Manufacturing Growth, Technological Progress, and Military Expenditure

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November 2005

During the Cold War a major justification of high levels of military spending was the 'spin off' of innovations to the civil sector, such as computers, which could then be exploited profitably and to the benefit of the economy and society. There is evidence that this has changed in more recent times, with the speed of consumer industry led technological change leading to 'spin in' to advanced weapons systems. If this is the case it has removed a major benefit of military spending. There is, however, little systematic evidence and little recent empirical work. This paper makes a contribution to the debate, analysing the impact of military spending on technological progress, and hence labour productivity and economic growth, for a number of major weapons producers. It uses data on the manufacturing sector, for the period 1966-2002 and estimates a CES production function in which military spending is assumed to effect growth through its impact on trend technological change.

Keywords: Military spending; spin off; employment; productivity; panel

JEL Classification:

Preliminary draft. Comments and suggestions welcome. Dunne is grateful to the ESRC for support under project R000239388. See: http://carecon.org.uk/Armsproduction

1. Introduction

The economic impact of military spending remains an enduring debate within the post Cold War environment. The end of the Cold War saw unprecedented reductions in military spending, admittedly from a spectacularly high base and a simple observation of the experience of most countries would suggest that this has not been at the expense of economic growth. Questions do still remain, however, as to what the likely impact of further reductions will be, or indeed the increases that seem to be in the pipeline. What is accepted generally is that the magnitude of military spending does not provide a measure of its overall importance to economies and there is concern that it may have particular effects within a number of areas. In particular its likely effect on technical progress is an issue of continuous discussion, as the recent paper by Kelly and Rishi (2003) shows. During the Cold War a major justification was the 'spin off' of innovations to the civil sector, such as computers, which could then be exploited profitably and to the benefit of the economy and society. There is evidence that this has changed in more recent times, with the speed of consumer industry led technological change leading to 'spin in' to advanced weapons systems. If this is the case it has removed a major benefit of military spending. There is, however, little systematic evidence and little recent empirical work.

This paper makes a contribution to the debate, analysing the impact of military spending on technological progress, and hence labour productivity and economic growth, for a number of major weapons producers. It uses data on the manufacturing sector, for the period 1966-2002 and estimates a CES production function in which military spending is assumed to effect growth through its impact on trend technological change. The next section provides a brief review of the general issues and literature, section 3 presents the data sample and section 4 outlines the theoretical model used. The panel estimation methods used are then discussed in section 5, the results of the empirical analysis presented in section 6, and the final section presents some conclusions.

2. Economic Effects of Military Spending

There is an extensive literature analysing the economic effects of military spending and a considerable range of results.[1] Theoretically, any evaluation of the impact of military spending on growth is contingent on the theoretical perspective used (Dunne, 1990). When statistical analysis is undertaken it is generally the neoclassical/Keynesian models that are used as these are most amenable to the creation of formal models, though some studies have adopted a more ad hoc approach. Studies also differ in terms of the country coverage, whether they use time series or cross section data, the time period covered and the empirical methods used. In general, the empirical analyses have identified a number of channels by which military spending can influence the economy and these can be positive or negative (Dunne, 1996).

One argument is that military spending assists growth through promoting technological innovations that spill over to civil industries –there is a 'spin off' of innovations to civil companies. Technology developed by arms producers may have applications for non military production, non military production may benefit from the enhancement of capital stock to complete military orders and the growth of output of advanced military technologies may spur on technological change in suppliers in the civil sector. There is also a human capital dimension, by which military spending leads to improvements in education and training and so allows the upgrading of capital. All of these have potential downsides, however, as military spending may have a high opportunity cost, may create skill and capital bottlenecks, may misallocate resources away from growing sectors, and may create unsustainable enclaves. Whether military spending has a positive or negative effect is clearly an empirical question and the empirical literature has produced a range of studies and answers. Overall, the results seem to suggest that there is an insignificant or negative impact of military spending on economic growth in developing countries and a clearer negative impact in developed economies, through military spending being at the expense of investment rather than consumption. There is, however, considerable scope for further work focusing on particular aspects of the relationship and using country case studies, or relatively homogenous groups of countries (Smith, 2000).

In this study the focus is on the impact of military spending on the economy through its effect on technological progress and we choose to focus on the major arms producers.

3. Data and Sample

[1] Dunne et al (2005) provide a recent contribution, while Brauer (2002), Smith (2000), Dunne (1996) and Ram (1995) provide reviews.

The principal concern in the selection of countries to include in this study is data comparability. The need for data consistency leads us to restrict our sample to countries in the OECD. This does, however, allow us to consider the main arms producers in North America and Western Europe. Table 1 lists the countries included in the study and provides a statistical breakdown of the nature of the data used.[2] Our data spans from 1966 to 2002, which allows us to also investigate the existence of any Cold War effects.

Table 1: Statistical Breakdown of the Included Manufacturing Sectors

Country	Annual Growth (%)	Average Employment (million)	Military Burden Milex/GDP
Greece	4.3	0.3	5.2
France	4.0	4.6	3.8
UK	1.6	5.9	4.4
Italy	4.4	3.3	2.4
Netherlands	3.1	0.9	2.8
Canada	3.4	1.8	2
Sweden	1.2	0.6	4.4
Spain	4.3	2.1	2.6
USA	2.8	17.7	5.7

The manufacturing data used is mainly taken from the OECD Main Economic Indicators Dataset. However, we also use UNIDO and Penn World Tables. These sources are used to test for the robustness of our results and also to estimate figures for the limited cases of missing data. The military burden term, defined as military expenditure divided by Gross Domestic Product, is taken from SIPRI data.

4. Theory and Method

In analysing the employment effects of military spending, previous work has tended to take two approaches. One was to estimate a simple reduced form model to analyse the relationship (eg Dunne and Smith, 1980 for unemployment and military spending). A second is to specify a simple Cobb Douglas production, derive an employment function and then estimate, introducing a dynamic specification to the empirical model in some way, eg Dunne and Watson (2000). There are, however, problems with the Cobb Douglas production function as it implies the elasticity of

[2]Countries that had to be excluded in the study include Austria, Finland, Portugal and Sweden. The chief reason for this decision rested on the availability and completeness of manufacturing hours data, given we are interested in total hours of employment.

substitution is unity and that technical progress is neutral. Some of these problems can be overcome, by using a CES production function as in Yildirim and Sezgin (2003)

A further issue is how to introduce military spending into the model. There are two concerns, whether to use the level or burden measure and where to bring in the effect within the theoretical model. In the case of the former it is often dependent on the study, as the share is more satisfactory for cross country comparison and the level for individual country studies. For the latter the usual approach is to take the empirical aggregate labour demand function and then introduce military burden as an explanatory variable.

Assuming that output follows a more general CES production function with labour augmenting technological progress:

$$Q = \gamma\left[s(K)^{-\rho} + (1-s)\left(Le^{\lambda t}\right)^{-\rho}\right]^{-(v/\rho)}$$

where Q is output, K is the real capital stock, L is labour, v is returns to scale, γ and s are production scale parameter, the elasticity of substitution is $\sigma = 1 / (1+\rho)$ and technological progress is labour augmenting at rate λ_t. We measure labour as total employee hours, rather than the total number of employees.

Following Barrell and Pain (1997), an expression for desired labour demand can then be derived via the first order condition that the marginal product of labour ($\delta Q/\delta L$) is equal to the mark-up adjusted real hourly wage ($\beta[w/p]$), where β is assumed to be a constant. Taking natural logs yields:

$$\ln(L^*) = c + \frac{1+\sigma(v-1)}{v}\ln(Q) - \sigma\ln(w/p) - (1-\sigma)\lambda t$$

The coefficient on the real wage provides an estimate of the elasticity of substitution, thus allowing technical progress and returns to scale to be identified. One means of introducing military spending into this model would be to simply add it to the employment demand equation as a separate independent variable. Previous studies using Cobb Douglas production functions (eg Dunne and Watson, 2000) and, more recently, Yildirim and Sezgin (2003) using a CES production function have done this. As our concern is to identify the impact of military spending on technological progress, we instead adapt Hubert and Pain's (2001) approach to endogenising technical progress by adding military burden to the technological progress term:

$$\lambda t = \lambda_T T + \lambda_M MB$$

This specification then assumes that technical progress will change at a constant rate if military expenditure also grows at a constant rate. The sign of λ_M provides us with a means to investigate the impact, if any, that the military sector has on technological progress. A negative coefficient would be consistent with the hypothesis that the military sector is encumbering, as resources are diverted away from the civilian sector and towards military purposes. Alternatively, a positive coefficient would provide evidence of spin-off effects, where military innovation is adapted for the civilian sector.

It is of course possible for military spending to have other impacts on technological progress as any increase in the use of specific technologies can increase profits from innovation and therefore increase R&D incentives.

The empirical specification used allows for adjustment lags in employment and output to provide a dynamic model with the technical progress (and thus military spending) embedded in the long run steady state solution:

$$\Delta \ln(L_t) = \beta_0 + \beta_1 \Delta \ln(\mathrm{Q}_t) + \beta_2 \ln(L_{t-1} / L^*_{t-1}) + \varepsilon_t$$

As Hubert and Pain (2001) note, this specification avoids the strong assumption that firms are able to always produce their output with the minimum necessary level of inputs. A useful property if one considers the nature of defence companies. This gives an estimable equation of the form

$$\begin{aligned} \Delta \ln(L_t) = \theta_0 + \theta_1 \Delta \ln(\mathrm{Q}_t) + \theta_2 \ln(L_{i,t-1}) + \theta_3 \ln(Q_{i,t-1}) \\ + \theta_4 \ln(W_{i,t-1} / P_{i,t-1}) + \theta_5 \ln(M_{i,t-1}) + \theta_6 T + \varepsilon_t \end{aligned}$$

5. Estimation Methods

A major problem with time series analyses of the economic effect of military expenditure has been the relatively small amount of variation in the data over time. It is simply difficult to identify any particular effect of military spending, given the other changes that are taking place. The size of the cuts in military spending that followed the end of the Cold War has improved the situation for researchers. At the same time the development of panel data methods, which pool cross section and time series data, have also assisted in overcoming the lack of independent exogenous variation in the data, especially when used for a relatively homogenous group of countries (Murdoch et al., 1997). There is a variety of approaches, with pooling the simplest form and fixed effect, random effect and random coefficient estimators providing more flexible approaches. The most common panel estimator is the one way fixed effects or 'between' estimator. This allows the intercept to differ across countries and is equivalent taking deviations from the mean of each group for the whole time period for each observation and then using these deviations in the regression. Taking deviations in this way means that only the within group variation is considered and the information in the between group cross sectional relation is ignored.[3]

With the relatively long time series available it has become possible to introduce dynamics to the panel data models. In dynamic models of the form:

$$y_{jt} = \alpha_j + \beta x_{jt} + \lambda x_{jt-1} + u_{jt}$$

the fixed effect estimator is not consistent as N, the number of groups, goes to infinity for fixed T because of lagged dependent variable bias, which biases λ downwards. It is, however, consistent as T goes to infinity. For samples where T is large, as it is here, the bias is small and so the method is used in practice. If the parameters differ over the groups, however, giving models of the form:

$$y_{jt} = \alpha_j + \beta_j x_{jt} + \lambda_j x_{jt-1} + e_{jt}$$

there is a further heterogeneity bias, as the error in the fixed effects equation is:

$$u_{jt} = e_{jt} + (\beta_j - \beta) x_{jt} + (\lambda_j - \lambda) y_{jt-1}$$

which is correlated with the regressors. In the usual case where x_{jt} is positively serially correlated, this will bias the estimate of λ upwards towards unity. The bias will be smaller in the long run effect $\beta/(1-\lambda)$ because the estimate of β is biased downwards and the estimate of λ biased upwards and can be avoided when T is large by estimating each equation individually and then taking the weighted or unweighted average of the individual estimates. A common weighted average is the random coefficient model (RCM) estimator discussed in Pesaran and Smith (1995).

6. Results

Table 2 presents the estimation results for the fixed effects panel model. This was estimated for the full sample and for the Cold War period, to investigate the impact of the change in strategic

[3] The pooled OLS method simply estimates a model on all of the data, implicitly assuming that all parameters are the same for each country. This gives both types of information, within and between, equal weight. It is also possible to allow for time fixed effects separately or together in a two way fixed effect model, which gives a completely flexible trend common to all countries. A random effects model allows for the intercepts to be random, drawn from some probability distribution with a finite number of parameters. This gives an estimator that is between the pooled and fixed effects models, but we do not use it here (Smith and Dunne, 2002).

environment and military expenditure levels since the end of the Cold War. In the first and third columns we report a conventional labour demand specification that includes only a deterministic time trend to indicate technical change. The coefficients are consistent with expectations. There is a positive effect of growth of output on the growth of employment, a negative effect of level of employment, a positive effect of the level of output, a negative real wage effect and a negative coefficient on the time trend. However, the estimated elasticities of substitution are low, particularly for the Cold War restricted results.

The endogenising of technical progress with the inclusion of our military term produces some interesting results, as shown in columns (2) and (4) of table 2 . Using our full sample we find no evidence of any significant impact of the military sector. The coefficient sign does suggest that there may be some impact of military spending on the efficiency in use of labour, through its impact on technology. This finding is more apparent when our data is restricted to the Cold War period where the coefficient is now found to be larger and significant. The military sector during this period is more important, with countries on average bearing higher military burdens. Our results suggest that a 10% rise in the military burden will eventually raise technical progress by 0.5%. We therefore find some support for the 'spin off' effect, but this effect is found to be rather small.

Table 2: Panel Results: Fixed Effects [dependent variable= $\Delta \log(L_{it})$]

	1966-2002		**1966-1989**	
	(1)	(2)	(3)	(4)
$\Delta \log(Q_{it})$	0.8844*	0.2132*	1.0930*	1.0492*
$\log(L_{i,t-1})$	-0.4235*	-0.4198*	-0.7070*	-0.7587*
$\log(Q_{i,t-1})$	0.3382*	0.3321*	0.8656*	0.9345*
$\log(W_{i,t-1}/P_{i,t-1})$	-0.0735**	-0.0689**	-0.1176**	-0.1729**
TIME	-0.011*	-0.011*	-0.0295*	-0.0300*
$\log(M_{i,t-1})$		-0.0016		0.0199**

(**) significant at 10%; (*) significant at 1%

To consider the possibility of heterogeneity bias, we now consider the mean group estimator technique. Individual country results, results of which are provided in the Appendix, present us with the results summarised in Table 3.

The coefficients are again as we would expect, with the estimates providing a conventional labour demand relationship. The elasticity of substitution is estimated to be 0.464 and there is some evidence of increasing returns to scale. Our military term again suggests weak evidence of an impact of military spending on technical progress. This effect, however, is very small. The coefficient is insignificant and our estimates again only imply a 10% rise in the military burden will eventually raise technical progress by 0.5%.

Table 3: Mean Group Estimator Results

	Mean	**t stat**	**Min**	**Max**	**Sd**	**Cov**
$\Delta\log(Q_{it})$	0.445	4.49	0.14	0.80	0.23	0.51
$\log(L_{i,t-1})$	-0.450	-12.2	-0.57	-0.35	0.08	-0.19
$\log(Q_{i,t-1})$	0.369	8.66	0.22	0.51	0.10	0.26
$\log(W_{i,t-1}/P_{i,t-1})$	-0.209	-5.25	-0.38	-0.11	0.09	-0.44
TIME	-0.006	-3.24	-0.01	0.004	0.004	-0.71
Constant	1.151	0.58	-5.13	8.79	4.58	3.98
$\log(M_{i,t-1})$	-0.013	-0.26	-0.17	0.18	0.12	-8.74

7. Conclusions

This paper has considered the economic impact of military spending through its impact on technical progress, using a standard labour demand specification. It thus proved an evaluation of the commonly cited ‘spin-off’ hypothesis. The results presented focussed on the benefits of panel data techniques to avoid problems of insufficient variation in the data over time. They indicated that there have been some minor benefits from the military sector in terms of higher technical progress, but that this effect was marginal. Estimating the model over the Cold War period, gave somewhat stronger effects as might be expected. This provides support for the idea that, with the development of modern weaponry, the impact of the military sector has declined, with ‘spin-in’ of civil technologies rather than ‘spin-off’ taking place and so military R&D being increasingly concerned with finding military purposes for civilian know-how.

These are interesting results, but more work is required to test the robustness of our results. In particular, more focus on collecting consistent and detailed military research and development data is required. This is likely to mean a move towards detailed case studies of the major arms producers.

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Appendix: Individual Country Results

	US		UK		France	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
$\Delta\log(Q_t)$	0.797	8.270	0.650	6.250	0.138	1.473
$\log(L_{t-1})$	-0.413	-1.670	-0.561	5.917	-0.568	5.066
$\log(Q_{t-1})$	0.365	2.152	0.479	4.912	0.369	4.967
$\log(W_{t-1}/P_{t-1})$	-0.214	2.443	-0.379	4.627	-0.187	3.009
TIME	-0.007	-1.935	-0.008	2.356	-0.010	3.190
Constant	-5.131	-1.851	5.020	2.023	8.785	4.165
$\log(M_{t-1})$	0.082	2.178	-0.137	3.008	-0.172	5.089
$\bar{R}^2$	0.823		0.776		0.604	
Sargan	Chi(5)=12.410		Chi(5)=11.385		Chi(3)=8.757	
LM	Chi(1)=6.625		Chi(1)=0.005		Chi(1)=0.509	
NORM	Chi(2)=0.786		Chi(2)=1.135		Chi(2)=0.857	
Het	Chi(1)=0.227		Chi(1)=6.810		Chi(1)=0.355	
V	1.321		1.828		2.095	
σ	0.517		0.675		0.329	
λ_m	-0.199		0.245		0.303	
	Italy		Canada		Greece	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
$\Delta\log(Q_t)$	0.331	2.679	0.569	8.994	0.239	1.779
$\log(L_{t-1})$	-0.433	3.392	-0.484	-3.032	-0.350	3.468
$\log(Q_{t-1})$	0.272	3.005	0.457	4.350	0.344	3.780
$\log(W_{t-1}/P_{t-1})$	-0.108	2.901	-0.238	-3.221	-0.171	2.617
TIME	-0.004	2.663	-0.008	3.677	-0.006	3.478
Constant	2.606	0.824	-2.143	-1.142	-0.433	0.336
$\log(M_{t-1})$	0.029	1.072	0.054	1.836	-0.008	0.206
$\bar{R}^2$	0.459		0.766		0.493	
Sargan	Chi(4)=9.016		Chi(5)=10.914		Chi(1)=5.804	
LM	Chi(1)=0.124		Chi(1)=0.385		Chi(1)=2.165	
NORM	Chi(2)=6.878		Chi(2)=2.391		Chi(2)=1.199	
Het	Chi(1)=1.062		Chi(1)=0.001		Chi(1)=0.186	
V	1.985		1.123		1.037	
σ	0.249		0.492		0.488	
λ_m	-0.068		-0.111		0.023	

	Spain		Netherlands		Sweden	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
$\Delta\log(Q_t)$	0.503	4.314	0.200	1.758	0.582	5.067
$\log(L_{t-1})$	-0.359	2.627	-0.369	2.857	-0.510	3.885

$\log(Q_{t-1})$	0.217	1.690	0.309	3.886	0.509	4.655
$\log(W_{t-1}/P_{t-1})$	-0.125	2.679	-0.139	2.645	-0.323	2.421
TIME	0.004	0.633	-0.005	1.774	-0.008	-2.081
Constant	3.340	2.023	-4.506	1.132	2.820	0.729
$\log(M_{t-1})$	-0.012	-2.679	0.183	2.278	-0.140	-1.683
$\overline{R}^2$	0.557		0.467		0.623	
Sargan	Chi(1)=2.882		Chi(4)=8.084		Chi(3)=6.54	
LM	Chi(1)=2.085		Chi(1)=0.001		Chi(1)=3.331	
NORM	Chi(2)=24.22		Chi(2)-2.667		Chi(2)=1.556	
Het	Chi(1)=0.399		Chi(1)=0.804		Chi(1)=0.207	
V	2.544		1.350		1.007	
σ	0.349		0.376		0.633	
λ_m	0.034		-0.498		0.274	