CUMULATIVE MILITARY RESEARCH AND DEVELOPMENT EFFORTS AND ITS SPILLOVERS IN NATO COUNTRIES

Professor Hüseyin Mahir FİSUNOĞLU

Çukurova University
Department of Economics

Adana, Turkey; July 1998

I. INTRODUCTION

Economic development has closely related with the utilization of resources, the rate of population growth, the saving rate, the structure of organization of economic activity, technological know-how, and more. The neoclassical theory assumes technological progress as an exogenous process and focuses on capital accumulation as the main endogenous source of output expansion. More recent studies have revealed that commercially oriented innovation efforts are the main engine of technological progress (e.g., Romer, 1990; Grossman and Helpman, 1991). According to this view, innovation feeds on knowledge that results from cumulative research and development experience that contributes to stock of knowledge.

In a world characterized by international trade, international exchange of information, and foreign direct investment,

The dynamic efficiency and competitiveness of an economy are significantly supported by research and development (R&D).. It should be emphasized that R&D investment that firms undertaking are unable to exclude others from obtaining the benefits of their R&D efforts. Therefore, the benefits from R&D spillovers. Military research and development efforts are a good example for the above statement. As a general rule, technological change has a positive effect on productivity growth, in turn, productivity growth stimulates to economic activity. Significant amounts of technological change obtained from the R&D capital accumulated by firms. Therefore, R&D capital accumulation accounts a major source of endegenous technological change which contribures to economic growth.

R&D investment is assumed to be a public good. Once R&D investment occurs, not only the R&D performer, but also many firms can make use it. Therefore, while a few firms perform R&D investment, many firms become "free-rider". R&D capital is nonrival,i.e., its use does not limit the use by other firms in the economy. In addition, other firms cannot be completely prevented from benefiting from the R&D capital stock of one firm. Therefore, the returns to R&D capital can only be measured incompletely. This would be called as "imperfect appropriation". Imperfect appropriation implicitly implies that some form of externality or spillovers are inevitable in R&D capital accumulation. While an inventor keeps his/her invention secret in order to have reaped all the returns, the costs incurred may be so high that the costs may be substantially higher than the benefits.

Military technology can give a significant momentum to economic growth. Innovations feed on knowledge that results from cumulative research and development on the one hand, and it contributes to stock of knowledge on the other. Consequently, an economy's productivity level depends on its R&D effort and on its effective stock of knowledge, with the two beng inter-related. A country's stock of knowledge depends on its own R&D investment, and since R&D spillovers extend beyond national boundries, on the R&D efforts of other cxountries as well. A country's productivity does not depends only on its own R&D, but also the R&D efforts on its partners, e.g., joint R&D projects, international exchange of information and dissemination of

knowledge. Emprical evidences state that military R&D is a significant determinant of productivity.(Coe and Helpman, 1993,i).

This project has two objectives. Its primary purpose is to investigate the importance of spillovers effect of NATO countries' military R&D expenditure in their economies. Cumulative military R&D expenditure may be taken as a proxy for a stock of
knowledge. The second objective is to measure productivity growth rates for some industries which are closely related with military industries and to determine the productivity gains associated with international spillovers. For each country, I construct a domestic and foreign stock of knowledge . Domestic stock of knowledge is based on domestic military R&D expenditure, and, foreign stock of knowledge is based on military R&D spendings of its partners. In addition, I calculate a measure of total military factor productivity for every country. This is a necessary step in order to understand the effects of domestic and foreign military R&D capital stocks on total military factor productivity. Indeed, this is a fairly well-known method to emphasize the importance of the interaction between international trade and foreign R&D (see, for example, Coe and Helpman, 1993).

The time-series data for this study are collected from different sources. It should be cautioned that the military expenditure data are of uneven accuracy and completeness.in the world It is possible that some countries only report operating expenditures. The better estimate of total military

expenditures would be obtain by adding to nominal military expenditures the value of arms import. This brings the problem of exchange rate. Local currency by exchange rate transformation may cause over- or underestimate. The military R&D data for every NATO-member country. are even more difficult to obtain.As expected, some countries do not have military R&D, and some countries with negligible level. Some countries do not report the data regularly. Canada, France, Germany, Italy, the Netherlands, Norway, Spain, U.K. and U.S.A have a regular reporting system. Belgium, Denmark, Greece, Iceland, Portugal, Turkey, and Luxembourg either do not have military R&D or do not reporting system. On the other hand, significant military R&D expenditure would be observed in France, Germany, U.K. and U.S.A. These four countries are analyzed seperately, and, Canada, Italy, Netherlands,
Norway, and Spain are pooled together under “CINNS”.

The classification is a reasonable one. France, Germany, U.K. and U.S.A. have a significant share in arms-trade and military expenditures. One would expect that these four countries do have a well-developed military R&D. CINNS follows them.

II.MILITARY EXPENDITURE AND MILITARY TECHNOLOGY: AN OVERVIEW

II.1. Military Expenditures

Military spending is conventially treated as government consumption rather than investment. This is a quite controversial area, but if such spending generates some form of “output” over a long period, then it should count as investment. The U.S.A. spent 1.3 percent of GDP on military, compared with an average of 0.5 percent of GDP in other rich countries in 1990-1994. As far as military spendings are concerned, there was a downward trend which continued in 1994 with a 5 percent decline to US$840 billion and US$ 811 billion in 1996.

These were the lowest level since 1966 and 35 percent below the all-time peak of US$1.3 trillion in 1987. (U.S. Arms Control and Disarmament Agency, Internet). Therefore, the cumulative world reduction between 1987 and 1994 reached to US$1.5 trillion dollars. Immediate effect is a dramatic decline in employment in defence-related industries from 17.5 million in 1987 to 11.1 million in 1996. Nevertheless, US$ 1.25 trillion reduction in military spending occured mainly in Eastern Europe. On the other hand, most of the cumulative reduction in military spending occured in the developed countries. This is due primarily to the dramatic decline in Soviet/Russia and less rapid but still large US decline.

As far as developing countries concerned, military sepending has began to decline in 1983,

excluding the Persian Gulf War in1990-1992 . Since 1983, developing countries have spent

cumulative US$ 300 billion less. This corresponds 2.7 percent annual decline from 1983 to 1994.

The shares of world spending by region between 1984-1994 reveal an increase from 27 percent to 36 percent in North America, from 16 percent to 22 percent in Western Europe, and from 10 percent to 17 percent in East Asia. The reduction has occured from 35 percent to 14 percent in Eastern Europe and from 8 percent to 5 percent in the Middle East (ibid).

Table 1 reveals military spendings as shares and growth. The figures for NATO countries are taken from NATO publications and are based on NATO definition. It means defence and other ministries' military-type expenditures are included, defence ministry's civilian-type expenditures are excluded. Should have a military grant, it is included in the donor country.

There is a growing evidence that a significat part of defence spending are not included in the national budgets of many developing countries. There are a number of budgetary techniques, such as aggregated budget categories, double-bookkeping, which hidden the spending. Therefore, all available statistics are employed in the estimation. These statistics are collected by the IMF, The World Bank, the United Nations, a numerous governmental statistics, the Central Intelligence Agency, the US Arms Control and Disarmament Agency (ACDA), the International Institute of Strategic Studies, (London), the Stockholm International Peace Research Institute SIPRI). The SIPRI estimates are useful because they are in local currency. Furthermore, they are more reliable than other sources because their coverage is clearly defined. However, SIPRI data do not cover estimates of military expenditures of Soviet Union and China. The ACDA estimates were used for used for these two countries. SIPRI does not provide foreign-financed expenditure in the military expenditures of the recipient country. as mentioned above, it is

likely that most foreign purchases are off- budget in developing countries. Foreign purchases were taken from the ACDA data.

Indeed, reliable and detailed data on foreign military aid are not widely available. The U.S. is one of the few countries that provides such data.

Research and development (R&D) generates future output. Government R&D spending is assumed as government consumption in the national accounts, private sector R&D is counted as a cost of production and therefore excluded from both investment and GDP. The U.S.A. has spent 2.7 percent of her GDP in R&D in 1990-1994, against an average of 2.0 percent for other rich countries.

R&D capital stock series is constructed by the following way: Military R&D expenditures are deflated by their price indexes.. the benchmark stok is calculated as R&D investment in an initial period deflated by the depreciation rate for R&D capital. And added the average growth rate. The depreciation rate is assumed asa 10 percent. One the initial military R&D capital stock is obtained, it is easy to calculate a time series data. Labour, intermediate inputs and their costs are taken fgrom statistics.

Table 1: Military Spending: Shares and Growth (in percent)

		World Shares		Real Growth Rate*
		1984	1994	1984-1994
World		100.0	100.0	-4.2
	Developed	81.4	80.5	-4.5
	Developing	18.6	19.5	-2.7
Region				
	North America	27.1	35.7	-1.7
	Western Europe	16.0	22.2	-0.6
	East Asia	9.7	17.2	1.7

Eastern Europe	34.9	13.6	-13.2
Middle East	8.0	5.4	-4.9
South America	1.6	1.9	2.3
North Africa	0.8	0.5	-7.3
Subsaharan Africa	0.3	0.4	0.8
Others	0.9	1.5	-9.7
Europe, all	50.1	35.7	-7.8
Africa, all	1.5	1.3	-3.8
Organization/Reference Group			
OECD	46.2	64.4	-0.9
OPEC	6.3	4.1	-4.9
NATO, all	41.7	55.9	-1.3
NATO, Europe	14.8	20.4	-0.6
Former Warsaw Pact	34.4	13.3	-13.2
Latin America	2.0	2.3	-2.8
CIS	---	11.8	---

(Average annual rate)

(U.S. Arms Control and Disarmament Agency, Internet)

As mentioned above, Eastern Europe's decline was mainly in the Soviet Union and its successor states. All together declined 70 percent in the 1990-1994 period. Although the U.S.

declined its spending by 3.2 percent annualy since 1990, it still covered almost one-third of the world total in 1994. Western Europe reduced 2.5 percent annualy in the same period. All NATO is providing for 56 percent of world military spending.

The effect of military spending in the developing countries are widely discussed. İn the literature. Military expenditures in these countries consist of 4-5 percent of their GNP. This figure is slightly less than total expenditures for health and education. The rate of increase between 1960 and 1990 was a rate twice that of income per capita. (World Bank, various statistics). Since these countries are in need of capital in order to increse

their growth rates and development efforts, should they reduce military spending? The common answer is that they should reduce. Unfortunatelly, the reduction of military spending is sometimes out of control of developing countries. Political situation generates a need for military spending. United Nations Security Council is working toward a peaceful world, and, one of the first condition is territorial integrity. On the other hand, big countries, too, should reduce the spending. Arm-exporting countries should reduce the export, and, finally, foreign financial aid should be diverted from military spending. A dramatic cuts in military spending may generate resources diverted to other areas of economic and social development. The international organizations and regional organizations are working for a better world. This can stimulates economic and social development, without reducing national security.

II.2. Military Technology

As opposed to many other industries which are becoming global, defence - related industries in the world are determinedly national. Moreover, their shareholders and top managers are national. Governments would like to keep them national for national security reasons. They protect their national market from import as much as possible and that ban takeovers and mergers of military industry. Some of these reasons are understandable as far as national security is concerned. However, this makes military R&D efforts also national and low level co-operation with the other countries.

Nevertheless, there are a number of developments in the recent years that force defence firms co-operate. i) Technological innovations are moving very fast. Commercial technologies such as digital communication and microelectronics are leading industries. The concept of economies scale makes that no single country-perhaps except the U.S.A.- can afford to develop all its weapons and related components by it is own. This is particularly true for aerospace industry. There are cost advantages in the other countries, if joint production is under consideration. The same is true for R&D efforts. ii) Most countries are reducing their defence budgets. (The figures were given in Section II.1). As defence budgets are declining, competition in export markets are increasing. iii) NATO countries are involved to be a part of a coalition and peacekeeping efforts. Joint forces are more likely to be successful if they use similar or compatible equipment.

These three reasons are forced to a restructuring to world defence industries. Particularly, technological innovations are creating more spin-on from the civilian economy to defence than spin- off from it. Defence industry, including research laboratories, less cut off from the rest of the economy than they used to be. Moreover, some countries are choosing weapons which are cheap and not specifically designed. This means defence firms have more foreign subcontractors.

Indeed, the part of American defence industry has gone a restructuring in the 1990s. However, until the Gulf War many managers in the American defensce industry failed tu understand what was coming. It was clear, however, that the military-aircraft programmes initiated during the Reagen

Administration had reached a peak in 1986. American defence indutry should have started to renew and rationalise production lines, diversify into adjacent commercial fields and sell marginal business. Only a few company attempted. However, this switch was not from military aircraft production to civilian aerospace industry Because there exists a overcapacity in civil aerospace industry. This situation has also effected the performance, importance and priority of military R&D.

Since aircraft industry (military or civilian) uses thousands of part in the production of aircraft or missile, either a firm produces all the parts necessary by itself, or operates with a sizeable numbers of subcontractors. Both of them have problems: The first approach increases the cost, the second makes difficult to control subcontractors. Aircraft R&D efforts have concentrated on this problem. The solution formulated in the way that subcontracting with a new approach. This is simply a joint work between prime contractor and a group of subcontractors. The question was that which parts of the manufacturing process the prime contractor will do itself, and which parts left to subcontractors. This was a management question that could be answered in different ways.

It seems that the importance of aeroplanes and ships likely to diminish in the future for a number of reasons: They are vulnerable to attacks; and, the missiles are increasingly becoming accurate. Therefore, the missiles would be substitute these weapons in the future; i.e., the demand would shift toward the missiles. Defence electronics, therefore, is becoming increasingly

attractive. (The Pentagon spends 45 percent of its procurement budget on defence electronics (The Economist,14-20 June 1997) This is one form of restructuring in American defence industry. This restructuring efforts have deeply effected the military R&D programmes in the recent years.

The other form of restructuring is mergers and acquisitions that has caused a small group of powerful concentration in the defence industry. As a result, some firms left the industry, while some have become more heavily involved in. The size of firms in defence industry is important. Large firms can spend more for R&D, can take the risks of untried technologies, and can compete for new contracts.

The same restructuring has not happened in NATO's European members. Despite to other sectors of economy, Article 223 of the Treaty of Rome provides an exemption to defence firms from European Union rules on mergers, monopolies, and procurements for national security purposes. Moreover, the European defence market is more fragmented than that of the U.S.A., The European governments give priority on military procurement to their own defence industries or to another European country. However, NATO's European members spend on military procurement and military R&D 60 percent of the U.S.A in 1996: The trend in NATO's European members is establishing joint ventures rather than mergers. Although this generates some advantage of economies of scale and technological synergy, each part is produced by a separate operating company which causes an

increase in the cost. Moreover, they have not concentrated production on their most efficient places.

III. THE THEORY

The theoretical model has introduced in two parts. This section is for general modeling. Theoretical modeling for particular industries will be given in Appendix.

The general theoretical model is simple and its basic model has widely discussed in the literature (Helpman, 1992; Grossman and Helpman, 1991). I introduce here only the basic equations and focus the results that are necessary for my purpose.

A simple production function for military output (MY) is:

$$MY = f(.) \qquad (1)$$

where f(.) is a linear homogeneous function of inputs in military production. Inputs reflect x(j), jE(0,n) where n is a measure of intermediate inputs.

There are two cases for f(.):

i) The inputs are horizontally differentiated. Then f(.) can be taken as a symmetric constant elasticity of substitution function. The elasticity of substitution may be greater than one, and each input is produced with a unit of labour per unit military output. All inputs are equally priced and equally employed in production.

$$f = n^{1/a-1}x \quad (2)$$

where a is the elasticity of substitution and X=n.x represents aggregate employment of military intermediates.

Aggregate use of military intermediates X is proportional to the labour force employed in military manufacturing. The measure of available inputs expands as a result of military R&D investment. The measure of available inputs n in military manufacturing is a function of the country's military R&D efforts. The logarithm of TMFP is measured by logMY-logML (ML stands for labour force in military production). TMFP depends on a measure of cumulative military R&D and the share of labour (X/ML) employed in production. Labour may be employed either in military manufacturing or in military R&D. As long as R&D is a small fraction of total military output that does not differ greatly across countries and time periods, X/ML remains approximately constant, implying , differences in cumulative military R&D explains most of the variation in TMFP.

ii) Alternatively, intermediate inputs could be treated as vertically differentiated, i.e., they are in different qualities. The effectiveness of input j in manufacturing depends on the number of times it has been improved. Inputs that have been improved more times are more productive, e.g. input j that has been improved k times is b times more productive than the same input that has been improved k-1 times. Let f(.) a Cobb-Douglas function with equal coefficients on all inputs. The measure of inputs is taken to be constant. Let, n=1 for simplicity. Assume a unit of labour produces a unit of x(j). This production technology would be applied to all inputs and all quality levels. Therefore, only highest quality of inputs will be utilized.

$$f = b^c.x \qquad (3)$$

Here, c depends on cumulative military R&D. Suppose that at time t=0 the quality of all inputs equals one. Therefore, proportional to the military R&D

effort that is put into effect in order to improve input j generates a probability of success. The target is the highest quality of j. Suppose all inputs are targeted with equal intensity at the same time t and I denote with g(t) the instantaneous fraction of inputs that are improved per unit of time, then g(t) is proportional to the instantaneous military R&D effort per product. This means that in a time interval of length dt innovators improve a fraction g(t)dt of inputs. Given the Cobb-Douglas production function, this specification implies that at time T the average quality of

input equals $b^{c(T)}$ Here $^{c(T)}$ is $\int_0^T g(t)dt$. Since g(t)

is proportional to the military R&D effort at time t, c(T) depends on the cumulative military R&D effort, i.e. TMFP depends on cumulative military R&D and the share of labour in military manufacturing. As I assumed in the case of (i) above, as long as military R&D is a small fraction of total military output that does not differ greatly across countries and time periods, I expect differences in cumulative military R&D to explain most of the variation in TMFP.

Now, I add military capital accumulation and international trade into the model. First, I introduce military capital accumulation. How does military capital accumulation change the basic relationship between TMFP and cumulative military R&D? I modify the model proposed by Grosman and Helpman (1991). Let the production function of final output MY be of the form

$$MY = MK^{d} f^{1-d} \qquad (4)$$

where MK is the stock of military capital and f is defined earlier. f could take one of the two forms that I discussed above. d is a parameter between zero and one. As before, military intermediates are manufactured from labour with one unit of military input per unit of military output. In this case, I measure log TMFP by logMY- dlogMK- (1-d)logML. As before, f is given by (2) in the case of horizontally differentiated intermediate inputs and by (3) in the case of vertically differentiated intermediate inputs. Therefore, variation in TMFP should be explained by variations in cumulative military R&D in either case. It is easy to see that the previous models are a special case with d=0. Therefore, the similar argument with production without capital applies here. As a conclusion, the possibility of military capital accumulation does not effect the results that differences in cumulative military R&D should explain differences in TMFP..

Secondly, I consider international military trade. Suppose, as an extreme case, that all intermediate inputs in military production j E(0,n) are traded internationally. All of them are equally priced, and final output is not traded. Then, equations derived above are valid, except that I need to interpret b^c as the measure of inputs in military production that are manufactured in the world economy rather than in any particular country. I need to interpret b as the average quality of inputs in military production in the world economy rather than in any particular country. It then follows that with internationally traded intermediate inputs in military production, n depends on cumulative military R&D in the world economy and so does c. It implies that variations in a country TMFP are mostly attributable to variations in the

world's military R&D capital stock in military production, i.e., domestic military R&D has the same productivity effects as foreign military R&D.

For empirical estimation of these models neither one of the extreme specification of tradebility of intermediate inputs seems appropriate. Therefore, it is practical to formulate an empirical equation. I estimate equations in which variations in TMFP are explained by variations in both the domestic and foreign R&D capital stocks. The equation has the following specification:

$$\log MF_i = h_i^o + h_i^e \log S^e_i + h_i^k \log S^k \qquad (5)$$

where i is a country index, logMF is the logarithm of total military factor productivity, S^e is the

domestic military R&D capital stock and S^k the foreign military R&D capital stock.

Constant h^0 differ across countries. There may be country specific effects on productivity that are not captured by the variables in equations. h^e and h^k are the elasticities.

The role of international trade is not apparent in equation (5). Only the foreign stock of knowledge of military import weighted foreign R&D capital stocks takes place. For this reason a modified specification of (5) that accounts for the interaction between foreign direct military R&D capital stocks and the level of international trade seems preferable. After this modification

$$\log MF_i = h_i^o + h_i^e \log S^e_i + h_i^k m_i^k \log S^k \qquad (6)$$

where m stands for the fraction of military imports in GDP. In this equation the elasticity of TMFP with respect to the domestic military R&D capital stock is equal to h^e while the elasticity of $TMFP_k$ with respect to the foreign military R&D capital stock is equal to h m. This implies that whenever h^k is the same for countries the latter elasticity varies across countries in proportion to their import shares.

IV. FINDINGS RELATED WITH THE GENERAL MODEL

First, I estimate the long-run relations between military factor productivity and foreign and domestic military R&D stock. Almost all of my data reveal a clear trend, i.e. I face with cointegration problem. This is a fairly common problem in econometrics when one utilizes time-series data: if two (or more) variables move closely together in the long run, (they can be apart in the short-run), they may be show a long-run equilibrium relationship Should this is the situation, a regression containing these variables will have a stationary error term. This is possible even if none of the variables alone is stationary. If the error term is not stationary, the estimated relationship may be spurious (Granger and Newbold, 1974).

Econometricans have found very interesting properties as they deal with cointegrated equations. According to “super consistency” property, as the number of observations increases, OLS estimates of the cointegrating eqaution converge on the true parameter value much faster than when variables are stationary. Super consistency does not require the assumptions of the classical regression model. Since military R&D capital stocks and human capital are likely to be estimated with some degree of

error, and because one can not exclude that there are omitted relevant variables, super consistency gives a freedom to researcher.

My model of international military R&D spillovers employs time- series panel data (the pooled data). There are a very few techniques available for the panel data. There are only a few application exists, e.g. Khan and Reinhart, 1993. Therefore, one can cautiously confine himself about the results, .i.e., the super consistency result will hold or be strengthened with pooled data. If the number of countries were increased, the efficiency of the OLS estimates would have substantially increased. I have all together five countries (one pooled) and 20 years time-series data. This is going to create some ambiguity in the interpretation of some econometric conclusions.

There are two issues to be explained before turning to findings. The first one is the nonstationarity of the variables in the cointegrating equation. The two well-known tests, the Dickey Fuller and the augmented Dickey Fuller tests on the time series for each country generally do not reject the presence of a unit root. Since my observations are low in amount, the power of these tests is low. The more recent test is developed by Levin and Lin that show the limiting distributions for unit root tests on panel data. Unit root tests on the pooled data confirmed that the variables are nonstationary.

The results are presented in Table 2.

Table 2: Pooled Unit-Root and Exogeneity Tests

Unit Root Test	Test Statistic DF	Test Statistic ADF	Critical Value %5	Critical Value %10
F_d	-.5.19	-3.43		

S_f	-2.93	-0.79		
S_f	-1.71	-3.33	-7.07	-6.78
S*m	-2.75	-2.66		
m	-6.87	-5.56		
Exogeneity Tests**				
▲S^d	2.28	2.60	2.08	
▲ S^f	4.53	2.37	1.94	
▲s^f*m	9.09	2.60	2.08	
▲ m	0.98	2.60	2.08	

* The critical values for the unit root test are taken from Levin and Lin (1992), Table 5.

** The Granger casuality test is a standard technique and is applied to all the lagged values of logF. It shows that if the estimated coefficients on the lagged values of logF are insignificantly different from zero, then X is exogeneous. The test statistics are based on regression with X (X= logS , logS , log S *m, and m) as the dependent variables and 3 or 4 lagged values of logF and X as the independent variables. The fourth lag is taken if it significantly different from zero..

F_d.... log of military factor productivity.

S_f . log of domestic military R&D capital stock.

S .. log of foreign military R&D capital stock.

m... the ratio of military imports of goods and services to GDP.

The second point is the estimated standard errors. According to the theory, if the independent variables are exogeneous, the standard errors and the significance tests must be unbiased, as long as the variables are nonstationary (see, for example, Cuthbertson, et all, 1992, pp. 138-40). I

would expect this is so for the two type of R&D stocks. Granger causality test (Table 2) in the pooled data confirm some of this expectation. It is possible to reject the null hypothesis that military factor productivity does not predict the import share or the domestic R&D stock. However, the null hypothesis can not be rejected in the case of the foreign R&D stock. Therefore, one should take the estimated standard errors with cautiously. Nevertheless, the super consistency of the OLS estimator softens the importance of confidence intervals and tests of hypothesis.

I report in Table 3 pooled cointegration regressions. These are based on equations (5) and (6) and that include constants. Equation (a) is the basic estimation where the estimated coefficients on the domestic and foreign military R&D capital stocks are constrained to be the same for all countries. The impact of domestic military R&D is allowed to differ between the four countries and CINNS in

Table 3: Total Military Factor Productivity Estimation Results
(Standard errors in parantheses)

	(a)	(b)	(ab)	(d)	(e)	(f)	(g)
log S^d	0.075	0.089	0.075	0.073	0.068	0.088	0.081
	(0.010)	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.008)
$\log S^d$ (4)		0.14	0.14	0.16	0.16	0.191	0.192
	(0.17)	(0.019)	(0.015)	(0.017)	(0.016)	(0.018)	
$\log S^f$	0.078	0.051	0.044	0.038	0.042	-0.11	-0.12
	(0.015)	(0.016)	(0.016)	(0.017)	(0.015)	(0.025)	(0.025)
$\log S^f$ * m		0.272	0.266	0.523	0.535	0.544	0.549
		(0.042)	(0.043)	(0.047)	(0.083)	(0.085)	(0.07)
m				0.075	0.055	0.066	0.088
							(0.051)
Standard error	0.05	0.05	0.048	0.049	0.047	0.046	0.049
R^2	0.49	0.58	0.56	0.61	0.66	0.62	0.68
Adjusted R^2	0.47	0.55	0.53	0.58	0.61	0.57	0.66
ADF_d	-5.955	-6.077	-5.843	-6.111	-6.247	-5.495	-5.190
$_f$							

S^d , S^f, m; as reported in Table 2. (4) stands for France, Germany, U.K., and U.S.A. on
equation $\log S^d$ * (4). Dummy variable is employed.

equation (b). This is done by interacting between the domestic military R&D stock with a dummy variable This constraint did not employed in equations (d), (e), and (f) where the foreign military R&D capital stock is interacted with the ratio of imports to GNP. This provides the information about time-varying elasticities on foreign military R&D related to trade shares for each country. I also tested the hypothesis that whether the coefficient on the foreign military R&D stock differed between the first group and CINNS. This is done adding foreign military R&D stock with the first group's dummy to equation (b). The estimated coefficient on this variable was not significantly different from zero.

This can be interpreted as that the first group countries involve military R&D across a broader range and therefore exploit possible complementarities. The result may be slower military R&D results spill over to other countries. Equations (ab), (e), and (f) include the ratio of imports to GNP as an additional independent variable. This provides testing the hypothesis that the import share has no independent effect on military factor productivity that cannot be rejected.

The estimated equations explain more than half of the variance. The coefficients reveal expected sign, and highly significant. The estimated elasticities are stable for different variations of estimation.For the first group

countries, the estimated elasticities of military factor productivity with respect to the domestic R&D stocks are large.

As far as the test statistics are concerned, the Levin and Lin's critical values for pooled ADF unit root tests are used to test whether the residuals are stationary. The test statistics reveals cointegration on estimated equations: At the 10 percent confidence level (a common level for similar studies) the critical value for the ADF is -6.78. This is insignificantly higher than the ADF test statistics on the residuals of the estimated equation reported in Table 3. This confines me that the estimated equations are cointegrated. Indeed, the ADF test statistics on the residuals of estimated equations is smaller than the ADF test statistics reported in Table 3. This fortifies the evidence for cointegration.

I have found equation (d) as the most interesting one as far as econometrics is concerned. This equation is also theoretically consistent. Indeed, this equation best fits to my model. The expected result is being reflected in this equation: The impact of the foreign R&D capital stock varies with all countries and over time. The estimated elasticies of military factor productivity with respect to the foreign R&D capital stock is reported in Table 4.

Table 4: The Estimated Elasticies of Military Factor Productivity with Respect to Military R&D capital Stock

	Total	Foreign R&D	Domestic R&D
France	0.294	0.066	0.239
Germany	0.310	0.077	
U.K.	0.315	0.071	

U.S.A.	0.261	0.035	
CINNS	0.215	0.151	0.075

The estimations are based on equation (d) in Table 3, and are calculated from the estimated coefficients from Table 3 multiplied by the imported military equipment shares.

Only the end- year calculations are reported in Table 4. However, as time taken into consideration, the estimated impact of foreign military R&D increases over time; reflecting more close integration among counties. The domestic military R&D capital stock has a much larger impact on military factor productivity in France, Germany, UK, and the USA, the CINNS countries are more open and therefore benefit more from military R&D.

IV.1 The Effects of Spillovers

Spillovers provide the knowledge transmitted from R&D investment as R&D capital accumulates. Spillovers can be regarded as ideas borrowed from the others. Because, purchase of machinery and equipment from one firm would be seen as the exchange of physical assets embodied with technology. Patented innovations, softwares, joint ventures, even hiring workforce from the other firms are the other forms of spillovers. R&D capital benefits users through a number of ways inside and outside the performing industry. Any R&D would provide new products, improvement of the existing knowledge and new processes.

R&D spillovers have an effect of reducing cost and therefore provide productivity gains. The size of cost reduction varies among countries. The

important finding is that interindustry spillovers stimulates greater downward pressure on average cost of production relative to intraindustry spillovers. Unit costs decrease more to an increase in the interindustry spillovers in industries with relatively small R&D cost shares. The contribution of own R&D within an industry to factor productivity growth has been found significant. Outside R&D spillovers contribute more than own spillovers (Bernstein, 1988;Grileches and Lichtenberg 1984). On the other hand, privately financed R&D has more significant effects on factor productivity than government financed R&D (Terleckyj, 1974 and 1980).

As expected, supply and profitability are closely connected. These two factors are determined by cost and price. R&D spillovers cause an expansion in output and a reduction in price. Numerous studies have estimated the elasticity of profit with respect to spillovers. For example, Jaffe (1986) has found that a 1 percent increase in spillovers 0.1 percent increase in profit. As spillovers increase, demand for labour and materials declines, demand for physical capital increases. This could be taken as, at least, a partial substitution between spillovers with labour and materials, complements to physical capital. It is easy to find that intraindustry spillovers are substitutes for R&D in industries where the propensities to spend on R&D are relatively small. Therefore, one can expect that industries with relatively large R&D increase their R&D spending since they obtain new knowledge from rival firms through intraindustry spillovers. One another point is rates of return to R&D. Social rates of return on R&D are greater than private rates. However, social rates of return to R&D show a significant deal of

interindustry variation. Although, the difficult point is a separation between spending on process R&D and product R&D, the social rates of return is higher on process R&D than the product R&D.

International spillovers occurs via export of goods and services, foreign direct investments, international joint ventures, international mobility of scientists, and conferences. It would also take place with input suppliers and intermediate input demanders. The magnitude and extent of international spillovers can be pervasive.

One important practical question is that how can we measure the effects of international spillovers on a country's economy. Mohnen (1990) employed a technique that international spillover variable as the sum of the R&D stocks in a foreign country, weighted by high-tech imports from the country of origin. This is measured as percentages of total high-tech imports. This technique implicitly assumes that the more a country imports high-tech products, technologically the closer the two countries are. Moreover, the technique assumes that importing country benefits from exporters' R&D efforts in proportion to its import share.

The next calculation, estimates of international spillovers, supports above findings. This is reported in Table 5.

Table 5: Elasticies of Military Factor Productivity with Respect to R&D Capital Stocks

	France	Germany	UK	USA
CINNS				
France	---	0.0132	0.0033	0.0354
0.0077				

Germany	0.0072	---	0.0061	0.0444
0.0411				
UK	0.0048	0.0157	---	0.0256
0.0116				
USA	0.0025	0.0043	0.0026	--
0.0777				
CINNS	0.0005	0.0003	0.0005	0.0066

Average elasticity of foreign military factor productivity	0.0037	0.0070	0.0033	0.0252
0.0183				
Elasticity of domestic military factor productivity	0.2322	0.2325	0.2326	0.2323
0.2325				
Average elasticity of military factor productivity in all countries	0.0165	0.0277	0.0175	0.1212
0.0111				

The figures reveal that as the R&D military capital stock of country i changes by 1 percent, the foreign military R&D capital stock of country j changes by country i's military import shares from country i times the military R&D capital stock of country i As expected, elasticies are larger with respect to the military R&D capital stocks of France, Germany, UK, and the USA. This is understandable, because their military R&D capital stock are larger than the CIINS countries. Moreover, the CIINS countries make the most military imports from these four countries, and therefore calculated military import shares are effected from this fact. The estimated R&D spillover elasticies are relatively large. The largest figures are found in the USA. The calculated elasticies show, the change of military factor productivity in the all countries

after a 1 percent change in, for example, in the USA. One can simply determine one county's effect on the others. Moreover, this can be rank from strongest to weakest. The very last column in Table 5 shows that 1 percent change in the R&D military capital stock in, for example, the USA changes the average productivity of all countries by 0.1212 percent. Therefore this row shows a country's effect on its own productivity as well as on its partners. As expected again, the USA has the largest impact. This is another implication of the fact that the USA has the largest military R&D capital stock. According to this figure, the rate of return on investment in the USA military R&D is smaller than those of the other countries.

IV.2 Specific Industries

Next, I look at to some specific industries closely related to military R&D in terms of elasticies of intraindustry spillovers and international spillovers. I choose four such industries for which data available: electrical products, nonelectrical machinery, telecommunication equipment, and transportation equipment. These four industries are assumed the represent the most important military- related industries. The data on microelectronics, hardware and software are not available.

I get the same country groups. CINNS are excluded because such an integration does not make sense for these countries.. (The small model for this section is introduced in the Appendix).

Table 6: Elasticies of Intraindustry Spillovers and International Spillovers: Electrical Products

Elasticies of Intraindustry Spillovers

	France	Germany	USA
Labour/Output	0.0088	0.00767	- 0.0066 -0 0056
Intermediate Output	0.0179	0.0011	0.0123 -0.0168
Physical Capital/Output	0.0013	0.0024	0.0018 0.0011
R&D Capital/Output	0.0225	0.0241	0.0011 0.0005
Elasticies of International Spillovers			
Labour/Output	0.0259	0.1298	0.1138 0.1478
Intermediate Output	0.0445	0.1975	0.3367 0.3854
Physical Capital/Output	0.0054	0.1032	0.0943 -0.1731
R&D Capital/Output	0.0287	0.1654	0.0087 0.0298

(Mean values)

There is a complementary relationship between R&D and international spillover in each countries.

This suggests that as R&D capital expanded in electrical products a 1 percent in one country (for example in the USA), there is a corresponding increase in the other countries. The converse is also true. In order to save place, standard deviations are not reported here. But, as standard deviations are taken into account, international spillover from France to Germany, for example, generates a negative effect on average variable cost. However, it is not always the case that the effect will be negative. It is possible for a spillover to have a positive effect on variable cost. If the factor prices, output quantity and R&D and physical capital intensities were effected from spillover, the variable cost would be increase: Spillover may

operate like a quality and/or characteristics change in output, changes in output characteristics can make existing labour and other inputs more expensive and hence the variable cost increases. As a conclusion, expensive labour and inputs cause a decline in profitability. A spillover may directly reduces average variable cost, but may cause an increase in variable factor intensities. This is going to increase the cost: the indirect effects of negative factors may offset the positive direct effect which, in turn, the average variable cost increases.

Labour and intermediate input intensities are substitutes for the international spillovers, physical capital intensity is substitute for all countries except for the USA. This suggests that the European partners have more substitute relation with each other.As far as intraindustry spillovers are concerned, this can be seen as the relation in the same country. Indeed, the effect of intraindustry spillovers and international spillovers reveal some differences.

The findings suggest, in some countries, the intraindustry spillover cause to a reduction of R&D intensity. This means that a country's industry borrows knowledge from other industries, and substitutes this knowledge for its own R&D. In some countries, (for example in the USA), the relationship between international spillovers and own R&D is small, suggesting a low level of international relation. One country's R&D expansion may cause a decline in other country's R&D intensity. For example, intraindustry spillovers cause a decline R&D intensity in France, but that an increase in the USA.

Table 7 is designed for transportation equipment, significantly related with military research.

Table 7: Elasticies of Intraindustry Spillovers and International Spillovers: Transportation Equipment

	Elasticies of Intraindustry Spillovers			
		France	Germany	USA
Labour/Output	0.0333	0.1187	0.0874	-0.2745
Intermediate Output	0.0312	0.0751	0.0575	-0.6753
Physical Capital/Output	0.0153	0.2325	0.1829	-0.6397
R&D Capital/Output	0.6581	0.8745	0.5412	0.3102
	Elasticies of International Spillovers			
Labour/Output	0.8632	0.6529	0.7731	-0.0764
Intermediate Output	0.6597	0.5439	0.7216	-0.0437
Physical Capital/Output	0.1145	0.3452	0.0975	-0.9542
R&D Capital/Output	0.2174	0.3329	0.1748	-0.1042
(Mean values)				

France, Germany, and UK transportation equipment industries have relatively little effect on USA capital and R&D intensities. But these countries get substantial benefit associated with international spillovers. As far as domestic spillovers are concerned, domestic spillovers are much more important than international spillovers. International spillovers play a more significant role in the other countries.

Table 8 reflects the findings on nonelectrical machinery industry, one another importantly

related industry with military research.

Table 8: Elasticies of Intraindustry Spillovers and International Spillovers: Nonelectrical Machinery

Elasticies of Intraindustry Spillovers

		France	Germany	USA
Labour/Output	0.0427	0.1254	-0.0231	-0.0016
Intermediate Output	0.0671	0.1634	-0.1104	-0.0022
Physical Capital/Output	0.0591	0.0459	0.0328	0.0035
R&D Capital/Output	0.5213	0.4287	0.6378	0.0012
Elasticies of International Spillovers				
Labour/Output	-0.1145	-0.1785	-0.1374	-0.1243
Intermediate Output	-0.2317	-0.1934	-0.1733	-0.2416
Physical Capital/Output	0.1256	0.4768	0.5790	0.6719
R&D Capital/Output	0.0965	0.1547	0.1365	0.1836

Generally speaking, the effects of international spillovers dominate the intraindustry effects in nonelectrical machinery industry. However, R&D intensity does not show the same situation. A 1 percent change in intraindustry spillovers result, in France, 0.52 percent change, while, the international spillovers causes 0.1 percent change. The international spillover elasticies are, generally, not more elastic. At the same time, international spillovers effects the labour and intermediate input intensities. While these two inputs decline, physical capital intensities increase.

Table 9 is designed for another important military R&D item, telecommunication equipment.

Table 9: Elasticies of Intraindustry Spillovers and International Spillovers: Telecommunication Equipments

		France	Germany	USA
Elasticies of Intraindustry Spillovers				

Labour/Output	0.0062	0.0094	0.0103	0.0165
Intermediate Output	0.0023	0.0051	0.0871	0.0118
Physical Capital/Output	0.0184	0.1938	0.1475	0.2176
R&D Capital/Output	0.2874	0.3375	0.6413	0.4487
Elasticies of International Spillovers				
Labour/Output	0.2156	0.1254	0.3123	-0.0451
Intermediate Output	0.2331	0.1237	0.2478	-0.0634
Physical Capital/Output	0.0751	0.1144	0.0973	0.0756
R&D Capital/Output	0.8746	0.9541	0.8823	0.0345
(Mean values)				

According to the table, the effects of international spillovers exceed the elasticies associated with the international spillovers. France seems relatively more elastic in response to spillovers from the USA. Although it did not calculated, it suggests that a 1 percent increase in international spillovers causes a more decline in France than in the USA. As one observes in the other industries investigated, international spillovers reduces labour and intermediate input intensities and increases physical capital intensity. (Indeed, almost all industries analyzed have divided into two groups as “Europeans” and “the USA”; i.e. elasticies approach each other in European countries and that quite different than of the USA).

Having analyzed some industries, I know turn to the concept of productivity growth in these industries. Productivity growth which is represented best as “total factor productivity” is a measure of dynamic efficiency. The idea of this section is to measure and decompose into the contribution of domestic and foreign military R&D spillovers to total factor productivity (TFP). I get the same countries and same industries which are closely related to military R&D spillovers. Here, I represented a simple model for the above purpose.

Traditionally, TFP is measured as the difference between output and input growth rates. Using inputs as labour, intermediate inputs, physical capital, and R&D capital; TFP growth rate is defined as:

$$TFPG(t,s) = (y_t - y_s)/y_m - S_{vm}^T(v_t - v_s)/v_m - S_{km}^T(K_t - K_s)/K_m \quad (1)$$

q is the change in TFG between two periods, subscript m is the mean value of a variable,
c is the vector of noncapital cost shares,
c_c^v the vector of capital cost shares,

Econometrically, total factor productivity growth rate can be decomposed by using the estimated variable cost function, derivation of which explained in Appendix. This can be shown as:

$$c_v^t - c_s^v = 0.5[\sum_{j=1}^{n}(V_{it} - v_{is})(w_{it} - w_{is}) + ((\partial c^v/\partial y)_t + (\partial c^v/\partial y)_s)(y_t - y_s) +$$

$$\sum_{k=1}^{m}((\partial c^v/\partial k_k)_t + (\partial c^v/\partial k_k)_s)(k_{kt} - k_{ks}) + \sum_{j=1}^{0}((\partial c^v/\partial s_j)_t + (\partial c^v/\partial s_j)_s)(s_{jt} - s_{is})$$

(2)

This is the difference in variable cost function between two time periods. The difference corresponds to the variable input prices, output quantity, capital stock, and R&D spillovers. Thus,

$$TFPG(t,s) = ((y_t - y_s)y_m)[1 - (\partial c^v/\partial y)_m(y_m/c_m^v)(c_m^v/c_m)]$$

$$-\sum_{j=1}^{0}(\partial c^v/\partial s_j)_m(s_{jm}/c_m)(s_{jt} - s_{is})/s_{jt} \quad (3)$$

The decomposition equation has composed from two parts: The scale effect and the R&D spillover effects. The scale effect is zero if there is constant return to scale. The R&D spillover effects have two parts: The direct effect (the effect(s) of traditional technological change on TFP= domestic spillover + international spillover) and the indirect effect (the impact on capital

intensities of the new technology obtained from other industries in the home country and from the same industry in the other countries).

Table 10: Decomposition of the Average Annual TFP Growth Rates: Electrical Products (in percent)

Period (1970-1995)	TFP	Scale	Domestic Spillover	International Spillover		
				Direct	Indirect	Indirect
France	1.845	1.112	0.211	0.016	0.437	-0.008
Germany	2.223	1.329	0.438	0.058	0.753	-0.008
UK	1.753	0.852	0.264	0.023	0.353	-0.005
USA	1.639	1.245	0.152	-0.043	0.547	-0.028

Total productivity growth rates quite high for all countries. Since military research enjoys from this industry, one can assume that the same is true for this particular industry. Scale effects are also important. Domestic spillovers played a significant role in contribution to TFP, but less than the international spillovers. All the four countries also have benefited from the international direct spillovers,

Table 11: Decomposition of the Average Annual TFP Growth Rates: Transportation Equipment (in percent)

Period (1970-1995)	TFP	Scale	Domestic Spillover	International Spillover		
				Direct	Indirect	Indirect
France	1.231	0.587	0.213	-0.015	0.427	0.087
Germany	1.476	1.042	-0.937	0.658	0.775	0.127
U.K.	0.841	0.147	-0.365	0.051	-0.076	0.053
U.S.A.	-0.231	0.652	-0.471	0.231	-0.497	0.023

Countries have shown quite significant total factor productivity growth and scale effects in the transportation industry. The U.S.A. has, however, negative total factor productivity growth rates. These four countries' total factor productivity gains have benefited from international spillovers. The results of domestic spillovers are mixed.

Table 12: Decomposition of the Average Annual TFP Growth Rates: Nonelectrical Machinery
(in percent)

Period (1970-1995)	TFP	Scale	Domestic Spillover	International Spillover	
				Direct	Indirect
France	1.254	0.487	-0.154	0.084	0.763
Germany	1.341	0.451	0.167	0.065	0.659
U.K.	1.115	0.548	0.095	0.084	0.363
U.S.A.	1.023	0.795	0.034	0.035	0.065

Nonelectrical machinery industry has shown quite similar patterns with the other industries under investigation. Total factor productivity and scale effects are significant, and, the most important reason for these gains seem to come from international spillovers.

Table 13: Decomposition of the Average Annual TFP Growth Rates: Telecommunication Equipment
(in percent)

Period (1970-1996)	TFP	Scale	Domestic Spillover	International Spillover	
				Direct	Indirect
France	0.534	0.254	0.041	0.003	0.375
Germany	0.773	0.367	0.023	0.003	0.666

U.K.	0.575	0.048	0.011	0.004	0.591
0.034					
U.S.A.	1.023	0.420	0.017	0.001	0.654
0.008					

Telecommunication equipment industry, too, has benefited from international spillovers. The effects of domestic spillovers are not as important as international spillovers. Total factor productivity and scale effects are also quite significant.

V. CONCLUSION

This study has attempted to identify the application of the new theory of economic growth that built around innovation and productivity developments, to military research and development in a number of NATO countries. Military research and development has always made a significant contribution to the science. The theory focuses international economic relations as transmission mechanisms of one country's productivity changes to its trade partners. As far as military is concerned, it has been discussed that this is not an important case, because each country keeps its innovation secret. This study is a cross-country study and that distinguishes explaining output growth as a result of increasing level of labour, capital, some other inputs, and, explaining the growth of total factor productivity, which is different than increasing level of inputs. The study takes the later approach in terms of military research and development. This enables us to have a link between research and development and productivity.

It seems that NATO has an important responsibility to creation of military market on both side of the Atlantic. There is a little progress which is supposed to harmonize procurement requirements over the years The

proposed transatlantic military market should have and should promote a clear definition of export, technology transfer, common research and development projects, distribution of project and production and similar subjects. This prevents dualities in production and research and development and therefore saves resources. The rise of military research and development project is possible on this way.

This is particularly discussed in literature in such a way that foreign R&D has a stronger effect on domestic productivity as an economy becomes more open and involves into more international trade. Therefore, trade partners' R&D capital stock have a significant effect on one country's own R&D stock and therefore total factor productivity. In the "general findings", I have had clear indication on a close link between productivity and R&D capital stock. Although I have not calculated for specific industries, it is clear that international spillovers have been generally reduced the production cost, and factor intensities as compare to domestic spillovers. This is because international spillovers connect the two industries in different countries. On the other hand, it has been showed that international spillovers are complements to domestic R&D capital in the most cases of specific industries. This means that, for example as the firms in the U.S.A. increase their R&D capital in telecommunication equipment, U.K. producers increase their output in telecommunication output. As far as labour and other input intensities are concerned, international spillovers generally cause to increases in physical capital intensities and decreases labour and other input intensities. As this tudy implies a potentially high benefit for the member countries, the following suggestion would be made in the direction

of more co-operation between NATO member countries in terms of R&D., i.e., barriers preventing international transmission of technology should be eliminated. Military R&D will get benefit from this situation. Although there exists a co-operation in military R&D, NATO should advance this co-operation.

APPENDIX (An Econometric Model For Some Industries and International Spillovers)

Production and International Spillovers

This is very simple model. Production is a function of labour, physical capital, R&D capital, and intermediate inputs. R&D has two kinds of spillovers effect: domestic and international. A simple and well-behaved production function can be written as:

$$q_t = q_t(v_t, K_t, S_{t-1}) \qquad (1)$$

Here:

q is output,

v is the vector labour and intermediate inputs,

K is the vector of physical and R&D capital,

S is the R&D spillover (S_1, domestic; S_2 international)

The domestic and international spillovers operate with lag. The domestic spillover is assumed to be the sum of one period lagged R&D capital stock of all industries other than the one industry under investigation. The

international spillover, on the other hand, is the lagged R&D stock of the corresponding industry in four countries (France, Germany, UK, the USA). It is assumed that the domestic spillovers indirectly captures spillovers that operate across national boundaries. Domestic spillovers are influenced by lagged values of R&D capital stocks.

Profit maximization problem is written as a dual approach of cost minimization. The cost function is translog.

$$c^v = c_t(w, q, K, S) \qquad (2)$$

where w is the vector of exogenous labour and intermediate input prices. Shephard's Lemma gives the demand for the variable factors. (Derivations are not shown here). The variable factor demands depend on the factor prices, output, capital, and R&D spillovers.

Next step is the derivation of the demands for the capital services and the supply of output. These are depends on labour and intermediate input prices, capital input prices, R&D spillovers, product prices.

The average variable cost function can be estimated by using the translog techniques. This is an implicit form c(w, K/q, S-1)

$$c^v / y_t = (\sum_{t=1}^{2} bw + 0.5\sum_{t=1}^{2_{t-1}} bwW^{-1})y + (\sum_{t=1}^{2} dk_{ij} + 0.5\sum_{t=1}^{2} qk/y + \sum_{t=1}^{2}\sum_{t=1} n_{ij}k_{ij}S_{t-1})1/2/t \qquad (3)$$

the parameters to be estimated are: b, d, a, n_{ij} , i,j=1,2,.,. and v is the inverse of the degree

of return to scale. K/q can be shown as by k; W=..$\sum_{t=1}^{2} \gamma w$ .....where y, 1=1,2,..are fixed coefficients.i

W is Laspeyres index of labour and intermediate input prices. These prices are taken as weighted average.

$$v/y = (b_i + \sum_{j}^{2} bwW^{-1} - 0.5\sum_{h=1}^{2} \sum_{j=1}^{2} b_{hj} w_{ht} w_{jt} W_t^{-2} \gamma_i) y^{\theta-1} + [\sum_{j=1}^{2} dk_{jt} + 0.5\sum_{h=1}^{2}\sum_{j=1}^{2} q_{hj} k_{i}$$

$$+ \sum_{h=1}^{2} \sum_{j=1}^{2} n_{hj} k_{ht} sj_{t-1}] \gamma i .... \; i = 1 .... 4$$

(4)

Equations (3) and (4) define the model to be estimated. Since I would like to concentrate on the effects that international spillovers have on production and hence production growth. It is possible to measure the decomposition of productivity growth on the impact of domestic and international R&D spillovers on factor intensities

The above framework enable us to obtain the effects of international and domestic spillovers by differentiating above equations with respect to S_1 and S_2 . One can obtain capital and noncapital (labour and intermediate inputs) intensities, such as:

$$S_j = Sy^{\theta-1}(a_i n_{di} - a_d n_i)/\Delta k.....i = 1...4$$

(5)

for capital, and

$$e^v / ys_h = s_n[n_h k_h + n_g k_g + (\partial k/\partial s)(d_i + \sum^{2} a_i k_j y_j^{\theta-1} + \sum_{j=1}^{2} n_{ij} s_j) + (\partial k/\partial s_h)(d_i + \sum_{j=1}^{2} aky^{\theta-1} + \sum_{j=1}^{2} n_{2i} s_i)]\gamma_i /$$

(6)

for noncapital. Here $ek_c S_j$ and . $e(v./y)S_h$ .... is the spillover elasticity of the ith capital and noncapital input demand. As expected, two effects, direct and indirect, of the spillovers on the noncapital intensities should be emphasized. The direct effect is related to the noncapital input price index which interacts with the spillovers, i.e., spillovers directly effect the prices of noncapital inputs. The indirect effect happens from the fact that the change in capital intensities effect the noncapital input intensities This could be written as

$$ec_y^v s_h = s_n[n_{hh}k_h + n_{gh}k_g + (\partial k/\partial s)(d_i + \sum_{j=1}^{2} ak_{ij}y_j^{\theta-1} + \sum_{j=1}^{2} n_{ij}s_j) + \tag{7}$$

$$(\partial k/\partial s_h);(d_i + \sum_{j=1}^{2} a_j k y^{\theta-1} + \sum_{j=1}^{2} n_j s_j)]W/(c^v/y).....i = 1..h.$$

Equation (7) represents the effects of spillovers on average variable cost where ec_y^v.S_h..... is the h th.,,,,spillover elasticity of average variable cost.

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