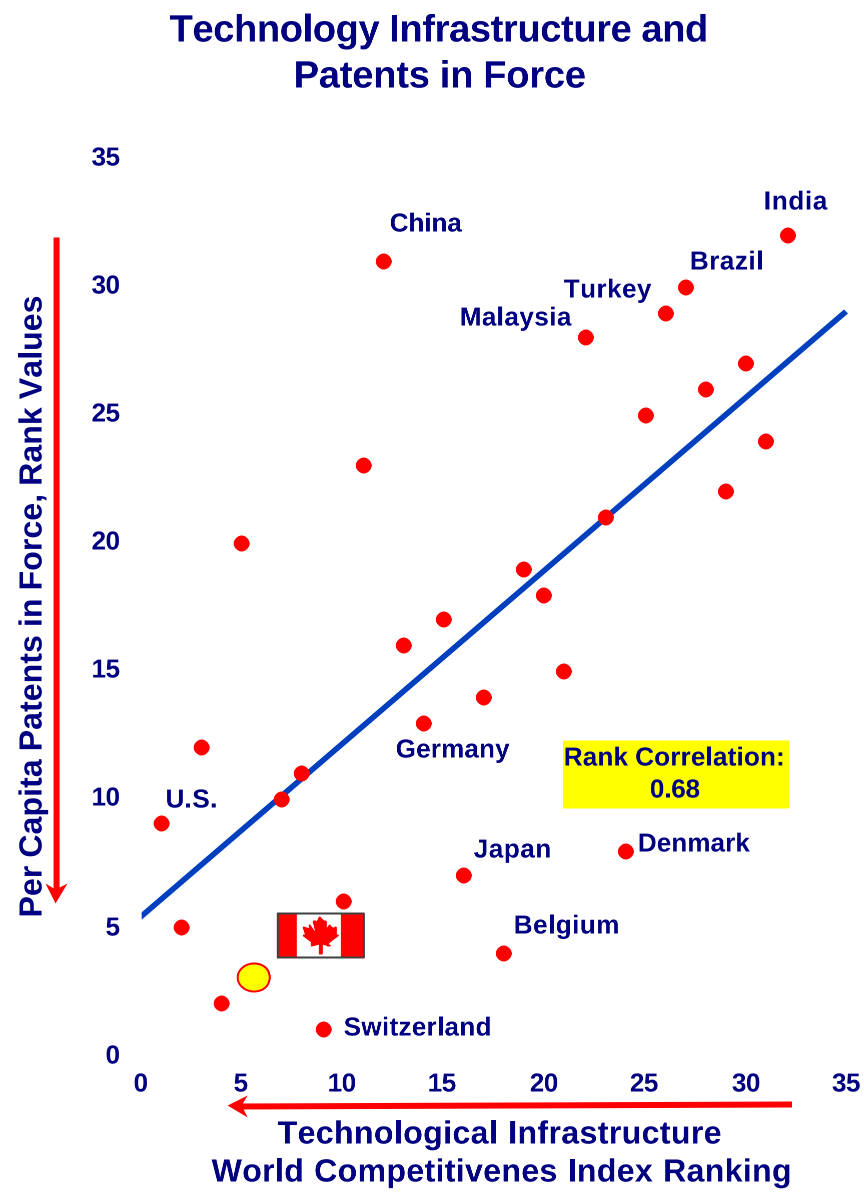
Chart 16



Source: World Competitiveness Yearbook, 1999

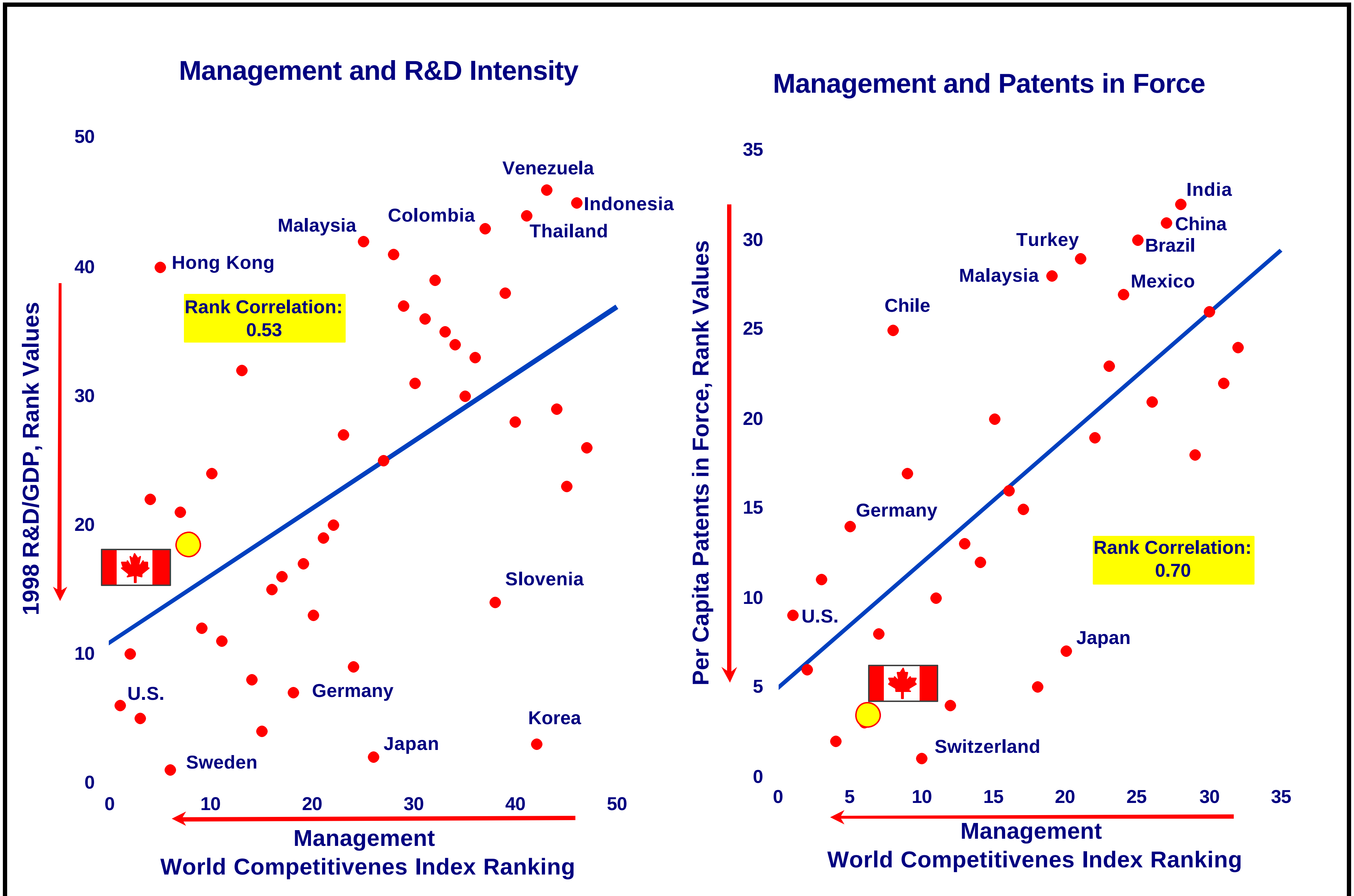
Chart 17





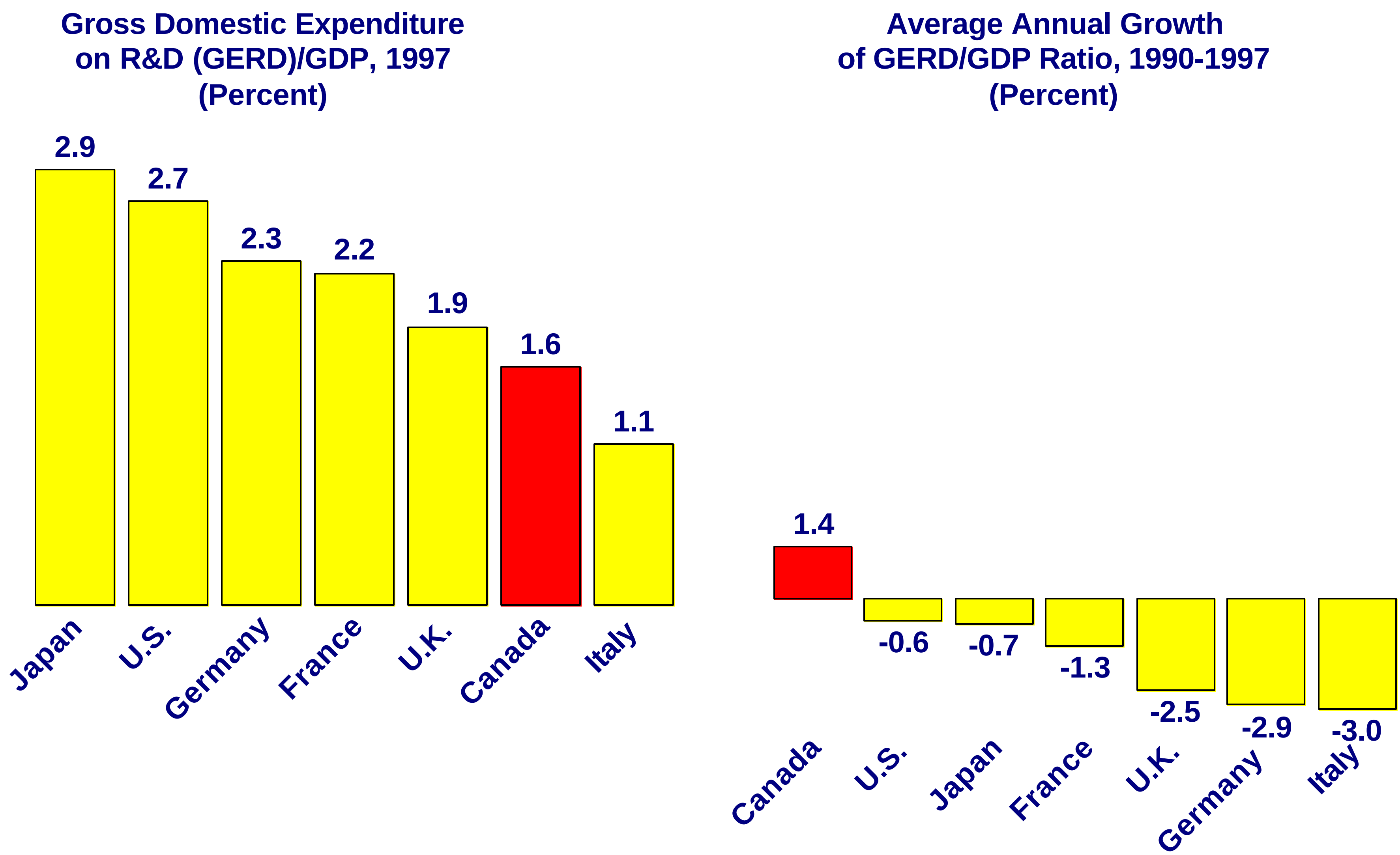
Source: World Competitiveness Yearbook, 1999

Chart 18



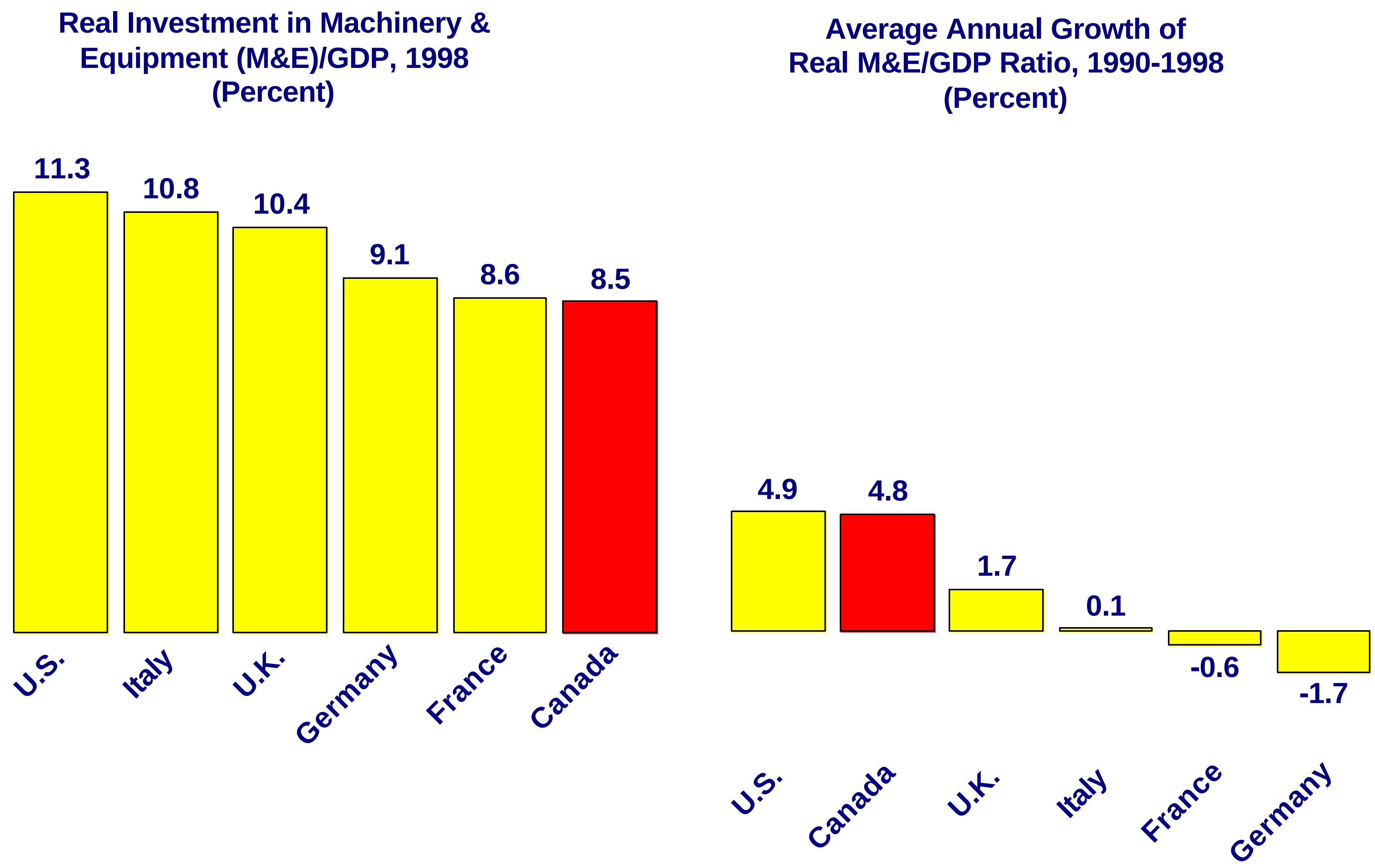
Source: World Competitiveness Yearbook, 1999

Chart 19



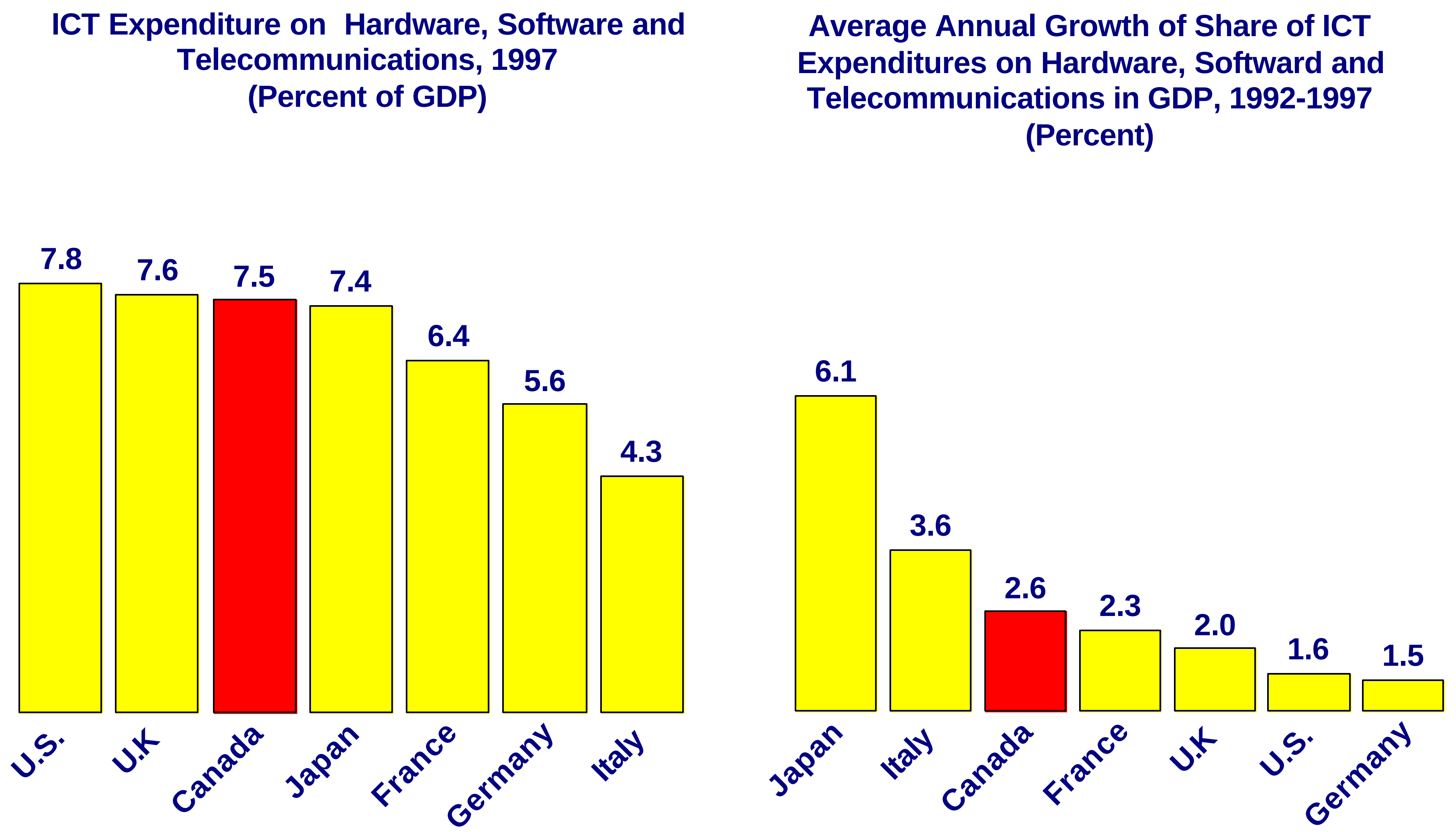
Source: Industry Canada compilations using data from OECD, EAS (MSTI Database), April 1999 and *Science Technology and Industry Outlook 1998,* OECD

Chart 20



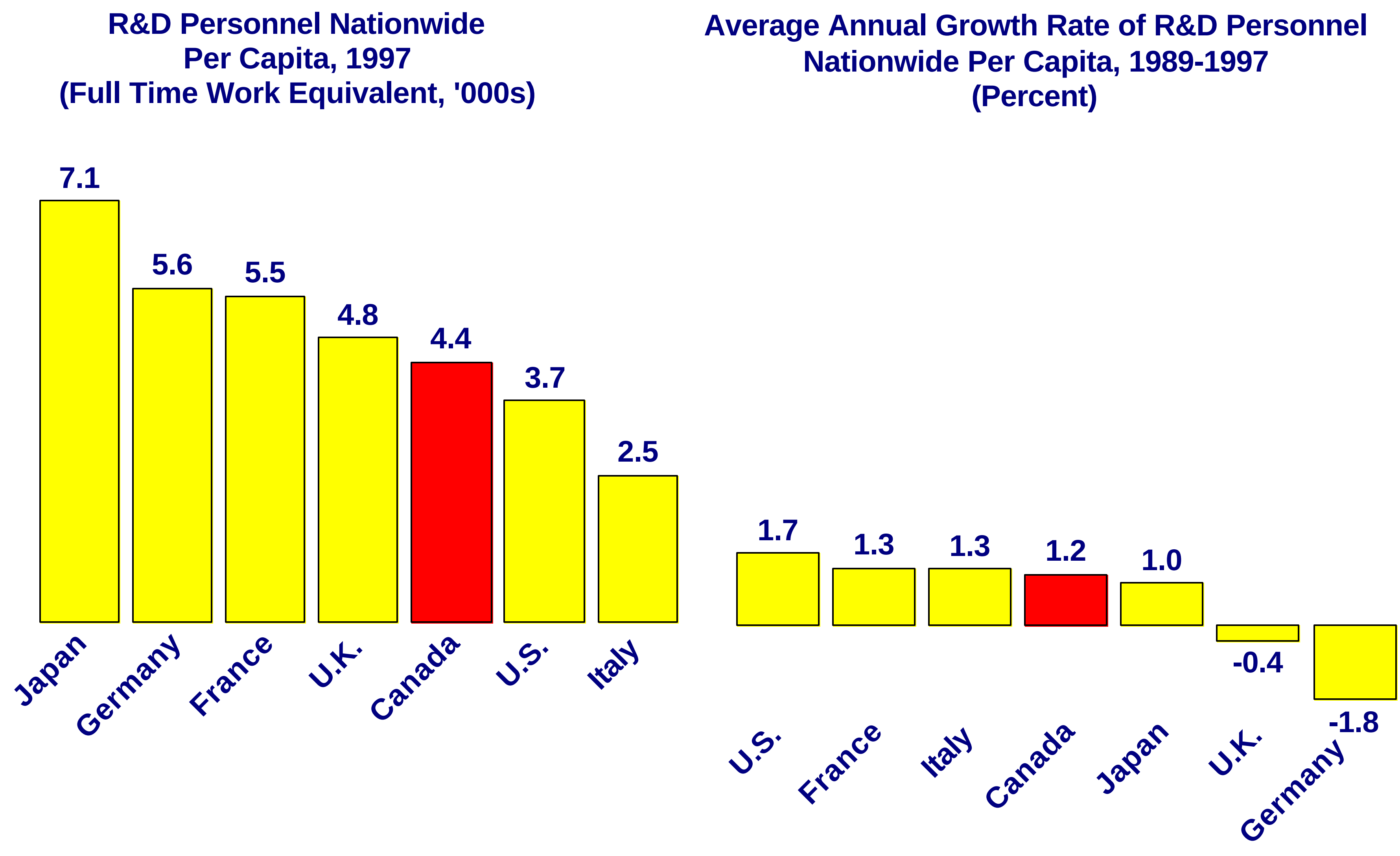
Note: Japan was excluded from G7 due to the lack of comparable data.
Source: Industry Canada compilations using data from the OECD

Chart 21



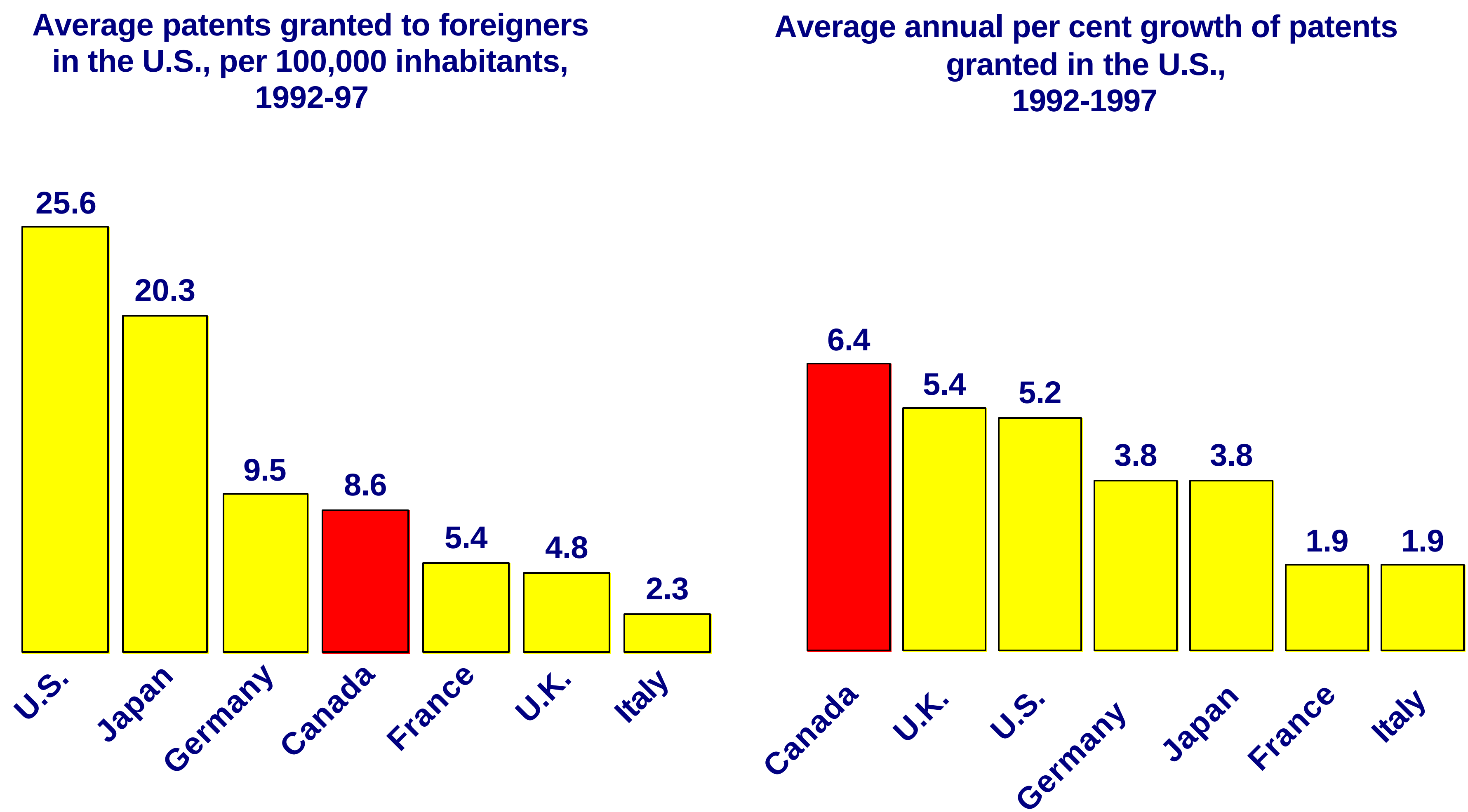
Source: Industry Canada compilations based on *OECD Science, Technology and Industry Scoreboard 1999*, obtained from ADB database and World Information Technology Services Alliance (WITSA)/ International Data Corporation (IDC), 1998

Chart 22



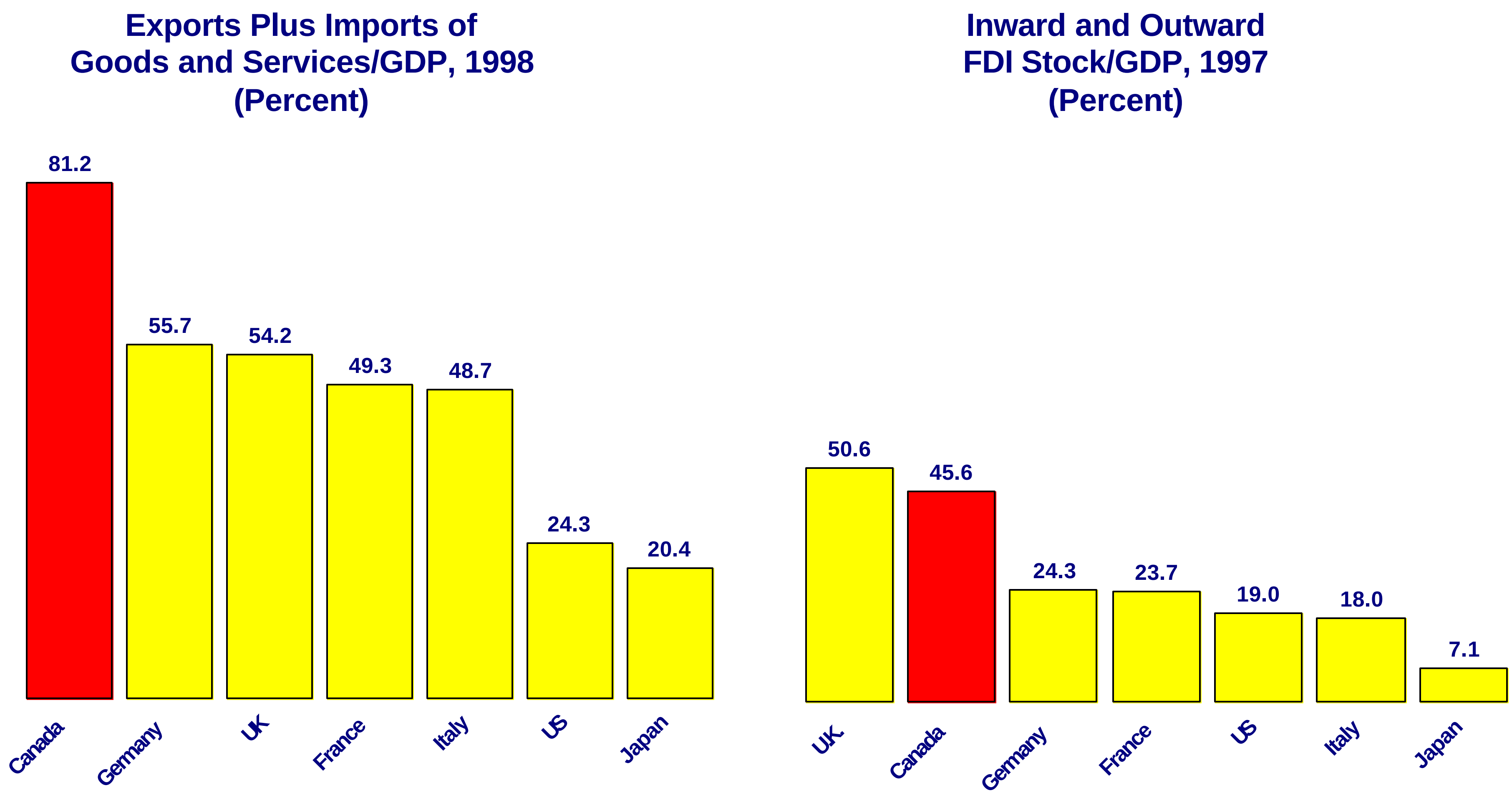
Source: Industry Canada compilations using data from *Science Technology and Industry Outlook 1998,* OECD

Chart 23



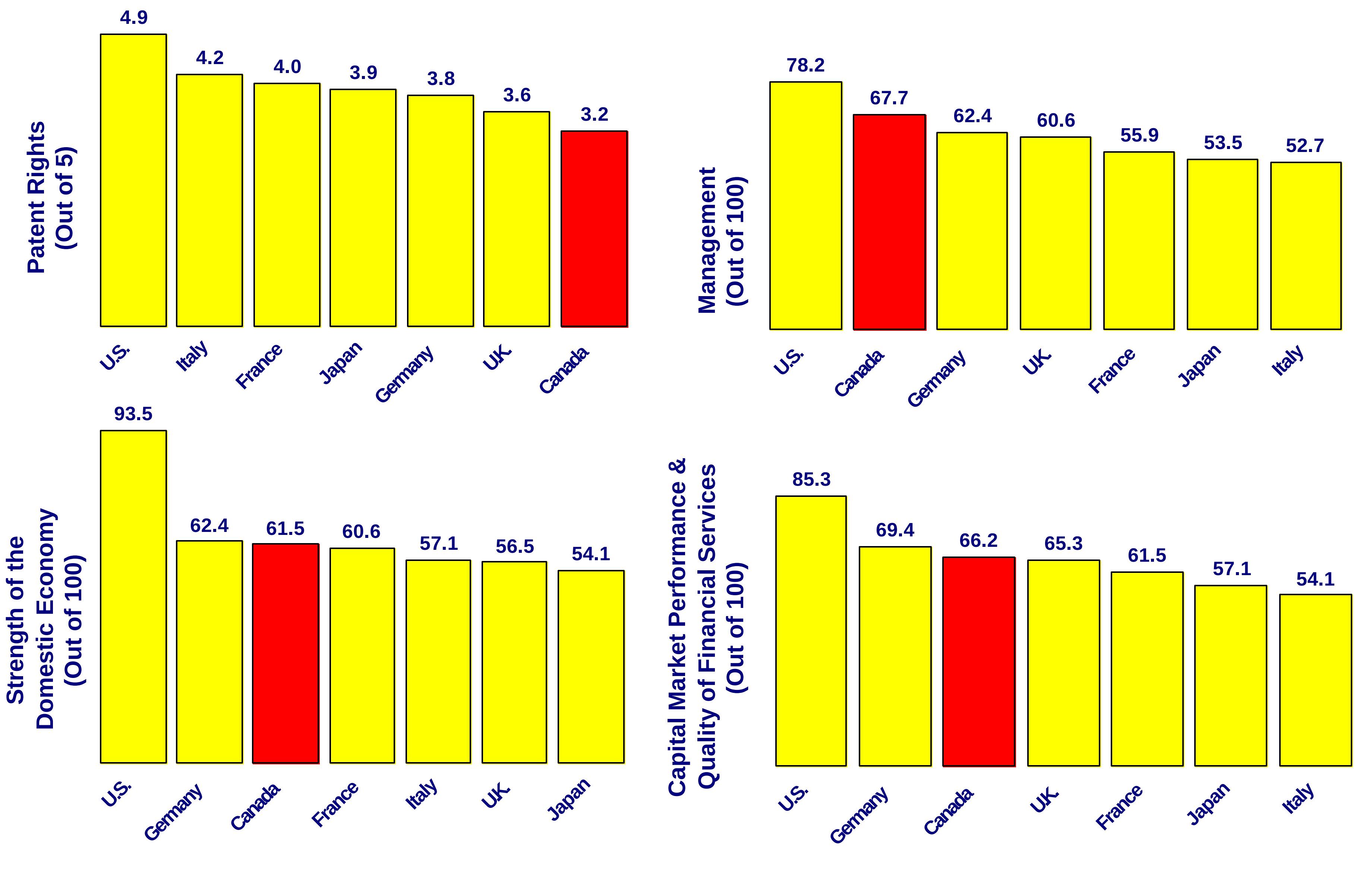
Source: Trajtenberg, M. (2000) *Is Canada Missing the Technology Boat*

Chart 24



Source: Industry Canada compilations using data from the OECD and the *World Investment Report 1999, Foreign Direct Investment and the Challenge of Development,* United Nations.

Chart 25



Source: The world Competitiveness Yearbook 1999 and Park and Ginarte 1997

Table 1

Innovation and Productivity: Cross Country Analysis

Equation 1 Dependent variable: Ln (Real GDP per employed person as % of OECD average)			Equation 2 Dependent variable: ln (Real GDP per Capita)		
Intercept	4.01	***	Intercept	7.94	***
	25.68			41.01	
Patents Granted	0.16	***	Patents in force	0.29	***
	3.72			8.75	
Adjusted RSq	0.37	***	Adjusted RSq	0.75	***

Patents Granted=ln(U.S. Patents Granted)/1,000,000 population

Patents in Force = ln (patents in force/100,000 inhabitents)

* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

Table 2

Productivity and Inovation- Cross Industry evidence from the Canadian manufacturing sector

Equation 1 Dependent variable: Average Labour Productivity - Ln (GDP per employed person)			Equation 2 Dependent variable: Average TFP growth		
Intercept	9.49	***	Intercept	-1.92	
	11.60			-0.53	
Human Capital	0.50		Human Capital	1.70	
	1.29			0.48	
M&E intensity	0.11		M&E intensity	0.82	
	1.05			0.89	
R&D Intensity	-0.01		R&D Intensity	0.21	
	-0.18			1.66	
Adjusted RSq	0.11		Adjusted RSq	0.25	*

Equation 1:
Human Capital = ln (Average share of employees with university Degrees)
M&E intensity = ln (M&E per employed person)
R&D intensity = ln (R&D per employed person)

Equation 2:
Human Capital = ln (Average share of employees with university Degrees)
M&E intensity = ln (M&E/GDP)
R&D intensity = ln (R&D/GDP)

* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

Table 3

Productivity and Inovation- Cross Industry evidence from the U.S. manufacturing sector

Equation 1 Dependent variable: Average Labour Productivity - Ln (GDP per employed person)			Equation 2 Dependent variable: Average TFP growth	
Intercept	7.83	***	Intercept	2.73
	11.67			0.44
Human Capital	0.03	**	Human Capital	0.06
	2.36			0.23
M&E intensity	0.43	***	M&E intensity	-1.07
	5.10			-0.33
R&D Intensity	-0.14		R&D Intensity	0.09
	-1.62			0.23
Adjusted RSq	0.84	***	Adjusted RSq	-0.27

Equation 1:
Human Capital = ln (Average share of employees with university Degrees)
M&E intensity = ln (M&E per employed person)
R&D intensity = ln (R&D per employed person)

Equation 2:
Human Capital = ln (Average share of employees with university Degrees)
M&E intensity = ln (M&E/GDP)
R&D intensity = ln (R&D/GDP)

* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

Table 4

Fundamental Innovation: Cross Country Evidence

Equation 1

Dependent variable: R&D intensity = (R&D/GDP*100)

	1a		1b		1c	
Intercept	-0.15		-0.51		2.51	***
	-0.23		-1.15		10.61	
R&D personel per capita	0.24	***	0.25	***		
	5.07		6.11			
Intelectual property rights	0.27	*	0.33	***		
	1.91		2.88			
† Domestic Economy	0.01		0.00			
	0.70		-0.35			
† Internationalization	0.00				-0.01	
	0.37				-0.65	
† Finance	-0.01				-0.02	
	-0.54				-1.12	
† Technology Infrastructure	0.00				-0.04	***
	-0.45				-2.96	
† Management	-0.01				0.02	
	-0.37				0.94	
Adjusted RSq	0.72	***	0.74	***	0.47	***

Equation 2

Dependent variable: ln (patents in force per 100,000)

	2a		2b		2c	
Intercept	1.33	**	0.56		3.33	***
	2.45		1.56		17.89	
R&D personel per capita	0.09	**	0.09	***		
	2.60		2.79			
Intelectual property rights	0.32	**	0.47	***		
	2.67		5.05			
† Domestic Economy	0.01		-0.02	**		
	0.61		-2.19			
† Internationalization	0.00				-0.02	
	-0.29				-1.63	
† Finance	-0.01				-0.02	
	-0.84				-1.08	
† Technology Infrastructure	-0.02				-0.04	***
	-1.44				-2.96	
† Management	-0.01				0.01	
	-0.44				0.70	
Adjusted RSq	0.79	***	0.77	***	0.63	***

* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

† Note that Domestic economy, internationalization, finance, technology infrastructure and management are rank indexes, with the strongest country ranked at 1. Thus the expected sign of the coefficients are negative.

Table 5

Applied Innovation: Cross Country Evidence

Equation 1
Dependent variable: ln (Log of internet users per 1000 inhabitents)

Intercept	2.12	***
	3.10	
ICT investment/gdp	0.72	**
	2.70	
Log of researchers/1000 population	0.33	
	0.57	
R&D/GDP	0.19	
	0.63	
Adjusted RSq	0.37	***

* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

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