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Defence and space expenditures in the US: An inter-firm analysis

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DEFENCE AND SPACE EXPENDITURES IN THE US:
AN INTER-FIRM ANALYSIS

by

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July 1991

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ABSTRACT

The economic impact of defence and space expenditures has been an important policy issue because of the secondary benefits expected to be accruing from it. Although defence and space activities can stimulate the early development of many technologies, the lasting economic impact of these technologies is difficult to measure.

To capture the scientific and technological values added of defence and space financed productions, we have depended on the patents and scientific and technical publications as the indicators. The economic performance has been measured by two separate indicators: (a) firm growth in terms of average annual rate of change in the number of employees, and (b) rate of return on sales measured by the company's net profits in relation to sales.

From 1970-75 and 1980-85 the weight within the manufacturing sector of both defence contractors and the civilian companies increased. Defence firms gained considerably in terms of sales, employment, gross plants and company funded R&D in the latter period under the Reagan Administration. Whereas this may be considered a "Reagan effect" in defence procurement, other indicators point to in the opposite direction: (a) decrease in the shares of defence R&D contracts, (b) relatively low growth of patent output as percent of total manufacturing from the defence firms, and (c) decrease in scientific publications from defence firms per 1000 employees.

Firm level analysis showed that military R&D contracts did not contribute to economic or technical efficiency. Space expenditure did not contribute to improvement of economic performance as measured by company growth and profitability. NASA contracts were not associated with technical progress measured by patents, but they improved scientific publications. Defence expenditures are not of importance for the overall economic efficiency. The standard financial variables, capital formation and own R&D activities prove mostly relevant. The study is restricted to an efficiency analysis in a cross sectional comparison and does not include the effect of market structure.

DEFENCE AND SPACE EXPENDITURES IN THE US:
AN INTER-FIRM ANALYSIS¹

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I. INTRODUCTION

a. The Issue

The economic impact of defence and space (D&S) expenditures⁴ has been an important policy issue. Proponents of military and defence budgets focus not only on the security needs of the country as a justification for defence spending, but also on secondary benefits expected to be accruing from it, so-called spin-offs. Those opposing high military spending point out the opportunity costs as well as the irrelevance of military technology and hard-

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⁴ Both D&S equipment producing activities are dealt with in the following, because both are considered important in the spin-off debate; in addition, both kinds of productions overlap considerably, with space activities financed by DoD as well as NASA, and with NASA prime contractors regularly at the same time being major DoD contractors. Data on the financial amounts of contracts are available both for DoD and for NASA.

ware for the civilian economy. Similar arguments have also been voiced for space programs. The discussion about the impact of D&S expenditures on the national economy has assumed a new level of importance in recent years under the impression of shifting economic power among major countries as well as under the impression of fundamental changes occurring in the formerly socialist countries more recently.

Spin-offs of D&S technology can take place in many contexts. Inter-industry spin-offs involve transfer of technology from the defence or space to the civilian sector in unrelated industries. For example, the laser technology developed for strategic defence programs may be used for ophthalmic surgery. Intra-industry spin-offs involve transfer of military or space technology to the civilian sector within related industries. Transfer of military aircraft technology to the civilian transport aircraft industry is an example of intra-industry spin-offs. Finally, spin-offs can be supposed to exist within the firm which is involved in defence, space and civilian sectors, such as Boeing, McDonnell Douglas, General Electric, Saab, Mitsubishi, etc. The possibility of intra-firm spin-offs was a forceful reason for the federal Ministry of Economics in West Germany to approve the merger of Daimler-Benz and Messerschmitt-Bölkow-Blohm (MBB) in 1989. Despite the difficulties cited for attaining economic welfare due to the Daimler-Benz and MBB merger by the Monopoly Commission of the West German Government, the Ministry of Economics approved the merger on the following three principles: (a) the merger will create system leadership through the MBB's technological know-how, Daimler's managerial know-how, and Daimler's connection with Deutsche Bank; (b) possibilities of spin-offs from MBB technology to other business of Daimler-Benz, and (c) improved possibility to compete with the monopolistic power of the American aerospace firms in the international market [Ministry of Economics, FRG 1989]. Possibilities for such synergy and technology transfer have lured many firms in the US for mergers and acquisition, though with dubious results [Chakrabarti & Burton, 1983; Chakrabarti & Souder, 1987; Chakrabarti, 1990b].

b. The Hypothesis

Secondary effects of D&S expenditures, if any, can logically be positive or negative. The first will be labelled spin-offs, the second inefficiencies. Spin-offs may occur because a new product or a new technology is developed on account of contracts from the Department of Defence or from NASA. The new product, or technology, may - if sold to third parties - increase the production possibilities (or decrease costs of production) in other firms, too. Thus, D&S procurement can foster progress in the private sector. Inefficiencies may occur due to the constraints of competition which often go hand in hand with government procurement, especially if secrecy requirements are a major feature of the contracts; the costs of inefficiencies may again affect third parties who e. g. buy inputs more costly. It can not be excluded that both kinds of secondary effects exist, even at the same time in the same firm. This would imply that analyses at the aggregate level of a firm, or an industry, may only assess the net outcome of spin-offs and of inefficiencies.

The hypothesis to be tested is that D&S related government procurement leads to spin-offs which significantly outweigh inefficiencies. In addition, it will be asked whether NASA-financed activities are different from DoD-financed activities; since the first is mainly concerned with space programs which also aim at civilian use, spin-offs may play a more important role there.

In this paper we concentrate on the structural peculiarities of the defence firms as opposed to non-defence firms and on the aforementioned secondary effects of D&S expenditures, in particular the secondary effects on the performance of those US firms which are the main D&S contractors. The structure of the paper is as follows: The next section II gives an overview of the spin-off literature, concentrating on the respective expenditures of the United States government. Section III deals with the problems of identifying spin-offs, discusses the method applied and describes the data basis. Section IV contains the empirical results, the implications of which are discussed in the concluding chapter V.

II. SECONDARY EFFECTS FROM US DEFENCE AND SPACE EXPENDITURES: LITERATURE ANALYSIS

There appears to be a lack of systematic approach in the studies related to the secondary effects from D&S expenditures. Different authors have focused on different issues related to D&S technology. Moreover, the research methods lack empirical rigor as they tend to be anecdotal case studies. Consequently, it becomes difficult to compare these studies and seek any convergence in terms of their findings. Based on their focus, the studies have been grouped in different categories (cf. Table 1).

Focussing on the effectiveness of the institutional structure to support technology transfer from D&S contracts, five studies out of the ten came to positive conclusions. Four other studies concluded that the institutional structure in D&S sector is not conducive for effective technology transfer. The study by Hirsch and Trento [1973] was inconclusive. Excepting Mathematica [1976] and Mathtech [1977], all the other studies mentioned above are descriptive and ad hoc in nature. They lack systematic research methods to support their positive or negative conclusions. Although Mathematica [1976] provided - in the context of NASA's expenditures - empirical evidence to support a conclusion of positive secondary effects, its research method needs to be discussed before one accepts its conclusion at the face value. It studied four technologies developed by the National Aeronautics and Space Administration, (1) cryogenic multilayer insulation materials, (2) integrated circuits, (3) gas turbines in electric power generation and (4) a software for structural analysis. It estimated the benefits of these technologies by computing the acceleration of the development time attributable to NASA and the consequent benefits. Mathtech [1977] used ten different NASA technology-utilization programs, such as nickel zinc battery, human tissue stimulator, computer software management center, etc., and estimated the cost-benefit ratios using various discount rates. Esti-

Table 1 - The Literature on Spin-offs in the United States: An Overview

Sector	Problem	Answer	Author	Analysis ^a Empi- De- rical scrip- tive	Year of Pu- bli- ca- tion
A. General	Does the institu- tional setting in the US foster com- mercial use of DoD and NASA technology?	inconclusive	Hirsch/Trento		x 1973
		yes	Mathematica	x	1976
		yes	Mathtech	x	1977
		no	Reich		x 1983
		yes	Tirman(b)		x 1984
		yes	IABG		x 1985
		no	Kubbig		x 1986
		yes	Stowsky		x 1986
		no	Gansler		x 1987
		no	Nelson		x 1987
B. Electronics					
a. General	There is a declining trend of the frequen- cy of spin-offs.	yes	Utterback/Murray		x 1977
		yes	De Grasse		x 1984
		yes	Flamm	x	1988
		yes	Borrus		x 1988
b. Very high speed inte- grated cir- cuits pro- gramme (VHSIC)	Any spin-offs to be expected?	no	Brueckner/Borrus		x 1984
		no	De Grasse		x 1984
		no	Perry/Sumney		x 1984
		no	Castellano		x 1986
		no	Rosenberg		x 1986
		no	Stowsky		x 1986
		no	McLoughlin/Miller		x 1987
c. Strategic computing initiative programme (SCI)	Any spin-offs to be expected?	no	Stowsky		x 1986
		no	Miller		x 1987
d. Demand side	Did the early demand of DoD accelerate ci- vilian developments?	yes	Utterback/Murray		x 1977
		inconclusive	Levin		x 1982
		yes	De Grasse		x 1984
		yes	Rosenberg		x 1986
		yes	Stowsky		x 1986
		yes	McLoughlin/Miller		x 1987
C. Aircraft					
a. General	Did military aircrafts precede civilian air- crafts?	yes	Miller/Sawers		x 1968
		yes	US Air Force		x 1972
		yes	Mowery/Rosenberg		x 1982
		yes	Tirman(a)		x 1984
		yes	Hochmuth		x 1985
		yes	IABG		x 1985
		yes	Rosenberg		x 1986

Table 1 - continued

Sector	Problem	Answer	Author	Analysis ^a Empi- De- rical scrip- tive	Year of Pu- bli- ca- tion
b. RDT&E	Did RDT&E produce a major part of technical progress in the aircraft sector?	yes	US Air Force	x	1972
		yes	Mowery/Rosenberg	x	1982
		yes	IABG	x	1985
		yes	National Research Council	x	1985
		yes	Rosenberg	x	1986
D. Machine Tools	Have there been any spin-offs?	no	Melman	x	1974
		no	Noble	x	1982
		no	National Research Council	x	1983
		no	Shaiken	x	1984
		no	di Filippo	x	1986
		no	Stowsky	x	1986
		no	Cypher	x	1987
E. NASA	Did NASA's expenditures lead to spin-offs?	yes	Midwest Research Institute	x	1971
		yes	Mathematica	x	1976
		yes	Chase Econometric Ass. Inc.	x	1977
		no	Comptroller General	x	1977
		yes	Mathtech	x	1977
F. Process Technologies					
a. General	Is there any regular pattern of spin-offs in process technology?	no	National Research Council	x	1981
b. MANTECH-programme	Have there been any spin-offs?	inconclusive	Lehn	x	1981
		no	Hetzner	x	1983
		inconclusive	General Accounting Office	x	1984
		no	IABG	x	1985
		yes	Cypher	x	1987

^a "Empirical" refers to testing procedures which subject the hypothesis to refutability. "Descriptive" refers to non-refutability, i. e. the analysis does not include valid testing procedures.

Source: Compiled from Schrader [1989a].

mation of the benefits hinges on some critical assumptions and thus makes the results suspect. Moreover, the problem of technology transfer is a complex one. In their study of transfer of technology from the National Aeronautics and Space Administration, Chakrabarti and Rubenstein [1976] found that successful cases of transfer involved personal linkage between the NASA centers and organizations adopting the technologies. The personal contacts often worked around the bureaucratic procedures for technology transfer.

In terms of benefits to specific industries, some few studies focussed on the electronics industry in the US and concluded that the impact of the defence sector on the electronics industry had decreased in later years; importance of the defence participation in these industries decreased over time as more commercial firms were engaged in development and production with the rise of demand in the civilian sector. Current defence programs, such as the very high speed integrated circuit program (VHSIC), are reported to have not contributed to the civilian sector as "defence needs have been met with ever more esoteric weapons-specific technologies" [Borrus; 1988, p. 250]. In a similar vein, Miller [1987] and Stowsky [1986] found out that the Strategic Computing Initiative (SCI) program has contributed no spin-offs to the civilian sector.

Several authors investigated whether defence procurement had accelerated the development of the electronics industry in the US by creating and stimulating demand. Suppliers in this industry depended on government contracts as these contracts constituted a significant portion of their market share. Defence contracts also helped to develop and maintain the product standards.

The aircraft industry has ever been the prime beneficiary of military spending. Many studies point to the fact that the military was responsible for developments in the aircraft industry: Military aircraft is said to have been the precursor to civilian

aircraft. One should, however, be cautious about the qualitative historical case analyses reported in these studies. For example, contrary to the claim of the US Airforce study, turbo-jet propulsion is of neither American nor military origin [Heinkel, p. 396].

It is interesting to note that the empirical studies are concentrated in the field of analyses of NASA spin-offs, all carried out in the 1970s. Four out of five studies did actually find spin-offs whereas the Comptroller General did not.

Seven studies concluded that there was little benefit for the machine tool industry. Others did not find any benefit of the defence technology to improve the process technology in the manufacturing sector. Only Cypher [1987] saw a positive result in terms of improving process technology. The problems here seemed to be that the requirements of precision and quality in high technology represented in the defence programs were not efficient solutions for civil applications. The first generation of numerically controlled machine tools and the second generation of computerized numerically controlled machine tools were developed through the defence procurement, but did not readily find their way into the civilian sector.

All in all, the impact of D&S expenditures on the economy may be viewed as controversial. Although it is accepted that D&S activities can stimulate the early development of many technologies, the lasting economic impact of these technologies is difficult to assess. On a macro-economic level, Schrader [1989b] confirmed earlier findings that military expenditure is, in a simple correlation, negatively associated with real productivity growth; for a group of countries including Australia, Belgium, Canada, Denmark, France, Italy, Japan, the Netherlands, Sweden, Spain, the United Kingdom, the United States, and West Germany, however, military spending did not affect the growth rate of productivity in the multivariate approach when considering also other vari-

ables such as investment, per capita GDP, and government spending without military expenditure. This points to the fact that the impact of D&S expenditure may not be important for the whole economy when compared with the impact of other economic variables.

III. IDENTIFICATION AND MEASUREMENT PROBLEMS

a. Identification Problems

Basically, spin-offs can be identified at four levels: within the firm at the department level, at the firm level, at the industry level, and at the level of the overall economy. It has been argued and in fact investigated - by collecting information from firms - that new technologies are in most cases only passed on among departments within the firm.¹ This aspect of the intra-firm level would make an analysis of firm data mandatory. In the second case of spin-offs created by firms and passed on among other firms there seem to be two viable ways of analysis. The first operates under the assumption of a profit maximising firm which does not hand out technologies for free, but instead sells the new products (production techniques) itself or sells the licences; under this assumption the firm's economic performance increases with the importance of spin-offs. The second viable way assumes that if a firm passes on new technologies it does so in most cases to firms of a similar production structure, i. e. to firms of the same industry. Thus, even if a firm cannot reap in the revenues from an innovation - as may be the case when property rights are with the procuring government agency - the positive effects will be revealed at the industry level. Finally, at the macroeconomic level, identification of spin-offs has to rely on international comparisons of macro-performance and e. g. of defence shares in gross domestic products.

¹ The research dealt with aerospace firms in the Federal Republic of Germany [Scientific Consulting, 1989].

The identification problem quite obviously tends to rise with the aggregation of data: in general, the number and variance of the determinants of success increase with aggregation, so that the simple share of public-procurement induced spin-offs in the explanation of performance decreases. When moving from the firm's department level to the macroeconomic level, identification needs increasingly powerful lenses to single out spin-offs.¹

In addition, defence procurement can be considered to be important for only a few companies, such as the Grumman Corporation which produces almost exclusively D&S equipment. For the fourteen prime contractors receiving the largest amounts of contracts from DoD, the share of defence business in total sales was between 37 percent and 50 percent in the period 1971 to 1985 [Glismann, Horn 1988, p. 152]. There may also exist smaller companies with large shares of defence business which cannot be identified because they do not show up in the statistics of prime contracts, due to the (in absolute terms) small amounts of contract awards or because they are subcontractors.

All in all, there are drawbacks with respect to identifying spin-offs at all possible levels of aggregation. In this study we have put emphasis on analysing the existence of spin-offs at the firm level of the engineering sector. The reasons are mainly that

- (1) firm statistics regarding some of the most important indicators for inputs as well as for output are available. This criterion of availability makes the analysis at the firm level superior to the department level where only scattered information, if at all, exists.

¹ On the other hand, but possibly rather far-fetched, one may argue that in the case of a high mobility of researchers in this field, spin-offs ought to be analysed at higher levels. Thus, spin-offs of a researcher moving from one firm (or industry) to another, or using his spin-off potential for founding his own company, can be observed with more confidence at the aggregate level (however, a more aggregated analysis would still be unable to cope with the international mobility of a researcher).

- (2) the economic rationale of firms is relatively easy to deal with. Firms act profit maximising. If they realize spin-offs they can be expected to make them pay off - by producing new goods, applying new technologies or by selling the spin-off to other firms. Thereby the statistics of firms should reveal any exploitation of spin-offs.¹ This is not so clear at the industry level, where such a behaviour of firms may become obscure due to the multitude and varieties of other factors influencing performance.
- (3) the production functions at the firm level can be assumed to be less diversified among firms within a particular industry - such as the engineering industries - than among industries - such as engineering and chemical industries. This production-function argument is certainly of major importance in cross-section analyses where structural divergencies may distort the outcome of a comparison of firms belonging to different industries.

b. The Problem of Indicators

To analyse whether D&S expenditures lead to spin-offs produced by contracting firms one needs to develop a suitable indicator of spin-offs. Since spin-offs mean that the people employed improve their knowledge, or that machines are improved, or that a new and different basket of products is produced, spin-offs have the same properties as technical progress. In strict economic terms, such a progress occurs when under the condition of constant employment and constant input of financial capital, real output rises. Pro-

¹ In other words: we address exploitation of firms' own technologies, not other firms', which effectively means that spin-offs are neither regarded as free goods nor as being stolen. The fact that spin-offs are defined as external effects of D&S contracts does not refer to economic externalities of the firms producing spin-offs. Since we assume that firms reap in the profits from spin-offs we assume, so to speak, internalisation of D&S externalities.

ductivity increase becomes manifest in an increase in real value added, due to product differentiation or through increased efficiency in the production process [Chakrabarti, 1990a]. Measurement of real value added or cost efficiency requires detailed firm-level data using consistent definitions of costs and accounting practices. Lack of availability of data mandates us to use alternative means of measurement [Chakrabarti, 1989]: There are basically two concepts of identifying the existence of spin-offs at the firm level. The first looks at spin-offs as an economically useful by-product of D&S production. From this it follows that - as has been argued above (p. 11, para. 2) - spin-offs can be identified by an increase in the profits of firms; firms either use the by-product themselves, or they sell it.¹ According to this concept the amount of spin-offs of D&S procurement should vary among firms by the amount of contract awards. To test this we will take the rate of return on sales as a proxy. Second best to this proxy of success would be a measure of firm growth because firms' growth defined by the increase in sales would not be able to solve the problems of different rates of "inflation" among firms; definition by a "real" variable, such as the number of employees can be misleading because of factor substitution taking place in the wake of spin-off creation. Nonetheless, firm size as measured by the number of employees will be taken as an auxiliary variable of economic success, the main reason being

¹ The intrinsic question with this argument is about the rôle of subcontracts: if a prime contractor passes on, say, 90 percent of the contract award to subcontractors the spin-off potential arises at the subcontracting level; then, it would be futile to search for spin-offs at the main contracting level. Two points seem to be worth mentioning which support the analysis at the main-contracting-firm level: Firstly, statistics reveal that subcontracting does not play such an important rôle in DoD awards; a major contracting industry such as aerospace (SIC 3721) had a share of only 6 percent of total government procurement passed on to subcontracting firms between 1965 and 1982 (Source: cf. Table 2, p. 20, which also contains some information on subcontracting in general government procurement at the two-digit-industry level). Secondly, it can be supposed that subcontracting firms are obliged to deliver to or to share eventual spin-offs with the prime contractor.

that successful firms normally expand employment even if the success rests upon a reduction in labour costs (i. e. we assume that the output effect outweighs the substitution effect; [cf. Donges et al., 1988; Verdoorn, 1956]).

The second and more directly operating concept for identifying spin-offs is to try to capture the scientific or technological value added of D&S financed productions, by simply counting scientific publications of a firm's employees or, alternatively, by counting the number of patents granted to firms. The working hypothesis is that the number of scientific publications of employees (the number of patents granted) correlates positively with the existence of spin-offs, and negatively in case of inefficiencies caused by government procurement.¹ Both indicators are technical in the sense that they say nothing about the market value of spin-offs; in order to capture these, the first concept ought to be applied. As regards the number-of-patents indicator, it has been doubted whether these have lost their meaningfulness in recent years [Glismann, Horn 1988a, pp. 1169 sqq.] because the product cycles of new knowledge are said to have shortened and therefore to have lessened the incentives to incur the time and the risks of the red tape connected with patent application; the risk is doublefold, consisting of the risk of refusal to grant a patent and the risk of revealing crucial information to the public. In addition, it is argued that patent laws have become less applicable to today's fast changes in technology, especially in the sphere of software production. The limitations of the publications variable are different in that publications are, in most western countries, an important criterion for the career of

¹ A speciality of the military-industrial complex is obviously that the requirements of national security demand secrecy. This would tend to lessen the significance of both the "real" indicators of spin-offs. Even if the distribution of knowledge creation is the same per dollar of sales for DoD sales and civilian sales, the sign of the side effects of DoD contracts may become negative due to the secrecy requirements (which means that a diagnosis of inefficiencies would possibly be a consequence of the "system" rather than a real fact).

a scientist. He will therefore devote part of the funds he receives from D&S contracts not only to research work but also to writing a well-formulated essay and to forming and keeping up connections which may help to publish. These activities besides pure research absorb resources and they are, most importantly, also in the interest of DoD and NASA who are in need of public success stories as well. To put it differently: the publication productivity of D&S contracts is not only a function of spin-offs but also depends on marketing inputs.

All in all, of the indicators of spin-offs variables representing economic success seem to be the most important ones. But it may be argued from a methodological point of view that the question of economic success can only be dealt with after spin-offs have been proven in "real" terms, that is after the potential for economic success has been elaborated.

c. The Method

We shall apply a simple cross-sectional regression analysis among firms whose D&S shares vary between almost 100 percent and zero percent (i. e. civilian firms). The central methodological idea is that any firm's economic and technical efficiency depends on inputs, the most important of which are capital investment and R&D expenditures. In the case of a firm receiving R&D funds from the government (such as RDT&E funds from DoD) the proceeds from the work often go to the government - only in the case of some of the RDT&E proceeds raising a firm's economic or technical well-being we do have reason to suspect that a by-product has been produced which can be called "spin-off". The same line of reasoning applies to the other kinds of D&S contracts and to NASA contracts. In the case of RDT&E contracts lowering economic and technical performance of firms this by-product is called "inefficiency".

In addition we included the number of employees as a proxy for firm size as an exogenous variable in order to prevent a bias in

the results on account of systematically diverging firm size between defence and non-defence firms.

Since the search for spin-offs of D&S contracts as well as for possible negative side-effects of D&S activities resembles the search for a needle in a haystack we shall test several spin-off indicators for correlation with several indicators of D&S activities. The following varieties of the central hypothesis are of particular concern:

- (1) The influence of RDT&E contracts on the four performance indicators,
 - (a) patent productivity (as measured by a firm's number of patents per employee);
 - (b) publication productivity (as measured by a firm's number of scientific publications per employee);
 - (c) firm growth (as measured by the average-annual rate of change in the number of a firm's employees);
 - (d) rate of return on sales (as measured by a firm's net profits relative to sales).
- (2) The influence of defence contracts excluding RDT&E contracts on the performance indicators (a)' to (d)', analogous to the RDT&E analysis of (1).
- (3) The influence of NASA contracts on the performance indicators (a)'' to (d)'' analogous to the RDT&E analysis of (1).

At a first sight, the most important analysis seems to be the one of the effect of RDT&E expenditures which is about technical progress and the production of knowledge. Since, however, analyses on NASA activities in particular tend to stress the above mentioned aspect of accelerating technical progress [Mathtech Inc. 1977; Mathematica Inc. 1976], analyses (2) and (3) may also capture these demand effects.

Tests of the hypotheses should yield positive signs between orders and company performance in the case of spin-offs; negative signs would result if inefficiencies accrued from D&S activities. In view of the many relationships tested the problem of interpretation in the most probable case of contradictory results must be dealt with. A possible interpretation of test results (a) to (d) and (a)' to (d)' could, for example be the following one: "Because the coefficients of the hypotheses (a), (b), (c), (d), (a)', (b)', (c)' and (d)' are positive and statistically significant, there existed (per saldo) spin-offs in the form of acceleration effects and of genuinely induced technical progress during the period under consideration, leading to an increase in profitability and company size as well as an increase in patent productivity and publications per employee". There are yet two other clear-cut constellations of regression coefficients, namely in the case of all coefficients being insignificant or of all coefficients being significantly negative. For example, if all coefficients are significantly negative D&S expenditures would have had negative side-effects.

In the regressions we used five years averages for periods 1975-79 and 1979-83 and pooled them. We chose these time periods because of the availability of data on patents and publications (see below: Sample and Data Basis).¹ Multi-year averages are presumed to deal with the distortions of the values of the variables due to reasons of business cycles or other short-run extraneous factors. Also, the averaging is more likely to capture lagged relationships between incoming orders and firm performance.

¹ We thank Dr. Michael Halperin of the Lippincott Library at the University of Pennsylvania for his help in obtaining the patent and publication data.

d. Sample and Data Basis

In contrast with the analysis of macro-level data, we have resorted to firm-level analysis to compare the defence and space oriented firms with a group of firms who have little or no defence business. We have restricted our study to the large public firms for which information is available through publicly available databases. We have used PATSEARCH and SCISEARCH databases available through the Institute of Scientific Information Inc. to obtain information on patents and publications [Halperin & Chakrabarti: 1987]. The choice of the 93 companies (defence contractors, NASA contractors and comparable "civilian" companies) investigated in the end, started with all public companies in the United States (more than 1000) for which data on company performance can be obtained from generally accessible sources. The defence contractors as well as the other companies were chosen out of the investment goods sector (comprising firms which produce machinery, electronics, instruments and transport equipment), because the production of D&S goods is typically to be assigned to this sector, according to the kind of final products as well as according to the production technology applied. The number of companies was further reduced by other data requirements - such as availability of time series for patents and scientific publications - leading to 93 companies in the end.

Two kinds of statistics will be elaborated, each of them taking a different sample out of these 93 companies. The first kind will deal with the general characteristics of "defence contractors" as opposed to the same characteristics of "non-defence contractors" within the same type of industrial activity. The "defence contractors" have been defined as firms (1) receiving 10 per cent or more of their sales from DoD in the two periods 1970/75 and 1980/85 and (2) who were among the top 100 firms with respect to DoD prime contracts. It turned out that 19 firms fell under this

criterion;¹ their characteristics are shown in Table 3. Of these 19 companies, 11 were important prime contractors of NASA at the same time: the 11 firms were among the top 30 firms with respect to NASA prime contracts in all the years considered. The "non-defence contractors" consisted of 52 firms not listed among the top 100 firms with respect to DoD prime contracts or to the top 30 of NASA contracts in the years mentioned.

The second sample refers to the regression analysis. It consists of the 19 defence contractors and the 52 non-defence contractors of the first sample plus 22 firms with a positive DoD-contract share below 10 per cent in the years under consideration. Due to a bottleneck in patent statistics, the period underlying the regressions was taken to be 1975 to 1979, and 1979 to 1983.²

¹ The 19 companies are: 1. AVCO, 2. Boeing, 3. Fairchild, 4. General Electric, 5. Gould, 6. Grumman, 7. Honeywell, 8. Lockheed, 9. Martin Marietta, 10. McDonnell Douglas, 11. Northrop, 12. Raytheon, 13. Sanders Ass., 14. Teledyne, 15. Texas Instruments, 16. Textron, 17. Tracor, 18. United Technologies, 19. Westinghouse. Of these 19 firms, the main prime contractors in terms of Dollars have been McDonnell Douglas, General Electric, United Technologies, Boeing, and Lockheed; DoD contracts have been most important (as measured by the DoD share in total sales) for Grumman, McDonnell Douglas, Northrop, Sanders Ass., and Tracor. With respect to "research, development, test and evaluation" contracts, Martin Marietta and Boeing have been the outstanding companies in terms of dollars received as well as in terms of the respective sales shares.

² The divergency of the firm samples in Tables 3 and 5 is thus due to divergent designs. Since Table 3 is to demonstrate the characteristics of the "typical" US DoD contractor we arbitrarily cut off firms with a DoD share below 10 percent. Such a procedure was obviously not indicated in the regression analysis of Table 5, in fact there it would have made no sense at all.

IV. EMPIRICAL RESULTS: THE CASE OF THE UNITED STATES

Before we test the hypothesis outlined above it may be prudent to have a general idea about the structural background of the D&S industry, in particular the importance of DoD and NASA contracts at the sectoral level (a); we shall also examine the main characteristics of defence as opposed to non-defence firms (b); in addition, we shall present some information on the much discussed issue of international competitiveness which is on the sectoral level, too (c).

a. Importance of D&S in the Economy

Table 2 provides the data on the relative importance of D&S contracts for different industries. The transportation equipment industry depends heavily on DoD contracts as almost 20 per cent of the average annual shipment is made to the defence; for the electrical industry, every eighth dollar is earned by sales to defence. 5 per cent of the shipment from the instrument industry is made to the defence. Thus defence plays a big role in only a few investment goods industries in the country. Space contracts account for a much lower fraction of the total annual shipment, also from these industries.

b. Characteristics of Defence and Non-Defence Firms

Table 3 provides information about the characteristics of defence and non-defence firms during the periods 1970/75 and 1980/85. The size of the typical major prime contractor is - when compared with the 52 non-defence firms - considerably greater; the average major defence contractor increased its employment from 70 000 to 80 000 (non-defence firms: from 18 000 to 20 000) employees. Therefore, one may expect some scale effects also when contrasting performances over time. In addition, as far as the large firm

Table 2 - Average Annual Share of Shipments to Federal Government in the US, 1965-1982 (% of sales of the industry)

Industry (SIC)	Federal Government	Sub Con-tracts	DOD Con-tracts	NASA Con-tracts
Chemicals (28)	2.30	0.20	0.20	0.03
Primary metals (33)	2.48	2.22	0.69	0.01
Fabricated metals (34)	4.28	1.78	2.92	0.06
Machinery (35)	3.57	1.59	2.17	0.08
Electrical equipment (36)	15.36	5.43	12.21	0.72
Transportation equipment (37)	23.65	4.27	19.89	2.42
Instruments (38)	7.62	2.78	5.06	0.27

Source: US Department of Commerce [current issues].

Table 3 - Comparison of Defence and Non-defence Firms in the US, 1970-1985

Indicator	Defence Firms ¹ N=19		Non-defence Firms ¹ N=52	
	1970-75	1980-85	1970-75	1980-85
Sales in Bill. \$	41.57	111.31	31.25	79.56
% of manuf. ind.	5.00	5.67	3.76	3.85
Employment in 1000	1324	1524	960	1047
% of manuf. ind.	6.93	7.84	5.03	5.39
Gross Plant in Bill. \$	16.48 ²	45.19 ²	11.34 ³	32.44 ³
% of manuf. ind.	5.26	6.43	3.63	4.63
Company-funded R & D				
% of sales	3.13	4.79	2.86	3.89
% of manuf. ind.	10.23	11.39	7.03	7.36
Publications ⁴				
total	2152	2254	308	383
per 1000 employees	1.63	1.48	0.32	0.37
Patents				
total	2236	1994	1139	1092
% of manuf. ind.	7.30	7.78	2.95	3.96
Net Profits				
% of sales	4.65	5.51	3.92	5.13
% of manuf. ind.	4.58	7.10	2.91	4.48
Total DoD Contracts				
% of sales	25.04	30.15	-	-
% of all DoD contracts	31.24	30.17		
RDT&E Contracts				
% of sales	6.37	5.47	-	-
% of all RDT&E	51.37	46.44		
NASA Contracts ⁵				
% of sales	1.97	1.11	-	-
% of all NASA contracts	33.09	20.18		
¹ For choice of these 19 companies see text.				
² 17 companies, not including AVCO and Sanders Corp.				
³ Based on data for 44 firms.				
⁴ 1975-1979 instead of 1970-1975, and 1979-1983 instead of 1980-1985.				
⁵ 11 companies; see text.				

Source: US Department of Defense [a and b, current issues]. - Aerospace Industries Association [current issues]. - PAT-SEARCH data bank and SCI-SEARCH data bank, cf. Michael R. Helperin and Alok K. Chakrabarti, [1987]. - Own data bank compiled from COMPUSTAT data bank, "Fortune", and "Business Week". - Own calculations.

represents a higher degree of vertical integration of production processes the sales should be relatively low (and the profit sales ratio relatively high) when compared with the average of non-defence firms. The 71 firms considered have had a share of almost 10 per cent of total sales in the manufacturing sector during the time period 1980/85. This share substantially increases when all the 93 companies, which are included in the subsequent regression analysis, are taken into consideration: The middle group, with defence shares of less than 10 per cent, comprises some very large corporations such as IBM or General Motors. It should be noted here that General Dynamics and Rockwell International were not included because of a lack of data on patents and publications.¹ The corresponding employment shares were even significantly higher as were, in particular for the defence contractors, the shares of gross fixed capital stock. 30 per cent of the total defence contracts are registered for both

¹ These were the only important defence-contracting firms in the engineering industries not included in Table 2 or in the regressions. As a matter of fact, there were performed some time-series analyses elsewhere which included both these firms but did not include as exogenous variables patents and publications [Glismann, Horn 1988b, p. 152, 157 and 158]. This analysis showed that

- in cross-section analysis as well as in a combined cross-section and time-series analysis (i. e. pool analysis) for the years 1969, 1977 and 1985 the share of DoD contracts in total sales had a significant negative impact on the profits/sales ratios and a significant positive impact on capital productivity (of the two other exogenous variables only the investment shares were significant - positive with respect to the profit/sales ratios and negative with respect to capital productivity; R&D intensity did not show up to be significant);
- in a firm-specific time-series analysis covering the years 1969 to 1985 the DoD intensity exhibited a negative sign with respect to the profit/sales ratios in the case of General Dynamics and no impact on capital productivity; investment activity turned out to improve the profit/sales ratios significantly. As opposed to the cross-section and pool analyses, the R&D intensity had a significant positive impact on the profit ratios and on productivity in the case of General Dynamics (this also held to be true for other companies, such as Grumman).

these subperiods. The share of NASA contracts decreased the second subperiod. This may be because the industrial structure of NASA orders has more strongly changed than that of defence orders, presumably with a rising importance of service companies and commercial or public research institutions.

It is important to note that from 1970-75 to 1980-85 the weight within the manufacturing sector of both defence contractors and the civilian companies increased. Defence firms gained considerably in terms of sales, employment, gross plant and company funded R&D in the latter period under the Reagan Administration. Whereas this may be considered a "Reagan effect" in defence procurement, other indicators point in the opposite direction:

- (a) decrease in the share of defence R&D contracts (while the share of company-funded R&D rose relatively quickly);
- (b) relatively low growth of patent output as percent of total manufacturing from the defence firms;
- (c) decrease in scientific publications from defence firms per 1000 employees.

All in all, there seem to exist considerable structural divergencies between the defence and the non-defence firms. As has been said above, structural divergencies may lead to performance divergencies among firms, such as that companies which are on average larger than their non-defence counterparts benefit from scale effects and may, therefore, be more competitive internationally or may be more productive with respect to the creation of knowledge.

c. Competitiveness and the Creation of Knowledge

In order to analyse the international competitiveness of industries a common approach is to rely on the working hypothesis that

trade flows are perfect mirrors of international differences in the costs of production; a country is said to have a revealed comparative advantage (RCA) when it exports (x) more of a certain product (i) than it imports (m), id est when $x_i/m_i > 1$, and vice versa with respect to a revealed comparative disadvantage ($x_i/m_i < 1$). Since misvaluations of currencies are almost a common pattern in international trade the level effects of the exchange rate are corrected for by comparison with an economy's average trade performance (id est: $(x_i/m_i)/((\sum x_i)/(\sum m_i))$). Taking the logarithm of this ratio ($RCA = \ln[(x_i/m_i)/((\sum x_i)/(\sum m_i))]$) provides for a dividing line of zero, with positive RCAs indicating comparative advantages, and negative RCAs indicating comparative disadvantages. This procedure obviously cannot be executed on the firm level because firms do not import substitutes to their own production.

Creativity in the production of knowledge is measured here on the industrial level, too, for the sake of comparison. It is taken to be approximated by the patent output (Pat) per employee (Empl) in industry (i) relative to the average patent productivity of the manufacturing industry, id est $\ln[(Pati/Empli)/((\sum Pati)/(\sum Empli))]$. Again, zero is the dividing line between above and below average performance in the production of new knowledge.

Table 4 allows a comparison of these "performance indicators" with the "structural indicators" of the D&S-contract shares for the relevant defence industries (cf. also Table 2). Since an analysis at the four digit level did not provide additionally meaningful results, we report the data at the two digit level of the Standard Industrial Classification. The table shows that D&S contracts did not systematically involve industries characterized by either a high inventive or high competitive position: The sector receiving the highest shares of D&S contracts - transportation equipment - had a patent productivity well below the manufacturing average and was not far away from average regarding international competitiveness. On the other hand, the sector with the

Table 4 - D&S Intensity, Patent Productivity, and International Competitiveness^a

Industry	Relative patent productivity			Revealed comparative advantage			Defense and space dependence		
	1963- 1970	1975- 1977	1982- 1984	1964- 1970	1975 1976 1978	1982- 1984	1965	1982	1965- 1982
Chemicals	1.21	1.37	1.33	0.97	0.82	0.94	0.30	0.20	0.20
Primary metals	-1.00	-1.74	-1.55	-	-1.02	-1.03	0.50	0.80	0.70
Fabricated metals	0.19	-0.12	0.10	-	0.60	0.36	0.50	3.50	2.90
Machinery	0.90	0.65	0.57	1.05	1.11	0.76	1.90	2.20	2.20
Electrical equipment	0.73	0.71	0.59	0.02	-0.29	0.10	13.10	12.00	12.20
Transportation equipment	0.79	-0.74	-0.90	0.03	0.18	-0.02	16.90	20.90	19.90
Instruments	1.84	1.35	1.28	0.46	0.48	0.48	6.00	4.90	5.10
^a See text for operational definitions and explanations.									

Source: US Patent & Trademark Office [1985]. - Trade Relations Council of the US [1985]. - US Department of Commerce [current issues]. - Own calculations.

lowest share of D&S contracts - chemicals - showed a remarkably good performance regarding knowledge production as well as international competitiveness. Taken together, rank correlations between D&S intensity and the two performance indicators did not come up with significant results; the same insignificance was obtained when ranking the changes over time of both variables with D&S intensity.

This leaves two interpretations open: firstly, D&S contracts did not go to industries which were characterized by a particularly high patent output or by a high degree of international competitiveness. Secondly, it may as well be possible that D&S contracts did not induce such higher levels of performance (or lower levels, as a matter of fact). This may mean that D&S contracts are not related with inventive activities or competitive factors in any special way. Since the firms are widely diversified in many industry categories, analysis at the firm level is necessary to discern these issues.

d. Firm-Level Analysis

In the following, we concentrate on the search for indicators for spin-offs at the firm-level, as discussed in section III. As has been outlined there, we define two endogenous variables as being indicators of the "economic efficiency", and two further endogenous variables as being indicators of the "technical efficiency". In the case of D&S spending raising either "technical efficiency" or "economic efficiency" we would have first evidence of systematic spin-offs across firms which, of course, does not say anything about the kind of spin-offs realized (i. e. whether it is a new kind of sun-glasses or a new coating for frying pans).

Table 5 shows the results of the regression analysis performed:

Table 5 - Firm-Level Analysis of Technical and Financial Performance of D&S Business^a

Regression	Criterion of Performance (endogenous variable)			
	Firm growth (% change in the number of employees)	Profits as % of sales	Patent pro- tivity (per 1000 employees)	Publication productivity (per 1000 employees)
Constant	-15.1 (-1.50)	3.00*** (5.89)	93.5*** (4.28)	29.9* (1.92)
Capital investment (% of sales)	6.61*** (3.62)	0.31*** (3.36)	-4.25 (-1.07)	-2.68 (-0.95)
Company-funded R&D (% of sales)	0.12 (0.06)	0.22** (2.03)	17.79*** (3.81)	10.89*** (3.27)
Defense RDT&E (% of sales)	1.41 (0.73)	-0.03 (-0.36)	1.91 (0.45)	0.85 (0.28)
Defense contracts (as % of sales excluding RDT&E)	0.07 (0.20)	-0.02 (-0.94)	-0.99 (-1.32)	0.96* (1.79)
NASA contracts (as % of sales)	-2.92 (-0.56)	0.18 (0.69)	-5.49 (-0.49)	34.11*** (4.23)
No. of employees	0.10** (2.23)	-0.01 (-0.28)	-0.06 (-0.61)	0.05 (0.78)
R^2	0.08	0.11	0.06	0.21
F	3.64***	4.81***	2.97***	9.22***
*** significant at 1 % level; ** significant at 5 % level; * significant at 10 % level.				
^a Pool analysis for 93 firms with average values for the 1975-1979 and 1979-1983 periods, 179 degrees of freedom.				

Source: Own calculations.

- (a) The standard variables of industrial organisation economics, capital formation and own R&D activities, proved mostly relevant without striking contradictions. Investment in fixed assets showed a close relation with both company growth and profitability. Own R&D activity correlated strongly with technical efficiency and with economic efficiency as measured by profitability.
- (b) Military R&D contracts did not contribute positively or negatively to economic or technical efficiency in the periods under consideration.
- (c) Space expenditures did not contribute to an improvement of economic performance as measured by company growth and profitability. NASA contracts were also not associated with patent productivity; but they helped to raise the number of scientific publications per employee.
- (d) Defense expenditures, excluding RDT&E, were also not of importance for the overall economic efficiency but they contributed to an increase of success with scientific publications.

In reviewing these results we note that we find no indication of spin-offs. Size differences across firms do play a role only in explaining the rate of growth of the firms, implying that economies of scale matter. Also, it is interesting that military R&D, in contrast to own R&D activity, contributed to an increase of neither "technical efficiency" nor "economic efficiency". It is worthwhile mentioning that the real output of technical novelties as measured by patent productivity is exclusively determined by own R&D activity while scientific publications also depend on government funding. This may reflect the "publish or perish" syndrome of the American scientific community reinforced by the desire for publicity of the public funding agency. It has to be taken into consideration, however, that, until recently, it has

been difficult for private organizations to patent the results of the work funded by the government. As has been argued above (III, c) patents and publications may be substitutes for each other [see also Halperin and Chakrabarti, 1987]. Publications may document the scientific progress without intellectual property rights which may not be obtained readily on government funded activities.¹

V. CONCLUSIONS

The importance of the defence and space contracts differs for different industries in the USA. Electrical and transportation equipment industries depend on the Department of Defense as their major customer. We also observed that in recent years the large defence firms increased their importance in the economy as they account for a large proportion of employment. The technical performance of the defence industry in terms of patents and publications did not improve during the Reagan Administration. On the contrary, publication efficiency of the large defence firms decreased during the 1980s as compared to the 1970s.

On a macro level we observed that industries relatively dependent on defence and space contracts did not perform any better than other industries in terms of their patent productivity or international competitiveness. If anything, industries highly dependent on defence contracts performed poorly in terms of their technical productivity and competitiveness.

On account of the uncertainties regarding the quality of data or the adequate definition of spin-offs we used two indicators of technical success in the inter-firm analysis, patents, and scien-

¹ A test for substitution between patents and publications, obvious as it may seem to be, cannot be performed: DoD contracting firms do not publish their patent and publication statistics separately for the civil goods producing units and for the military goods producing units.

tific publications, and two indicators of economic success, profitability and firm-growth rate. We tested their relationship with three indicators of D&S activities, military R&D (RDT&E), other defence contracts, and NASA contracts. The results indicate that D&S expenditures are hardly conducive to promote technical and economic efficiency.

It thus appears that D&S expenditures are not an appropriate instrument of a policy aiming at fastening technical progress. There may be, of course, other important aims which do not have spin-offs as a strategic variable - aims such as the international prestige or the simple protection against domestic or foreign competitors. D&S expenditures are therefore not the effective means to achieve a superior international competitive position for the US. Contrary to the frequently supported hypothesis it seems that the technological leadership which the United States unquestionably possessed in many areas may not be based on its intensive D&S activities. This conclusion is supported by the above analysis of international competitiveness as revealed in trade flows at a high level of aggregation. We note here that our firm level analysis does not lead us to conclude that D&S expenditures cause a loss for the overall economy. Although it may be argued that demand for qualified technical personnel from the defence sector creates additional scarcity for the civilian sector in industry and academe, one has to take into account national security is a fundamental precondition for the development of the civilian economy.

The study was restricted to an efficiency analysis in a cross section comparison. The questions regarding effects of D&S activities on market structures and competition were not dealt with. These issues are, however, also highly relevant in discussions about the military industrial complex.

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