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Comparative invention performance of major industrial countries: Patterns and explanations

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COMPARATIVE INVENTION PERFORMANCE
OF MAJOR INDUSTRIAL COUNTRIES:
PATTERNS AND EXPLANATIONS

by

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July 1986

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Abstract

The paper first presents an analysis of invention performance, as measured by patenting activities, of six countries (France, Italy, Japan, United Kingdom, USSR, West Germany) relative to the United States for 41 SIC industries over the past twenty years. It turns out that Non U.S. countries as a whole have increased their (relative) invention performance in all fields of technology, including high technology fields. In the second section hypotheses which can be supposed to explain the relative decline of the United States' patenting activities are discussed and tested. There is strong evidence that catching up processes as well as integration effects contributed most to the relative decrease of the United States; there also is evidence, that government interventions regarding technology production have had counter-productive effects in the United States.

I. Introduction

1. Economic growth has been slowing down in highly industrialised countries since the 1960s. Two fundamentally different explanations have been put forward. One links bad growth performance to a bad climate for investors: Incentives should be restructured in order to assure a higher rate of capital formation¹. According to the other explanation technical progress has become too slow to compensate for the increase in the capital coefficient; therefore, policies should aim at stimulating technical progress, either through more government research or through government support of private research.

2. The superior growth performance of Japan and, in most recent years, of the United States has been taken by European countries to back the relevance of the technology approach: Whilst Japan for a long time had acquired the image of mainly imitating foreign techniques, i.e. of successfully catching up, it is today widely held that Japan also, like the United States, is more successful in producing new (and high) technologies than Western European countries². In fact, the phrase "Eurosclerosis" precisely describes the alleged (relative) inability of Western Europe to innovate. Similar to the 1960s "gaps" have again been discovered, this time in the fields of, inter alia, microelectronics, communication techniques, robotics and gene engineering.

3. One way out of deficits in high technology application would, of course, be importing technologies³. However, the

world's most important exporter of technology, the United States, has been increasing her efforts to curtail such outflows. Whilst part of these efforts is strictly for military ends, there is also a widespread feeling in the United States that the country could lose ground technologically on account of too many or too cheap high technology exports⁴.

4. Quite obviously, European countries as well as the United States suspect each other to overtake in the technologies race. Suspicion has its roots. As far as these roots reach into the past one can analyse which countries gained and which countries lost in the race. With respect to past performance, at least, somebody's suspicion must be wrong.

5. In the following it is first tried to present a complete picture of invention performance of six countries (France, Italy, Japan, United Kingdom, USSR, West Germany) relative to the United States over the past twenty years. We call this picture "complete" because all 41 industries according to the two- and three-digit Standard Industrial Classification level are included for the whole period⁵. The aim of this fact-finding section is to identify the winners, losers, and also-rans in the technology race by industry over the past two decades. In the second part, hypotheses to explain why some countries performed better than others are discussed and empirically tested. Among these hypotheses are the development of international economic integration as well as the "research-socialism-hypothesis",

referring to the degree of government interference in the production of new technologies.

II. Assessment of Inventions by Country

1. Method

6. The assessment of inventive activities by country and field of activity refers to patents granted by U.S. authorities between 1963 and 1983⁶. The reasons for choosing the U.S. market are that the United States is the internationally most important market for inventions, and that international comparisons relying on respective national statistics are misleading due to both national peculiarities of patent laws as well as practices of patent granting. Second, patents by date of grant are chosen rather than by date of application since the latter would imply either operating with an increasingly uncertain data base (in case where only those applications are listed which eventually lead to grants) or to include rejected applications, thereby burdening the analysis with short and long run cyclical problems⁷. Also, data are analysed in "share" form, which circumvents some of these lag problems - unless, of course, U.S. authorities have discriminated against (or in favour of) foreign patent applications in a manner varying over time.

The assessment has three analytical parts. One is about the average performance of six industrial countries, including the

USSR, measured relative to the United States between 1963 and 1983. The others are about the estimated starting position in 1963, and about the dynamics during the past two decades. It is assumed that the number of patents granted, if only large enough, is a reliable indicator of invention performance also in economic terms⁸.

7. The relative average invention performance (RAIP) of the six countries in the 21 years under observation is measured by the ratio of the number of patents granted to country j in the field i to the number of patents granted to the United States in field i :

$$RAIP_j^i = \frac{1}{21} \cdot \frac{\sum_{1963}^{1983} \frac{Patents_j^i}{Patents_{U.S.}^i}}$$

Analysing $RAIP_j^i$ for particular fields of activity in relation to the average one for all activities corresponds to the familiar concept of "revealed comparative advantage", commonly used in studies of foreign trade performance.

For each field of activity in each country the following straightforward exponential trend was calculated:

$$\frac{Patents_j^i}{Patents_{U.S.}^i} = a \cdot e^{b \cdot t}$$

Coefficient a , the interception with the relative patent activity axis, was taken to represent the estimated relative starting position in 1963.

Coefficient b of the exponential trend represents the "estimated relative dynamics" of patent activity of country j in the period 1963 to 1983. The exponential trend is chosen because of the ease of interpretation as an indicator of growth.

2. Patterns: The Technologies Race

a. Average Performance Between 1963 and 1983

8. Table A1 exhibits that the number of all patents granted to foreigners by the United States was on average 43 per cent of patents granted to U.S. citizens ("domestic patenting")⁹. The structure of foreign invention activity reveals relative strength in the fields of drugs and medicines (Standard Industrial Classification No. 286), engines and turbines (SIC 351), and five other fields out of 41 SIC sections. Comparative strength of U.S. domestic patenting lay in the fields of petroleum and natural gas extraction and refining (SIC 13, 29) as well as regarding guided missiles, space vehicles and parts (SIC 376) and some other patent fields.

9. Looking at high technology industries (defined as SIC-fields 289, 283, 351, 354, 357, 369, 366, 367, 376, 372, 38 excl. 3825)¹⁰ reveals that West Germany, closely followed by Japan, had the highest country share of patents granted to Non-U.S. citizens (table 1); however, a comparison of high technology performance with average performance (in all fields of technology) shows Japan leading distinctly. Since all these ratios

are comparisons with the United States one arrives at the result that the U.S. did not perform in any way superior or even equal

Table 1: Average Relative Performance in High Technology Patenting in the United States by Country^a

France	Italy	Japan	UK	USSR	West Germany	Non-U.S.
0.049 (+19.5%)	0.013 (-7.1%)	0.108 (+38.5%)	0.073 (+23.7%)	0.005 (0%)	0.114 (+5.6%)	0.474 (+9.2%)

^aHigh technology patents granted to foreigners relative to high technology patents granted to U.S. citizens between 1963 and 1983. Numbers in parantheses refer to deviation from national average regarding all fields of activity.

The figures are unweighted averages of the coefficients in table A1. E.g. 0.049 says that France had 4.9 patents granted when U.S. citizens had 100 patents. (19.5%) means that French high technology patent performance is 19.5 % above her national average in all fields of technology.

Source: Table A1.

to West Germany, Japan, the UK or France in high technologies relative to average technologies.

b. The Starting Line: 1963

10. All in all, the number of Non-U.S. patents was less than 25 per cent of the number of patents granted to U.S. citizens in 1963. The relative starting position of foreigners was quite good in parts of the chemical industry (SIC 281, 286, and 283), and of machinery (SIC 351 and 355). A comparatively weak position of foreigners can be observed in the fields of petroleum and gas (SIC 13 and 29), food (SIC 20), and soaps and related products (SIC 284).

11. As regards intercountry differences, West Germany and the United Kingdom had a leading position, with Japan and France following far behind. The USSR was of virtually no account.

12. In the high technology fields West Germany and the United Kingdom again held about the same starting position (table 2).

Table 2: Relative Starting Position in High Technology Patenting in the United States by Country^a

France	Italy	Japan	UK	USSR	West Germany	Non-U.S.
0.042 (+53.7%)	0.007 (-11.3%)	0.024 (+27.4%)	0.073 (+37.7%)	0.002 (+50%)	0.076 (+17.1%)	0.27 (+13.5%)

^aAs of 1963. Numbers in parantheses refer to deviation from national average. Interpretation as in table 1.

Source: Table A2.

When compared to the individual country's relative average performance France, together with the USSR, did particularly well in high technology industries in 1963. In addition, table A2 indicates that West Germany had in almost every respect (i.e. compared to her averages and to other countries) a strong position in the field of guided missiles, space vehicles and parts (SIC 376); even stronger, incidentally, was her position in other fields of military relevance (SIC 348, 3795, 372) - which is surprising in view of the heavy allied regulation of the German economy regarding such productions after World War II¹¹.

c. Dynamics

13. Whilst average performance as well as the starting position give information on patterns gone, dynamics - i.e. the change in invention performance relative to the United States - provides information also on recent developments. Non-U.S. patenting per annum rose 6 percentage points faster than U.S. patenting (table A3). Since OTAF data show that the U.S. patenting trend alone had a slightly negative slope¹² the absolute number of Non-U.S. patents grew by less than 6 %.

Comparative advantage of Non-U.S. inventors increased most obviously in the case of radio and television equipment (SIC 365), miscellaneous machinery (SIC 359), and soaps, detergents, etc. (SIC 284). Patent development of the United States did lose least ground - but nevertheless lost ground - in the fields of ordnance (SIC 348 + 3795), guided missiles (SIC 376), and inorganic chemistry (SIC 281). It is quite remarkable that the indicators of relative dynamics exhibit a but small variance across the fields of patent activities: The growth rate of the best performing field of Non-U.S. patent holders (SIC 365) was only 2.7 percentage points above average, worst performance was some 3.3 points below average (SIC 348+3795).

14. Inter-country differences are such that the dynamics of patent grants was most rapid in the case of Japan, with the USSR in her wake. All other countries' dynamics was below Non-U.S. average, although above U.S. performance; the United Kingdom was

- besides the United States - slowest. Some peculiarities show up when looking at the levels of significance and at the sign of coefficients (table 3): West Germany's, Japan's, and the Soviet Union's trend of relative patent dynamics is significant in all fields of activity; the trends calculated for these countries also indicate, with the only exception of guided missiles in the case of West Germany (and disregarding the four missing

Table 3: Indicators of Relative Patenting Dynamics by Country

	France	Italy	Japan	UK	USSR	West Germany	Non-U.S.
Trend estimate ^a							
Positive	33	33	41	16	37	40	41
Insignificant	7	6	0	20	0	0	0
Negative	1	2	0	5	0	1	0
Trend coefficient for							
High technology fields	0.021	0.049	0.140	0.009	0.093	0.035	0.057
Deviations from national average	-51.4%	-7.0%	-1.4%	-21.8%	-7.0%	-30.4%	-4.3%

^a Number of trends with a positive (negative, insignificant) coefficient.

Source: Table A3.

observations in the case of the USSR) a significantly superior performance as compared to the United States. Of the patents given to France and Italy some 15 % of the dynamics-coefficients by industry are insignificant, but in the remaining 85 % almost all exhibit a superior performance, too. The United Kingdom plays an exceptional rôle among Non-U.S. patent holders in that half of the coefficients are insignificant - i.e. dynamics does not differ much from that of the United States; five of the

remaining 21 industries reveal negative relative dynamics.

15. Relative dynamics in high technology patenting was highest in Japan, followed by the USSR¹³ (still table 3). The United Kingdom's performance was less than 1 percentage point above that of the United States.

Of a surprising uniformity is the deviation of high technology patenting trends from overall patenting trends. Not one of the Non-U.S. countries considered had a particular strength in the high technology area: total performance off all countries was more or less superior to high technology performance. Or, to put it differently, the United States lost least ground in the high technology fields as compared to the other sectors.

III. Explanations: Why the U.S. Has Been Falling Behind

1. Hypotheses

16. The analysis has shown that the United States' share in patent grants has decreased across all fields of inventive activity. This seems to confirm to apprehensions in the public debate in the United States about a decline in technological competitiveness, and it seems to contradict fears currently articulated in Western Europe about a widening technological gap to the United States. Whether this decrease implies that the United

States has really lost in the technological race is still an open question. For example, for the same rate of technological advance, an appreciation in the exchange rate will bring in more imports, and along with it a greater incentive for foreign exporters to patent the technology content of their products. The diagnosis of a decline in technological advance relative to other countries would thus have to eliminate "disturbing noises" coming in from exchange rates and from rising international trade patterns.

One may speak of a "real" loosing out in the technological race if other countries advance faster due, in particular, to catching up processes or due to more efficient economic institutions. If, for example, the United States is the technologically leading country, other countries' catching up would imply a relatively declining share in domestic patent grants beyond what would have to be expected anyhow on account of increasing trade patterns. The same effects may occur in case economic policies in the United States discourage domestic inventors.

17. In the following, five hypotheses contributing to explain invention performance in the United States by country relative to the United States will be tested. This will not be done industrywise, as tables A1 to A3 might suggest, but for the total of patenting activities, and for the high-technology subtotal. The reasons are that (1) grosso modo the performance of the six countries in the United States does not vary much across industries, as table 3 has shown, that (2) problems of concor-

Since the empirical evidence pertains to changes in relative invention performance over the past twenty years, all those perennial features of invention activities which Taussig and others discussed - like: why do inventors invent, or: what skills and incentives does it take to create new technologies - can be assumed to be of minor importance¹⁴. As far as institutional determinants of inventive activity are concerned, changes in the systems of education, in international migration of highly skilled people, and in the macroeconomic structure of production are assumed to have not been decisive for patenting patterns over the past two decades. The assumption of constancy of institutional determinants may be regarded questionable because the foundation of the European Patent office as well as the standardisation of procedures of patent application in the framework of the World Industrial Property Organisation (WIPO) have changed the conditions for international patenting. However, these changes occurred not before the late seventies and anyhow should not have affected country performance in relative terms.

- (a) the international integration hypothesis (II-hypothesis),
- (b) the catching-up hypothesis (CU-hypothesis),
- (c) the free enterprise hypothesis (FE-hypothesis),

- (d) the research socialism hypothesis (RESOC-hypothesis),
- (e) the inertia of aggregates hypothesis (LAG-hypothesis).

(a) The II-Hypothesis predicts that patenting activities in foreign countries depend on (and change along with) the degree of mutual economic interlocking¹⁵. An increase in exports of new goods and new modes of production makes it profitable to also secure against imitations by the importing countries. Thus, the upsurge of worldwide agreements to liberalise international trade and capital flows beginning in the late 1940s should have also positively affected international flows of technology - not only incorporated technologies but also technological exchange as such. A relative increase in the number of patents granted to foreigners by United States' authorities thus would not necessarily indicate an increase in technological competitiveness of foreign countries but an increase in the incentive to apply for patent protection in the United States. To put it differently: If returns from international appropriability rise as a result of an increase in international trade one might expect the domestic share of the "home" country (here the U.S.) to have fallen in all countries - without it implying a "real" deterioration of the country's performance.

The indicator chosen to capture the relevance of the II-hypothesis is total trade (exports plus imports) of the United States with the particular country as per cent of U.S.' gross domestic product; the expected sign of the coefficient is positive.

(b) CU-hypothesis: Generally, countries catching up can be expected to increase their capability in inventive activities because overall educational standards rise and high scientific and engineering qualifications become more frequent. Technologically backward countries are characterised by, first, a scope for catching up through technological imitation, and, second, by a comparatively low capacity to adopt the leading country's new technologies¹⁶. Catching up would then imply a decrease in the scope for imitation and a rise in the returns on own inventions. Therefore one should expect e.g. French patenting activities in the United States (as well as in France) to increase with catching up. In case the capacity to adopt foreign technologies rises with catching up, this should induce corresponding increases in the capacity to invent.

Catching up will be defined as the per capita income (PCI) ratio of each country to the United States ($= \text{PCI}_{\text{Foreign Country}} / \text{PCI}_{\text{USA}}$). PCIs are measured at constant international prices according to the Kravis/Summers/Heston work, thereby avoiding errors due to fluctuating exchange rates¹⁷.

The CU-variable being defined as above one would expect a positive correlation with the foreign country's patenting activity in the United States. A problem to be aware of is that the development of per capita income differentials not only reflects growth differentials but also relative business cycles, if computed on an annual basis. However, business cycle analyses show that in the period under consideration, especially in the

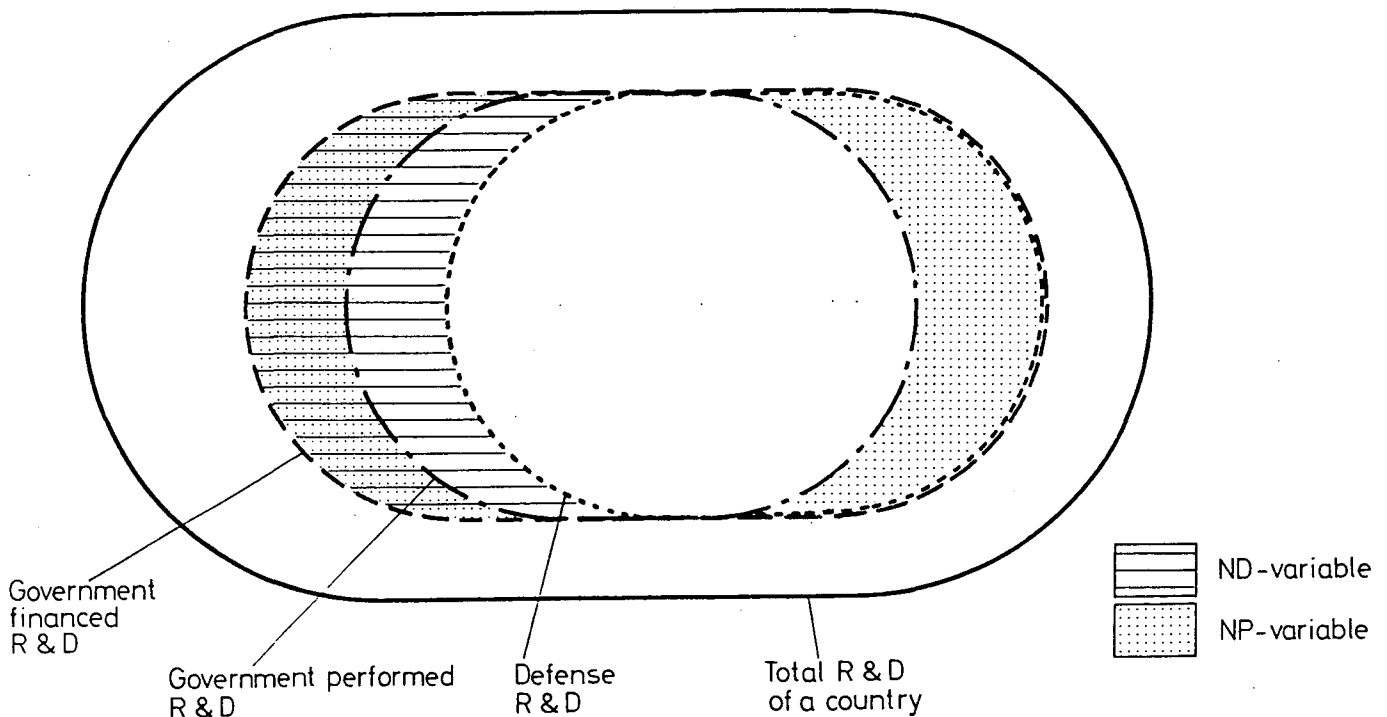
1970s, business cycles in the United States, in Japan, France, West Germany, in the United Kingdom, and in Italy were factually closely synchronised¹⁸.

(c) The main two sources of R&D finance are government funds and companies' own funds¹⁹. Often, government expenditures aim at national interests, like national security, or at keeping up a high level of innovation, rather than at companies' interests, like profit seeking in commercial markets. It can be expected that both sources have therefore a different impact on national invention performance. The "free enterprise" variable, measured as the ratio of a country's companies' own funds as percent of total R&D expenditures relative to the same ratio for the United States, is to explain whether the relative decline of U.S. invention performance can be explained by relatively decreasing companies expenditures of R&D.

(d) Regarding government funds for R&D expenditures (RESOC) two variables seem worth testing: One is about government expenditures for R&D not performed within the government sector; this NP variable is measured as a country's public R&D funds minus expenditures for government performed R&D in percent of total R&D expenditures (relative to the United States). The other RESOC variable refers to government's non defense R&D expenditures (ND), defined as a country's public R&D funds minus expenditures for government's defense R&D. The NP and ND measure overlap, as can be seen in graph 1. The shaded area in graph 1 is Non Defense, the dotted area is Non Performed. The bleak

outer area is R&D financed by

Graph 1: Taxonomy of R & D expenditures



companies' own funds. Of course, it would be interesting to also separately include the bleak inner space; this core area comprises defense R&D performed in the government sector. However, it seems impossible to obtain internationally comparable data in this respect, not even by inference.

The expected sign of the RESOC variables is unsure, at least debatable²⁰. The authors' prior is that R&D under public control is less efficient, and that efficiency decreases with the

intensity of control. Thus, the stronger a government's interference in overall R&D activities, the less efficient the country should be in overall invention performance²¹. Indeed, markets for technologies seem to have always been at the very heart of government interventions, be it due to defence and (today) space research requirements, or to simply keep the economy in a technologically leading position, or to close "gaps" to other nations. Different intensities of intervention in the countries under consideration would thus result in differing patent performance. If it is true, for instance, that the United States has become increasingly restrictive regarding export of high technologies, U.S. inventive activities can be expected to have slowed down. Such restrictions - which have been based on a number of provisions, like the "Atomic Energy Act" (1976), the "Invention Secrecy Act" (1951), the "Arms Export Control Act" (1976), the "International Emerging Economic Power Act" (1977), the "Export Administration Act" (1978)²² - generally discriminate technology producing U.S. companies by reducing their revenues from abroad. In the short run, U.S. buyers may profit from an increased supply when American producers have no choice but to sell domestically; in the long run, however, domestic price decreases together with the artificially reduced foreign demand provide disincentives for U.S. technology producers.

Despite these considerations arguments can also be found which back the opposite prior, namely that government financed R&D can have a generic function in the invention process²³. It is for

this ambivalence that the following empirical test will use the more rigorous two-tail test of the RESOC variables.

(e) In addition, the lag variable will be introduced in the time series analysis. This variable is commonly used to solve econometric problems in order to arrive at estimates unbiased by serial correlation. I.e. all variables that might have an important effect besides integration, catching up, and the ways of R&D financing should be caught by this procedure. Correspondingly, the Durbin h-statistic had to be applied instead of the simple Durbin-Watson-statistic. A reader interested in the total magnitudes of the impact of the exogenous variables, and about the number of years it takes to achieve complete adjustment to changes in these variables may also interpret the lag variable as the familiar Koyck-lag.

2. Results

19. Table A4 gives the results of regressions performed. All estimated equations are of the double-logarithmic type because of the ease of interpretation; since the statistics applied are highly aggregated there is no "zero-problem". The endogenous variable, relative invention performance in the United States, was specified in two ways: one is concerned with all fields of patent activity, the other only with high technology fields. The pool analysis refers to the combination of all country data, making problems of serial correlation less important.

20. Pool results indicate that the integration and catching up

parameters estimated (as well as the total equation) are statistically significant at the 5 % level for all fields of technology as well as for high technology patenting; the signs are as expected. Of the RESOC variables non defense R&D financed by government is significant and negative, both for all fields of technology and for high technology production. Companies own R&D funds (the FE variable) shows no significant impact on relative invention performance in three out of the four pool equations. It should be noted, that the data pool is without the USSR due to the lack of data for the ND, NP and FE variables.

At first glance the first two pool equations contradict with respect to the ND and FE variable. The econometric explanation is multicollinearity: FE and ND are negatively correlated. The two estimates say that a high share of companies' own funds improves a country's patenting performance and a high share of government R&D subsidies disimproves it - which seems to be confirmation of the same message by the two different estimates.

21. Individual country results vary around the pool estimates, as should be expected. Grosso modo, also time series analyses confirm the relevance of the hypotheses tested, though with less force.

- The integration effect is particularly weak in the case of West Germany and Italy (for all industries as well as for high technology fields).
- Catching up, the strongest explanatory variable regarding significance levels and expected signs, in time serie shows

distinctly lower levels of significance as compared to the pool regression.

- RESOC is only significant in some cases ; in these cases, however, signs are negative like in the pool regression.
- The FE variable turns out to be the weakest. Except for West Germany (all industries) and Italy (high technology fields) the companies' own efforts did not significantly influence relative invention performance in the United States. The two exceptions exhibit the "wrong sign" in terms of the prior described above.

As should be expected the LAG variable in the time series regressions is quite strong, implying that a considerable part of current invention performance is determined by past performance.

22. The country regressions, however, seem to improve with closer inspection. Table 4 summarizes the results. A fair judgement should suggest that the variables II, CU, LAG and the NP variant of RESOC (excluding high technology fields) turn out to explain the relative decline of the United States invention performance quite well: In no case the prior (i.e. the expected sign) is refuted and the worst result is insignificance. Random events would be different, either by being insignificant or by showing up with wrong signs.

23. Together with the pool results, the "best" variables in terms of t-statistics seem to be international integration and catching-up, the least efficient is the "free enterprise" hypothesis. As regards the increase in international

Table 4: Determinants of Relative Invention Performance^a: A Summary

Variable	Result	number of coefficients			Total number
		signifi- cantly +	signifi- cantly -	insignifi- cant	
II					
All fields		2(3)	0	5	10
High Tech		1(3)	0	6	10
CU					
All fields		8(1)	0	1	10
High Tech		7(2)	0	1	
RESOC ^b					
NP					
All fields		0	1(2)	2	5
High Tech		0	0	5	5
ND					
All fields		0	1	4	5
High Tech		(1)	1	3	5
FE ^b					
All fields		0	(1)	9	10
High Tech		0	(1)	9	10
LAG					
All fields		9(1)	0	0	10
High Tech		7(1)	0	2	10

^a 5 % level (10 % level in brackets). - ^b Two-tail test.

Source: Table A4.

integration which no doubt has taken place over the past twenty years, this variable may exaggerate the true impact of integration on relative U.S. performance: The integration effect is the only one tested of a two way nature; the integrating country should also exhibit tendencies like the United States, i.e. an increasing share of foreign patenting. However, it has been shown that the share of U.S. patenting in industrial countries has been declining since the early seventies²⁴.

24. In terms of significance levels, catching up is slightly, though systematically less important in the field of high technologies as compared to all technologies. The reason seems straightforward: High technologies very often are of military importance, and thereby under close government surveillance. Thus, access to leading countries' high technologies is more difficult for foreign countries; at the same time high technology research results of other countries are under control, too, which means that patenting abroad is not of first order importance for them.

25. Research socialism is of explanatory power, too; it helps explain why some countries have improved their position in comparison to the United States by relatively decreasing interventions (like the United Kingdom; see also the height and direction of minima and maxima in table A4).

An outstanding example of the importance of RESOC should be the USSR. Relative measurement is easy in this case because government control in the USSR can be assumed to be 100 %, which

means that - due to the expanding share of government performed research in the United States - her relative RESOC indicator has decreased in the period under consideration. Calculations in order to explain the USSR's invention performance are shown in the bottom rows of table A4. As far as the t-statistics of the regression coefficients is concerned, integration is most powerful in explaining the Soviet Unions' success on U.S. invention markets, regarding all fields of technology as well as high technology inventions. RESOC matters, too. Catching up is of no importance, which would imply that inventive activities in the USSR are quite independent from the stage of economic development as measured by relative per capita incomes.

IV. Summary and Conclusions

26. The assessment of invention performance by country revealed that Non-U.S. countries as a whole have increased their share in patenting on the U.S. market significantly in all fields of technology, including high technology fields. Among the six foreign countries considered the United Kingdom's performance was closest to that of the United States. Japan and West Germany have been the most successful of the foreign countries, which clearly contradicts apprehensions articulated in European countries.

27 . Why has the United States been falling behind? Three answers follow from the analysis:

- other countries have caught up to the United States regarding per capita incomes;
- integration with foreign countries has effectively increased the incentives to apply for patents in the United States;
- United States interventions in the field of technology production have diminished the efficiency of the research system.

These answers come out quite clearly, i.e. without inherent contradictions like changes in sign; the evidence, however, is not as strong as is usual when correlating national accounts data. The first answer circumscribes an increase in international technology competition. New sources of supply have enlarged world inventive output and have diminished the importance of U.S. technologies. The second answer says that the decline of economic distances among countries has increased competition on product and factor markets with corresponding effects on patenting activities. The third answer is about voluntary restraints of technology supply by the United States herself.

Notes and References

- ¹ HERBERT GIER SCH, BELA BALASSA (eds.) "Economic Incentives", Symposium 1984, The MacMillan Press Ltd., London (forthcoming).
- ² HENRY ERGAS, Why Do Some Countries Innovate More than Others? CEPS Paper No. 5, Bruxelles 1984. The currently most discussed programmes (SDI, EUREKA, ESPRIT) are mixtures between government performed and government supported research.
- ³ EDWIN MANSFIELD et al., Technology Transfer, Productivity and Economic Policy, New York 1982.
- ⁴ U.S. DEPARTMENT OF LABOR, Office of Foreign Economic Research, Report of the President on U.S. Competitiveness. Together with the Study on U.S. Competitiveness, transmitted to Congress, Sept. 1980, Washington 1980; U.S. DEPARTMENT OF COMMERCE, International Trade Administration, An Assessment of U.S. Competitiveness in High Technology Industries, Washington, D.C. 1983. THE PRESIDENT'S COMMISSION ON INDUSTRIAL COMPETITIVENESS, Global Competition. The New Reality. Washington, D.C., January 1985.
- ⁵ The analysis of 41 sections is the deepest disaggregation possible according to available patent statistics.
- ⁶ The OTAF patent statistics was heavily criticised for inaccurate assignment of patent classes to industries and for double counting by multiple assignment of the same patent classes to different industries. The statistics used in the following is a new version, revised in 1984, where duplicate counts were eliminated "through a process of fractional counting". See L. SOETE, Comments on the OTAF Concordance between the USSIC and the USPC, Sussex 1983 (mimeo.) and OFFICE OF TECHNOLOGY ASSESSMENT AND FORECAST, OTAF Custom Report. Patenting Trends in the United States and Other Countries. Fractional Count Report 1963-1983 (mimeo.).
- ⁷ See CHRISTOPHER FREEMAN (ed.), Long Waves in the World Economy, Butterworths 1983.
- ⁸ It can be shown, for instance, that a close relationship exists between the number of patents granted and the value of exports of patents and licences. For a detailed discussion see KEITH PAVITT, Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems. In: Scientometrics, Vol. 7, Nos. 1-2, 1985; LUC G. SOETE, SALLY M. E. WYATT, The Use of Foreign Patenting as an Internationally Comparable Science and Technology Output Indicator. In: Scientometrics, Vol. 5, 1983; JACOB SCHMOOKLER, Invention and Economic Growth, Harvard 1966.
- ⁹ The intercountry differences of patents granted seem to reflect relative intercountry differences in per capita incomes: Comparing average relative patent performance as shown in table A1 (weighted with population ratios in order to adjust for country size) with relative per capita incomes exhibits a high congruency of ranks. From this it may be in-

ferred that inventive activity is positively correlated with economic performance (or vice versa)

- 10 Distinction between "high technology" and other fields is, of course, a matter of judgement. Our best guess is supported by the R&D funds statistics for the United States. It shows that high technologies as defined here had an R&D input (as per cent of net sales in R&D-performing manufacturing companies) roughly 4.3 times higher as the other SIC groups (referring to unweighted averages of SIC groups). See NATIONAL SCIENCE FOUNDATION, Research and Development in Industry, 1981. Funds, 1981, Scientists & Engineers, January 1982, NSF 83-325, Washington, D.C. 1983.
- 11 Explanation of this phenomenon may be dual technologies. In some fields not R&D and production as such were interdicted but R&D and production for military ends. West German military equipment production was liberalised by the allies in a stepwise fashion after 1955. Remaining constraints were abolished in the 1980s (though there are voluntary West German restraints still today).
- 12 OFFICE OF TECHNOLOGY ASSESSMENT AND FORECAST: OTAF Custom Report 1963-1983 op. cit.
- 13 It should be noted that all countries considered here had a worse position regarding "dynamics", or even a negative one (like West Germany, and France) in the field of guided missiles (SIC 376); this worsened the overall high technology position of Non-U.S. countries considerably. With respect to the data of the USSR, the calculated dynamics (most obvious in the field of electronic components, SIC 366+367) can be overestimated due to the sometimes very low starting level (see also table A2).
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- 15 JIRI SLAMA, Analysis by Means of a Gravitation Model of International Flows of Patent Applications in the Period 1967-1978. In: World Patent Information 3 (January), 1981, gives an analysis fitting a gravitational regression model to both patent and conventional trade flows. For further evidence on international patenting patterns see also ROBERT E. EVENSON, International Invention: Implications for Technology Market Analysis. In: ZVI GRILICHES (ed.), R and D, Patents, and Productivity, The University of Chicago Press, 1984, pp. 89-127.
- 16 STANISLAV GOMULKA, Inventive Activity, Diffusion, and the Stages of Economic Growth, Aarhus 1971; ROBIN MORRIS, How Much of the Slow-down was Catch-up? In: R. L. O. MATTHEWS (ed.), Slower Growth in the Western World, London 1982.
- 17 R. SUMMERS, ALAN HESTON, Improved International Comparisons of Real Product and Its Composition: 1950-1983. In: The Review of Income and Wealth, Series 30, 1984.
- 18 SACHVERSTÄNDIGENRAT ZUR BEGUTACHTUNG DER GESAMTWIRTSCHAFTLICHEN ENTWICKLUNG (COUNCIL OF ECONOMIC ADVISERS), Jahresgut-

achten 1978/79 as well as Jahresgutachten 1985/86, Part A.

- 19 RACHEL MACCULLOCH, Research and Development as a Determinant of United States International Competitiveness. National Planning Association, Report No. 161, Washington 1978.
- 20 Regarding efficiency of public versus private activities only those studies can be considered conclusive which compare public and private production in the same fields of activity, in the same country, and at the same time. In this respect the overwhelming majority of research seems to support the notion of relatively inefficient public production. See for example EBERHARD HAMER, Creating New Entrepreneurship by Privatizing Municipal Service; ROBERT W. CRANDALL, The Emerging Competition in the U.S. Telecommunications Market; THOMAS G. MOORE, Deregulating Ground Transportation; HERBERT G. GRUBEL, Free Enterprise Zones in Economic Development; all in: HERBERT GIERSCHE (ed.), New Opportunities for Entrepreneurship, Symposium 1983, J.C.B. Mohr (Paul Siebeck), Tübingen 1984. With respect to the efficiency of public R&D support see ZVI GRILICHES, Productivity, R and D, and Basic Research, National Bureau of Economic Research, Working Paper 1547, Cambridge (Mass.) 1985; and OLE BÖRNSSEN, HANS H. GLISMANN, ERNST-JÜRGEN HORN, Der Technologietransfer zwischen den USA und der Bundesrepublik, Kieler Studie 192, J.C.B. Mohr (Paul Siebeck), Tübingen 1985.
- 21 RICHARD R. NELSON (ed.), Government and Technical Progress. A Cross-Industry Analysis, New York 1982; RICHARD R. NELSON, RICHARD N. LANGLOIS, Industrial Innovation Policy: Lessons from American History. In: Science, Vol. 219, 1983.
- 22 Empirical evidence for an increase in "protectionism" regarding exports as well as domestic production of U.S. technologies is gathered in WERNER HEIN, Beschränkung des internationalen Technologietransfers durch die USA - Auswirkungen auf die Innovationsentscheidungen deutscher Unternehmen. Study on behalf of the West German Federal Ministry of Research and Technology. - Frequent and recent evidence can also be found in newspapers; see e.g. GARY PUTKA, Raising Barriers - U.S. Restricts Access of Foreign Scientists to High Technology. The Wall Street Journal, European Edition, 28.01.1985, or the INTERNATIONAL HAROLD TRIBUNE, Even Friends Will Be Watched Closely as U.S. Guards Its High Tech, 23.05.84.
- 23 NATHAN ROSENBERG, Inside the Black Box. Technology and Economics. Cambridge University Press 1982. JAMES A. BRANDER, BARBARA SPENCER, International R&D rivalry and Industrial Strategy. The Review of Economic Studies, No. 163, Vol. 50 (1983) pp. 707-722. PAUL KRUGMAN, The U.S. Response to Foreign Industrial Targeting. Brookings Papers on Economic Activity, 1984, 1, pp. 77-121.
- 24 Evidence for the major industrial countries can be found in: NATIONAL SCIENCE BOARD, Science Indicators 1982, Washington D.C. 1983, U.S. Government Printing Office, p. 209 ff.

Table A1: International Comparison of Inventive Activities^a: Average Relative Performance by Country 1963 - 1983^c

Code ^b	Field of Activity	Inventing Country							
		West Germany	Japan	United Kingdom	France	Switzerland	Italy	USSR	Non-U.S. Total
20	Food and Kindred Products	0.048	0.069	0.040	0.020	0.021	0.008	0.004	0.316
22	Textile Mill Products	0.158	0.101	0.086	0.046	0.053	0.016	-	0.542
281	Industrial Inorganic Chemistry	0.148	0.088	0.075	0.060	0.012	0.021	0.006	0.535
286	Industrial Organic Chemistry	0.185	0.107	0.072	0.054	0.082	0.028	0.004	0.628
282	Plastics Materials & Synthetic Resins	0.182	0.141	0.055	0.039	0.026	0.035	0.006	0.565
287	Agricultural Chemicals	0.149	0.083	0.082	0.070	0.074	0.017	0.003	0.579
284	Soaps, Detergents, Cleaners, Perfumes, Cosmetics & Toiletries	0.095	0.041	0.068	0.036	0.026	0.008	-	0.347
285	Paints, Varnishes, Lacquers, Enamels, & Allied Products	0.128	0.094	0.053	0.024	0.022	0.012	0.003	0.400
289	Miscellaneous Chemical Products	0.073	0.079	0.042	0.031	0.008	0.004	0.004	0.315
283	Drugs and Medicines	0.153	0.156	0.095	0.087	0.071	0.034	0.006	0.731
13,29	Petroleum & Natural Gas Extraction & Refining	0.024	0.012	0.029	0.017	0.005	0.006	0.002	0.147
30	Rubber & Miscellaneous Plastics Products	0.108	0.083	0.058	0.032	0.015	0.016	0.002	0.407
32	Stone, Clay, Glass and Concrete Products	0.089	0.076	0.073	0.046	0.013	0.010	0.005	0.422
331,332,339,3462	Primary Ferrous Products	0.149	0.165	0.078	0.066	0.025	0.016	0.013	0.725
333-336,339 (exc.3399)	Primary & Secondary Non-Ferrous Metals	0.110	0.150	0.086	0.055	0.026	0.012	0.016	0.631
3463									
34(exc.3462, 3463,348)	Fabricated Metal Products	0.074	0.041	0.047	0.033	0.015	0.008	0.002	0.315
351	Engines & Turbines	0.170	0.110	0.110	0.062	0.022	0.012	0.006	0.647
352	Farm & Garden Machinery & Equipment	0.066	0.021	0.040	0.030	0.024	0.007	0.003	0.318
353	Construction, Mining & Material Handling Machinery & Equipment	0.092	0.032	0.060	0.039	0.018	0.013	0.006	0.387
354	Metal Working Machinery & Equipment	0.141	0.063	0.063	0.041	0.024	0.014	0.015	0.482
357	Office Computing & Accounting Machines	0.093	0.109	0.048	0.034	0.019	0.018	0.002	0.415
355	Special Industry Machinery, Except Metal Working Machinery	0.179	0.079	0.077	0.055	0.049	0.029	0.010	0.629
356	General Industrial Machinery & Equipment	0.134	0.068	0.068	0.044	0.024	0.015	0.006	0.482
358	Refrigeration & Service Industry Machinery	0.095	0.047	0.047	0.030	0.019	0.013	0.004	0.368
359	Miscellaneous Machinery, Except Electrical	0.118	0.073	0.067	0.048	0.018	0.012	0.005	0.474
361,3825	Electrical Transmission & Distribution Equipment	0.087	0.078	0.056	0.044	0.020	0.011	0.003	0.399
362	Electrical Industrial Apparatur	0.118	0.114	0.069	0.053	0.033	0.011	0.017	0.527
363	Household Appliances	0.121	0.084	0.043	0.027	0.024	0.037	0.003	0.443
364	Electrical Lighting & Wiring Equipment	0.071	0.038	0.048	0.033	0.011	0.013	0.003	0.311
369	Miscellaneous Electrical Machinery, Equipment & Supplies	0.136	0.080	0.060	0.054	0.011	0.007	0.005	0.462
365	Radio & Television Receiving Equipment Except Communication Types	0.085	0.186	0.061	0.032	0.010	0.010	0.003	0.508
366-367	Electronic Components & Accessories & Communication Equipment	0.075	0.099	0.057	0.043	0.043	0.007	0.000	0.385
371	Motor Vehicles & Motor Vehicle Equipment	0.158	0.082	0.074	0.059	0.013	0.013	0.002	0.525
376	Guided Missiles & Space Vehicles & Parts	0.036	0.005	0.081	0.028	0.008	0.008	-	0.268
373	Ship & Boat Building & Repairing	0.063	0.058	0.069	0.048	0.010	0.010	0.005	0.413
374	Railroad Equipment	0.111	0.045	0.077	0.056	0.022	0.013	0.008	0.455
375	Motorcycles, Bicycles & Parts	0.141	0.119	0.120	0.076	0.008	0.013	-	0.618
379(exc.3795)	Miscellaneous Transportation Equipment	0.067	0.040	0.088	0.051	0.006	0.009	0.005	0.398
348,3795	Ordnance Except Missiles	0.123	0.009	0.021	0.034	0.045	0.011	0.003	0.356
372	Aircraft & Parts	0.157	0.095	0.126	0.076	0.011	0.012	0.004	0.607
38(exc.3825)	Professional & Scientific Instruments	0.105	0.099	0.051	0.036	0.024	0.009	0.005	0.432
	All Other SIC's	0.055	0.042	0.033	0.025	0.013	0.010	0.001	0.278
	All Industries	0.108	0.078	0.059	0.041	0.025	0.014	0.005	0.434

^a As measured by patents granted in the United States. Inventive activities are measured by:

Number of patents granted to country i
Number of patents granted to the United States

in the United States. - ^b Standard Industrial Classification of the

United States. - ^c Unweighted 21 years average of inventive activities (see footnote a).

Source: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office: OTAF Custom Report 1963-1983. - Own calculations.

Table A2: International Comparison of Inventive Activities^a: Estimated Relative Starting Position in 1963^c.

Code ^b	Field of Activity	Inventing Country							
		West Germany	Japan	United Kingdom	France	Switzerland	Italy	USSR	Non-U.S. Total
20	Food and Kindred Products	0.028	0.025	0.022	0.007	0.007	0.005	0.001	0.149
22	Textile Mill Products	0.090	0.028	0.074	0.026	0.032	0.015	-	0.291
281	Industrial Inorganic Chemistry	0.106	0.030	0.094	0.059	0.011	0.016	0.001	0.385
286	Industrial Organic Chemistry	0.119	0.042	0.065	0.034	0.071	0.020	0.001	0.416
282	Plastics Materials & Synthetic Resins	0.127	0.043	0.049	0.021	0.020	0.042	0.002	0.328
287	Agricultural Chemicals	0.069	0.026	0.036	0.043	0.041	0.005	0.000	0.271
284	Soaps, Detergents, Cleaners, Perfumes, Cosmetics & Toiletries	0.056	0.007	0.029	0.014	0.012	0.005	-	0.154
285	Paints, Varnishes, Lacquers, Enamels, & Allied Products	0.078	0.024	0.051	0.013	0.012	0.011	0.000	0.212
289	Miscellaneous Chemical Products	0.046	0.024	0.033	0.019	0.006	0.003	0.001	0.167
283	Drugs and Medicines	0.090	0.076	0.054	0.064	0.059	0.019	0.002	0.453
13,29	Petroleum & Natural Gas Extraction & Refining	0.015	0.002	0.036	0.008	0.001	0.002	0.000	0.088
30	Rubber & Miscellaneous Plastics Products	0.065	0.021	0.048	0.029	0.009	0.012	0.000	0.218
32	Stone, Clay, Glass and Concrete Products	0.049	0.018	0.052	0.030	0.009	0.006	0.001	0.213
331,332,3399,3462	Primary Ferrous Products	0.085	0.050	0.070	0.046	0.021	0.009	0.003	0.363
333-336,339 (exc.3399)3463	Primary & Secondary Non-Ferrous Metals	0.093	0.052	0.094	0.034	0.018	0.007	0.004	0.368
34(exc.3462,3463,348)	Fabricated Metal Products	0.042	0.009	0.044	0.021	0.010	0.004	0.001	0.173
351	Engines & Turbines	0.119	0.021	0.146	0.058	0.020	0.007	0.003	0.415
352	Farm & Garden Machinery & Equipment	0.040	0.006	0.035	0.017	0.017	0.004	0.001	0.189
353	Construction, Mining & Material Handling Machinery & Equipment	0.052	0.008	0.047	0.025	0.010	0.007	0.003	0.223
354	Metal Working Machinery & Equipment	0.077	0.014	0.059	0.026	0.014	0.006	0.003	0.245
357	Office Computing & Accounting Machines	0.069	0.022	0.050	0.019	0.011	0.010	0.001	0.207
355	Special Industry Machinery, Except Metal Working Machinery	0.098	0.023	0.079	0.035	0.031	0.015	0.003	0.355
356	General Industrial Machinery & Equipment	0.075	0.016	0.068	0.031	0.015	0.007	0.002	0.267
358	Refrigeration & Service Industry Machinery	0.051	0.012	0.037	0.016	0.013	0.007	0.001	0.196
359	Miscellaneous Machinery, Except Electrical	0.057	0.008	0.056	0.032	0.016	0.006	0.002	0.207
361,3825	Electrical Transmission & Distribution Equipment	0.052	0.018	0.057	0.025	0.016	0.006	0.001	0.219
362	Electrical Industrial Apparatur	0.062	0.024	0.067	0.036	0.023	0.006	0.004	0.256
363	Household Appliances	0.066	0.025	0.039	0.014	0.014	0.022	0.000	0.224
364	Electrical Lighting & Wiring Equipment	0.038	0.008	0.041	0.018	0.007	0.009	0.001	0.164
369	Miscellaneous Electrical Machinery, Equipment & Supplies	0.066	0.025	0.041	0.051	0.010	0.007	0.002	0.258
365	Radio & Television Receiving Equipment Except Communication Types	0.054	0.035	0.057	0.020	0.005	0.005	0.001	0.214
366-367	Electronic Components & Accessories & Communication Equipment	0.049	0.024	0.057	0.024	0.024	0.003	0.000	0.200
371	Motor Vehicles & Motor Vehicle Equipment	0.088	0.011	0.068	0.049	0.009	0.008	0.001	0.265
376	Guided Missiles & Space Vehicles & Parts	0.085	0.002	0.094	0.064	0.005	0.005	-	0.193
373	Ship & Boat Building & Repairing	0.028	0.028	0.064	0.028	0.011	0.009	0.001	0.249
374	Railroad Equipment	0.043	0.008	0.080	0.046	0.010	0.022	0.006	0.271
375	Motorcycles, Bicycles & Parts	0.081	0.018	0.123	0.076	0.006	0.021	-	0.328
379(exc.3795)	Miscellaneous Transportation Equipment	0.039	0.006	0.136	0.051	0.003	0.008	0.001	0.283
348,3795	Ordnance Except Missiles	0.100	0.006	0.018	0.022	0.056	0.008	0.000	0.272
372	Aircraft & Parts	0.087	0.014	0.153	0.065	0.008	0.006	0.002	0.341
38(exc.3825)	Professional & Scientific Instruments	0.073	0.020	0.043	0.025	0.017	0.005	0.001	0.222
	All Other SIC's	0.035	0.011	0.025	0.017	0.008	0.006	0.000	0.153
	All Industries	0.065	0.019	0.053	0.027	0.017	0.008	0.001	0.238

^aAs measured by patents granted in the United States. Inventive activities are measured by:

Number of patents granted to country i in the United States. - ^b Standard Industrial Classification of the

United States.-^cInterception of the exponential trend of 1963/1983 with the ordinate.

Source: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office: OTAF Custom Report 1963-1983. - Own calculations.

Table A3: International Comparison of Inventive Activities^a: Estimated Relative Dynamics 1963-1983^c

- 30 -

Code ^b	Field of Activity	Inventing Country							
		West Germany	Japan	United Kingdom	France	Switzerland	Italy	USSR	Non-U.S. Total
20	Food and Kindred Products	0.055 (5.87)	0.101 (11.12)	0.059 (5.87)	0.104 (10.08)	0.112 (7.84)	0.045 (6.19)	0.169 (8.00)	0.075 (13.53)
22	Textile Mill Products	0.056 (10.31)	0.129 (16.88)	0.015 (2.26)	0.056 (8.88)	0.049 (6.89)	0.007 (0.43)	-	0.062 (16.04)
281	Industrial Inorganic Chemistry	0.033 (7.72)	0.107 (11.82)	-0.022 (-3.73)	0.002 (0.22)	0.009 (1.12)	0.027 (2.89)	0.153 (6.38)	0.033 (9.37)
286	Industrial Organic Chemistry	0.044 (10.47)	0.093 (11.40)	0.010 (2.50)	0.048 (6.82)	0.013 (2.17)	0.035 (9.11)	0.114 (6.54)	0.041 (9.41)
282	Plastics Materials & Synthetic Resins	0.036 (6.04)	0.119 (9.90)	0.013 (1.51)	0.062 (4.74)	0.026 (3.97)	-0.019 (-1.61)	0.113 (6.19)	0.054 (7.61)
287	Agricultural Chemicals	0.077 (10.77)	0.116 (18.17)	0.082 (10.80)	0.048 (6.20)	0.059 (9.33)	0.126 (9.58)	0.205 (6.19)	0.076 (15.94)
284	Soaps, Detergents, Cleaners, Perfumes, Cosmetics & Toiletries	0.054 (8.73)	0.171 (10.87)	0.087 (8.59)	0.097 (7.05)	0.077 (7.44)	0.045 (2.05)	-	0.081 (11.64)
285	Paints, Varnishes, Lacquers, Enamels, & Allied Products	0.049 (11.83)	0.135 (11.74)	0.005 (0.84)	0.063 (6.79)	0.060 (7.19)	0.010 (0.50)	0.209 (6.90)	0.064 (13.84)
289	Miscellaneous Chemical Products	0.046 (7.10)	0.118 (10.84)	0.022 (3.53)	0.051 (5.64)	0.033 (4.63)	0.044 (1.65)	0.136 (7.01)	0.063 (14.80)
283	Drugs and Medicines	0.053 (10.37)	0.072 (10.49)	0.056 (7.81)	0.030 (5.67)	0.019 (2.98)	0.058 (8.73)	0.109 (6.19)	0.048 (14.19)
13,29	Petroleum & Natural Gas Extraction & Refining	0.044 (5.34)	0.198 (7.87)	-0.021 (-3.53)	0.073 (6.36)	0.147 (6.19)	0.096 (6.19)	0.236 (6.72)	0.051 (11.03)
30	Rubber & Miscellaneous Plastics Products	0.051 (15.41)	0.136 (13.52)	0.018 (3.50)	0.010 (0.44)	0.055 (8.95)	0.030 (4.95)	0.132 (7.47)	0.062 (14.71)
32	Stone, Clay, Glass and Concrete Products	0.061 (12.43)	0.147 (13.83)	0.033 (4.44)	0.042 (8.00)	0.035 (4.63)	0.045 (5.32)	0.161 (6.21)	0.068 (13.52)
331,332,3399,3462	Primary Ferrous Products	0.056 (7.78)	0.120 (16.06)	0.011 (1.44)	0.036 (5.08)	0.016 (1.05)	0.057 (2.96)	0.134 (4.81)	0.069 (15.00)
333-336,339 (exc.3399) 3463	Primary & Secondary Non-Ferrous Metals	0.017 (2.39)	0.107 (15.32)	-0.009 (-0.84)	0.048 (5.32)	0.039 (3.16)	0.056 (4.89)	0.151 (8.00)	0.054 (12.75)
34 (exc.3462, 3463,348)	Fabricated Metal Products	0.056 (15.29)	0.146 (13.86)	0.007 (1.75)	0.045 (13.89)	0.047 (10.78)	0.066 (9.02)	0.117 (7.66)	0.060 (15.51)
351	Engines & Turbines	0.035 (9.44)	0.168 (16.04)	-0.029 (-5.72)	0.006 (1.03)	0.009 (0.86)	0.047 (2.99)	0.057 (3.08)	0.045 (14.71)
352	Farm & Garden Machinery & Equipment	0.051 (10.91)	0.121 (13.23)	0.015 (3.56)	0.054 (7.46)	0.035 (3.17)	0.061 (5.90)	0.102 (3.37)	0.052 (16.95)
353	Construction, Mining & Material Handling Machinery & Equipment	0.058 (13.16)	0.142 (11.65)	0.024 (5.56)	0.045 (7.63)	0.059 (8.04)	0.058 (7.96)	0.071 (3.95)	0.055 (12.39)
354	Metal Working Machinery & Equipment	0.060 (14.83)	0.151 (14.57)	0.006 (1.15)	0.047 (8.09)	0.049 (6.66)	0.080 (12.02)	0.153 (7.36)	0.068 (14.91)
357	Office Computing & Accounting Machines	0.030 (8.06)	0.162 (16.39)	-0.004 (-1.04)	0.058 (11.21)	0.054 (5.65)	0.056 (6.28)	0.104 (4.71)	0.070 (18.35)
355	Special Industry Machinery, Except Metal Working Machinery	0.060 (16.21)	0.125 (15.90)	-0.003 (-0.88)	0.045 (9.39)	0.046 (11.41)	0.068 (12.93)	0.113 (5.68)	0.057 (14.91)
356	General Industrial Machinery & Equipment	0.058 (18.61)	0.145 (17.73)	0.001 (0.28)	0.035 (9.10)	0.049 (10.43)	0.076 (9.39)	0.095 (6.64)	0.059 (19.71)
358	Refrigeration & Service Industry Machinery	0.063 (13.91)	0.135 (12.96)	0.024 (4.18)	0.060 (8.58)	0.040 (4.44)	0.058 (8.08)	0.121 (5.62)	0.063 (14.10)
359	Miscellaneous Machinery, Except Electrical	0.073 (14.07)	0.222 (16.06)	0.019 (3.26)	0.041 (5.67)	0.017 (1.37)	0.069 (6.00)	0.103 (4.92)	0.083 (13.86)
361,3825	Electrical Transmission & Distribution Equipment	0.053 (9.88)	0.146 (16.70)	-0.001 (-0.21)	0.056 (13.73)	0.023 (2.44)	0.063 (4.86)	0.144 (4.92)	0.060 (16.20)
362	Electrical Industrial Apparatus	0.064 (9.94)	0.154 (14.38)	0.004 (0.55)	0.038 (5.90)	0.033 (6.71)	0.068 (6.11)	0.141 (8.16)	0.072 (14.42)
363	Household Appliances	0.061 (10.12)	0.122 (16.01)	0.009 (1.06)	0.069 (10.39)	0.057 (6.76)	0.051 (6.22)	0.197 (7.50)	0.063 (13.38)
364	Electrical Lighting & Wiring Equipment	0.062 (7.37)	0.158 (10.96)	0.015 (1.08)	0.062 (7.42)	0.037 (1.75)	0.034 (2.69)	0.153 (9.15)	0.064 (9.12)
369	Miscellaneous Electrical Machinery, Equipment & Supplies	0.072 (9.67)	0.117 (16.46)	0.039 (3.22)	0.006 (0.86)	0.012 (0.84)	-0.001 (-0.05)	0.083 (3.20)	0.058 (13.05)
365	Radio & Television Receiving Equipment Except Communication Types	0.046 (8.80)	0.167 (14.39)	0.006 (0.86)	0.048 (6.76)	0.066 (4.99)	0.072 (4.62)	0.126 (9.97)	0.087 (15.03)

continued

Table A3 continued

Code ^b		Inventing Country							
		West Germany	Japan	United Kingdom	France	Switzerland	Italy	USSR	Non-U.S. Total
366-367	Electronic Components & Accessories & Communication Equipment	0.044 (13.22)	0.143 (15.37)	0.000 (0.11)	0.058 (14.98)	0.058 (14.98)	0.082 (9.95)	1.397 (5.58)	0.065 (18.49)
371	Motor Vehicles & Motor Vehicle Equipment	0.058 (14.66)	0.198 (16.51)	0.008 (2.21)	0.018 (3.89)	0.038 (3.48)	0.046 (4.11)	0.058 (3.91)	0.068 (18.80)
376	Guided Missiles & Space Vehicles & Parts	-0.086 (-2.35)	0.117 (6.19)	-0.014 (-1.33)	-0.082 (-3.72)	0.048 (6.19)	0.048 (6.19)	- -	0.033 (2.23)
373	Ship & Boat Building & Repairing	0.081 (9.42)	0.073 (6.37)	0.008 (0.72)	0.054 (4.99)	-0.010 (-1.62)	0.008 (6.19)	0.130 (6.82)	0.051 (10.40)
374	Railroad Equipment	0.095 (10.50)	0.171 (11.35)	-0.004 (-0.56)	0.019 (1.18)	0.083 (4.24)	-0.052 (-6.19)	0.030 (6.48)	0.052 (8.70)
375	Motorcycles, Bicycles & Parts	0.055 (7.13)	0.189 (11.71)	-0.003 (-0.33)	0.000 (0.02)	0.037 (6.19)	-0.046 (-8.07)	- -	0.064 (12.61)
379(exc.3795)	Miscellaneous Transportation Equipment	0.054 (7.81)	0.193 (11.74)	-0.043 (-4.46)	-0.001 (-0.07)	0.073 (4.27)	0.011 (3.80)	0.135 (6.19)	0.034 (8.11)
348,3795	Ordinance Except Missiles	0.021 (3.71)	0.052 (3.56)	0.014 (0.76)	0.043 (2.76)	-0.021 (-2.11)	0.028 (1.38)	0.209 (7.42)	0.027 (5.03)
372	Aircraft & Parts	0.058 (11.45)	0.193 (15.99)	-0.019 (-4.69)	0.016 (2.49)	0.033 (3.95)	0.063 (4.19)	0.075 (3.38)	0.058 (17.68)
38(exc.3825)	Professional & Scientific Instruments	0.036 (13.56)	0.160 (13.80)	0.017 (5.92)	0.036 (13.20)	0.038 (8.92)	0.059 (13.88)	0.121 (7.85)	0.066 (19.12)
	All Other SIC's	0.046 (10.40)	0.136 (12.37)	0.027 (9.25)	0.040 (6.93)	0.050 (7.13)	0.043 (7.09)	0.204 (10.99)	0.060 (14.01)
	All Industries	0.050 (17.28)	0.142 (15.14)	0.011 (5.23)	0.044 (13.36)	0.039 (11.31)	0.053 (13.89)	0.121 (6.99)	0.060 (17.20)

^aAs measured by patents granted in the United States. Inventive activities are measured by:

$$\frac{\text{Number of patents granted to country } i}{\text{Number of patents granted to the United States}}$$
 in the United States. - ^bStandard Industrial Classification of the United States. - ^cRegression coefficient of the exponential trend between 1963 and 1983 (t-value in parenthesis).

Source: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office: OTAF Custom Report 1963-1983. -
 Own calculations.

Table A4: Determinants of Relative Invention Performance of Major Industrial Countries in the United States 1963-1983: Multiple Regression Results

Type of Analysis	Results ^a								Durbin h	DFG
	Intercept	II- Hypothesis	CU- Hypothesis	RFSOC-Hypotheses ^b		FE- Hypothesis	Lag- Variable	R ²		
				NP	ND					
<u>All Fields of Technology</u>										
Pool analysis	3.62** (54.40)	0.86** (19.55)	2.79** (14.68)	0.12 (1.50)	-	0.33** (2.15)	-	0.92	-	95
	3.70** (51.97)	0.85** (19.82)	2.90** (16.95)	-	-0.20** (-2.54)	-0.48 (-0.40)	-	0.93	-	95
Country analysis										
France										
Coefficient	1.89** (7.25)	0.19** (2.27)	1.91** (5.93)	-0.24 (-1.21)	-	-0.28 (-1.07)	0.20* (1.71)	0.99	-0.94 ^f	14
Minimum (period ^C)		0.13(1)	0.64(2)	0.21(14)		0.32(18)	2.9(1)			
Maximum (period ^C)		0.40(17)	0.85(19)	0.41(18)		0.57(13)	5.8(20)			
Coefficient	1.80** (7.48)	0.21** (2.06)	1.70** (7.00)	-	0.79 (0.90)	0.17 (1.06)	0.27** (3.12)	0.99	-0.85 ^f	14
Minimum (period ^C)					0.25(13)					
Maximum (period ^C)					0.50(2)					
Italy										
Coefficient	1.32** (3.19)	0.21 (1.12)	1.64** (3.20)	-0.49* (-1.91)	-	-0.57 (-1.49)	0.73** (5.76)	0.96	-0.39 ^f	14
Minimum (period ^C)		0.13(2)	0.47(2)	0.20(2)		0.36(18)	0.9(1)			
Maximum (period ^C)		0.29(16)	0.58(19)	0.39(18)		0.59(1)	2.2(19)			
Coefficient	1.51** (3.69)	0.23 (1.17)	1.38** (2.42)	-	-0.24 (-1.36)	-0.21 (-0.76)	0.73** (5.42)	0.95	-0.37 ^f	14
Minimum (period ^C)					0.38(3)					
Maximum (period ^C)					0.60(18)					
Japan										
Coefficient	2.28** (8.03)	0.25* (1.41)	2.04** (4.97)	0.02 (0.28)	-	-0.07 (-0.13)	0.45** (6.64)	0.99	-0.12 ^f	14
Minimum (period ^C)		0.32(1)	0.41(1)	0.01(1)		0.70(15)	2.5(1)			
Maximum (period ^C)		1.66(18)	0.77(19)	0.18(15)		0.86(1)	24.0(20)			
Coefficient	2.15** (6.70)	0.29* (1.59)	1.75** (3.01)	-	0.16 (0.73)	-0.03 (-0.09)	0.44** (7.05)	0.99	-0.23 ^f	14
Minimum (period ^C)					0.14(1)					
Maximum (period ^C)					0.30(15)					
United Kingdom										
Coefficient	1.31** (2.29)	0.25* (1.74)	0.68 (0.79)	-0.39* (-1.81)	-	0.36 (-1.11)	0.50** (2.55)	0.68	-0.41 ^f	14
Minimum (period ^C)		0.24(1)	0.61(4)	0.23(8)		0.36(16)	5.3(1)			
Maximum (period ^C)		0.61(17)	0.65(p ^e)	0.38(16)		0.52(17)	6.6(16)			
Coefficient	1.71** (2.95)	0.14 (0.90)	1.21* (1.38)	-	-0.15** (-2.04)	-0.13 (-0.68)	0.42** (2.14)	0.70	-0.31 ^f	14
Minimum (period ^C)					0.19(13)					
Maximum (period ^C)					0.32(16)					
West Germany										
Coefficient	1.41** (6.57)	-0.75 (-0.70)	2.23** (4.20)	-0.43** (-2.56)	-	-0.45* (-1.82)	0.62** (8.47)	0.99	-0.83 ^f	14
Minimum (period ^C)		0.25(1)	0.67(4)	0.26(2)		0.50(11)	7.3(1)			
Maximum (period ^C)		0.73(17)	0.85(19)	0.33(10)		0.58(6)	16.0(20)			
Coefficient	1.40 (5.27)	0.36 (0.26)	1.65** (2.73)	-	0.01 (0.05)	0.01 (0.05)	0.61** (6.29)	0.98	-0.75 ^f	14
Minimum (period ^C)					0.34(1)					
Maximum (period ^C)					0.43(11)					

Table A4 continued

Table A4 continued

Type of Analysis	Results ^a									
	Intercept	II- Hypothesis	CU- Hypothesis	RESOC- NP	Hypotheses ^b ND	FE- Hypothesis	Laq- Variable	R ²	Durbin h	DEG
<u>High Technology Fields^d</u>										
Pool analysis	3.90** (42.96)	0.85** (14.06)	3.38** (13.01)	-0.74 (-0.69)	-	0.14	-	0.88	-	95
	4.07** (45.73)	0.84** (15.73)	3.30** (15.40)	-	-0.47** (-4.84)	-0.21 (-1.39)	-	0.90	-	95
Country analysis										
France										
Coefficient	2.93** (6.16)	0.15 (1.01)	2.27** (4.28)	-1.12 (-0.35)	-	-0.11 (-0.27)	-0.27 (-1.34)	0.91	-1.18 ^f	14
Coefficient	2.96** (6.79)	0.24* (1.43)	2.24** (5.29)	-	0.17 (1.08)	0.34 (1.15)	-0.23 (-1.32)	0.92	-0.64 ^f	14
Italy										
Coefficient	1.12 (1.29)	0.13 (0.35)	1.55* (1.44)	-0.80 (-1.45)	-	-1.21* (-1.56)	0.55** (2.47)	0.85	0.38 ^f	14
Coefficient	1.44* (1.77)	0.17 (0.43)	1.10 (0.94)	-	-0.42 (-1.18)	-0.71 (-1.30)	0.52** (2.30)	0.84	-0.17 ^f	14
Japan										
Coefficient	2.27** (6.98)	0.29* (1.60)	1.72** (4.09)	-0.02 (-0.31)	-	-0.27 (-0.51)	0.46** (5.67)	0.99	0.19 ^f	14
Coefficient	1.79** (5.95)	0.45* (2.45)	0.99** (1.78)	-	0.38* (1.78)	0.18 (0.50)	0.45** (6.95)	0.99	-0.17 ^f	14
United Kingdom										
Coefficient	2.08** (3.27)	0.28* (1.55)	2.11* (1.65)	-0.10 (-0.34)	-	0.17 (0.38)	0.54** (1.93)	0.24	0.57 ^f	14
Coefficient	2.43** (4.38)	0.07 (0.43)	2.45** (2.27)	-	-0.20** (-2.40)	-0.13 (-0.56)	0.38* (1.54)	0.46	0.43 ^f	14
West Germany										
Coefficient	2.09** (5.17)	0.18 (0.10)	2.48** (2.71)	-0.29 (-0.99)	-	-0.35 (-0.83)	0.43** (3.21)	0.96	-0.67 ^f	14
Coefficient	2.14** (5.32)	0.19 (1.02)	1.91** (2.27)	-	0.14 (1.14)	0.12 (0.36)	0.37** (2.69)	0.96	-0.59 ^f	14
<u>The Case of the USSR</u>										
All fields of technology										
Coefficient	23.44** (2.07)	0.65** (3.31)	0.55 (0.41)	-3.22* (-1.87)	-	-	0.28* (1.64)	0.93	0.29 ^f	15
Minimum (period) ^c		0.00(1)	0.39(1)	621(19)			0.14(1)			
Maximum (period) ^c		0.05(13)	0.53(20)	732(1)			1.23(18)			
High technology fields	22.83** (2.21)	0.57** (2.90)	0.09 (0.07)	-3.20** (-2.02)	-	-	0.37** (2.32)	0.95	0.36 ^f	15

^at-statistics in brackets under each coefficient; **: Significant at the 5 % level; *: Significant at the 10 % level (one-tail test for the II, CU and LAG variables, two-tail test for RESOC- and PF- variables). - ^bIn the case of the USSR RESOC has been tested by referring to the share of R & D performed by the government sector relative to the United States (excluding universities). - ^cThe minimum and maximum figures indicate the exogenous variables' height, variation, and direction of change, reaching from 1 (for 1964) to 20 (for 1983). - ^dDefined as Miscellaneous Chemical Products (SIC 281), Drugs and Medicines (283), Engines and Turbines (351), Metal Working Machinery and Equipment (354), Office Computing and Accounting Machines (357), Misc. Electrical Machinery, Equipment and Supplies (369), Electronic Components and Accessories and Communications Equipment (366, 367), Guided Missiles and Space Vehicles and Parts (376), Aircraft and Parts (372), Professional and Scientific Instruments (38 excl. 3825). - ^epassim. - No serial correlation at the 5 % level of significance.

Source: As tables A1 to A3. - R. SUMMERS, ALAN HESTON: Improved International Comparisons of Real Product and Its Composition: 1950 - 1980. In: The Review of Income and Wealth, Series 30, 1984. - OECD: Trade by Commodities, Series C, Paris, current issues. - NATIONAL SCIENCE BOARD: Science Indicators 1982, Report of the National Science Board 1983, Washington 1983. - Own calculations.