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March 2013

Online at https://mpra.ub.uni-muenchen.de/46688/
MPRA Paper No. 46688, posted 03 May 2013 15:02 UTC

Labour substitution and the scope for military outsourcing*

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Abstract

This article argues that the observed elasticity of substitution between military and civilian labour within a defence ministry provides an indication of the likely scope for efficient outsourcing of military services. Military labour can only be employed by government, so outsourcing military services to private firms requires replacement of military labour with civilian labour. The degree to which such substitution occurs under in-house provision offers an insight into how much may be undertaken through outsourcing without compromising operational effectiveness. We obtain an estimate of the elasticity of substitution between military and civilian labour in the UK over the period 1970 and 2008 by estimating the Ministry of Defence's relative demand for military labour. Instruments based on the relative supply of military labour are used to account for the endogeneity of relative wages. The long run elasticity is estimated to be around 0.75, though a value of 1 cannot be rejected. The estimated elasticity suggests that there remains scope for further outsourcing of military activities in the UK.

Keywords: defence, contracting out, military labour
JEL classification: H1, H44, H56, H57

*The author is grateful to Keith Hartley for valuable advice and to participants at the Sixteenth Annual International Conference on Economics and Security (Cairo, June 2012) for helpful comments.

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1 Introduction

This article is concerned with the optimal mix between public and private provision of defence. Over the past 30 years the mix between public and private provision of defence activities has been transformed in many countries, largely driven by a desire to produce defence more efficiently. Today, neither the US nor the UK can deploy their Armed Forces without extensive use of civilian contractors employed by private firms. At the height of the Gulf War twenty years ago, the ratio of US contractors to uniformed military personnel was 0.017:1 (Camm and Greenfield, 2005, pp. 138–139). As of March 2011 the ratio was 1.41:1 in Iraq and 0.91:1 in Afghanistan (having peaked at 2.23:1 in March 2008) (Schwartz and Swain, 2011). In April 2011 contractors accounted for around 35% of the UK MODs total workforce in Afghanistan (Heidenkamp, 2012).

Whilst the use of private firms in defence is not new, what has changed is the number and variety of tasks now being contracted out, including many in operational theatres. Even activities which were once considered the sole preserve of the Armed Forces are now produced under contract by private producers. For example, in the UK the provision and operation of the RAF's air-to-air refueling capability, the training of military pilots, and the provision of military communications satellites are contracted out. Similar changes have been seen internationally, especially in the United States.[1]

The budgetary pressures now faced by defence departments in many countries, including almost all NATO members, mean that private provision of defence and military activities is likely to continue to expand. However, precise guidelines as to which aspects of defence are most efficently provided privately and which most efficiently produced publicly do not currently exist.

Theoretical approaches are unable to make precise recommendations about specific services and activities.[2] In line with the corporate literature (Johnson *et al.*, 2005), it is fre-

[1] Although in the US there is currently a moratorium on A-76 public-private competitions (Bailey Grasso, 2012) and there have been initiatives to bring back in-house some outsourced activities (Gates, 2009; Geren and Casey, 2009).

[2] See, for example: Fredland and Kendry (1999) and Fredland (2004) for a transaction cost perspective;

quently suggested that retaining core activities in-house and outsourcing noncore activities improves effectiveness by allowing greater focus on core activities. However, given the range, complexity and interdependence of activites undertaken in order to produce national defence it is not at all clear how to define the core of activities that should not be outsourced (Dunn *et al.*, 2011; Taylor and Tatham, 2008).

Ultimately, determining the most efficient mix of public and private provision is an empirical issue. However, in spite of the large empirical literature comparing the costs of public and private provision of public services generally (see, for example, surveys by Andersson and Jordahl (2011) and Jensen and Stonecash (2005)), there is relatively little specific to defence. It is difficult to construct direct comparisons of the costs of public and private provision of military activities. They tend to be undertaken only once, or at most a few times, in each country making impossible the cross-sectional and panel comparisons of different forms of provision widely used in other areas of public services (e.g. in refuse collection (Stevens, 1978; Domberger *et al.*, 1986; Ohlsson, 2003); in health (Propper *et al.*, 2008); in water (Bel and Warner, 2008)). Differences in the organisation of the production of defence across countries mean that cross-country comparisons are unlikely to be comparing like-with-like. Comparing activities before and after they are outsourced (e.g. Domberger *et al.*, 2002; Kulmala *et al.*, 2006) is complicated by both changes to the specification of the service at the time of outsourcing, and by the available data being insufficiently detailed to allow a thorough assessments of the costs and benefits of outsourced contracts (Uttley, 2005).[3]

Given the difficulties of obtaining direct estimates of the relative efficiency of public and private provision of defence activities, this article proposes that the elasticity of substitution between military and civilian labour within a defence ministry offers an indirect means to infer the core and the likely scope for efficient military outsourcing.

Martimort *et al.* (2005) for a survey of the incomplete contracts approach to outsourcing public services; Iossa and Martimort (2008) and Martimort and Pouyet (2008) on Public Private Partnerships and the bundling of provision of capital assets and services.

[3]Such information is frequently unavailable to even the contracting authority (US Government Accountability Office, 2005; National Audit Office, 2007, 2008). For example, comparison of the contract for RAF air-to-air refueling with previous arrangements is impossible because the Ministry of Defence did not record costs of in-house provision in a way that enabled comparison (National Audit Office, 2010).

The rationale for this exploits the distinctive nature the military employment contract. Although voluntarily entered into, they share some aspects of slavery; servicemen have no say over when and where they serve, or what they are asked to do. Only government may enforce such contracts, and it typically uses a mix of military and civilian labour when providing military activities in-house (using the armed forces). Private firms can only hire civilian labour. Given this, outsourcing military services to private firms requires replacement of military labour with civilian labour. The degree to which such substitution occurs under in-house provision offers an insight into how much may be undertaken through outsourcing without compromising operational effectiveness: a high elasticity of substitution between military and civilian labour suggests that the scope for efficient outsourcing is large (since the defence department is prepared to undertake lots of labour substitution when undertaking an activity in-house); a low estimate suggests that the scope of outsourcing is limited, at least without adversely affecting output or capabilities.[4]

This article follows the approach of Ridge and Smith (1991) and MacDonald (2006) who estimated the elasticity of substitution between capital and military labour and incorporates civilian labour as a third factor in the military production function in order to explore the possibility of substitution between military and civilian labour. Two previous papers have considered substitution between labour types in military production functions. Smoker (1979) examined the cost implications of the mix of military and civilian labour in the US Department of Defense finding that replacing a military post with a civilian job frequently leads to cost savings, but in 40% of cases actually increases the costs of performing that role. Albrecht (1979) used a similar, though more disaggregated, production function to that used here to consider the efficient allocation of experienced and inexperienced military manpower in seventeen United States Air Force occupational specialities. A similar approach

[4]Rather than substituting civilian labour for the military labour they are unable to hire, it is possible that private contractors will instead substitute equipment for military labour. Previous studies suggest that the elasticity of substitution between capital and military labour within a (two factor) military production function is low: Smith *et al.* (1987) estimated it to be around 0.6 in a 1976 cross section of countries. For UK time series data MacDonald (2006) obtained and estimated elasticity of close to zero respectively. These results suggest that the scope for replacing military labour with capital is not large.

is used in the literature investigating substitution between more and less educated workers (e.g. Ciccone and Peri, 2005; Katz and Murphy, 1992).

The remainder of the article is devoted to obtaining an estimate of the elasticity of substitution between military and civilian labour within the UK's Ministry of Defence (MOD) over the period 1970–2008. Estimates of the elasticity are obtained by estimating the relative demand for military and civilian labour. To account for the likely endogeneity of relative wages instruments based on the relative supply of military labour are used: the proportion of the population young enough to serve in the armed forces and the numbers of young people in full-time education. The estimated long run elasticity is around 0.75, though a value of 1 cannot be rejected, suggesting that there remains further scope for outsourcing military activities in the UK over and above that already undertaken. As well as allowing inference as to the scope for efficient outsourcing to be made, an accurate estimate of the elasticity of substitution between military and civilian labour may also allow forecasts of the armed forces' labour costs, and the implications of aging populations, to be improved.

The next section outlines the approach taken and derives the relative demand for military and civilian labour. Section 3 details the data used and justifies the instruments used to account for the endogeneity of relative wages. The results are presented and discussed in Section 4 and finally some conclusions are drawn.

2 Approach

Three factors are used in the production of defence: military labour, L_M, civilian labour, L_C, and capital, K (comprized all factors other than labour). Military output, M, is produced according to the military production function:

$$M = f\left[K,\ A\left[\eta L_M^{\theta} + (1-\eta)\, L_C^{\theta}\right]^{\frac{1}{\theta}}\right] \tag{1}$$

Labour and capital enter the production function in a (weakly) separable way such that military and civilian labour are first combined according to a constant returns to scale, constant elasticity of substitution (CES) labour aggregation function. This aggregate labour input is then combined with capital to produce output. A CES aggregation function is chosen because, although it may be desirable to allow the elasticity of substitution between labour types to change over the sample period, the small sample size (39 observations) makes this unfeasible.

If labour and capital are separable, the relative factor demand for military labour depends only on the labour aggregation function.[5] The elasticity of substitution between military and civilian labour is $\sigma = 1/(1-\theta)$.

Given the military production function (1), if: the military are cost-minimizers; the level of output is exogenously given by government; and input prices are exogenously given, then the logged relative demand for military labour (L) may be written as:

$$L = a - \sigma W \tag{2}$$

where $L = \ln(L_M/L_C)$, $W = \ln(W_M/W_C)$ and W_M and W_C are military and civilian wages respectively.[6]

Although deriving the relative demand (2) requires a number of troublesome assumptions (especially separability and constant returns), its advantage is that it allows the elasticity of substitution between military and civilian labour to be estimated without requiring information on either the stock and price of capital or defence output. Data on the stock and price of military capital are simply not available. Defence output is difficult to define, let alone measure. It may be considered to be peace and security, whether achieved through deterrence or conflict; the value of lives saved (Sandler and Hartley, 1995); force readiness

[5] Separability is not an innocuous assumption: it implies the (untestable without data on capital) restrictions that the ease of substitution between each labour types and capital are both equal and unaffected by the stock of capital.

[6] Although the same relative demand might also be obtained by adopting a simple three factor CES production function, or Sato type two level CES production function. The interpretation relying on separability is preferred because it avoids the need to assume that the elasticity of substitution between labour types and capital is the same as the elasticity of substitution between labour types.

or capabilities (Warner and Asch, 1995; Ministry of Defence, 2004; Anagboso and Spence, 2008). Many of these aspects of output are unmeasurable and there is no single measure which captures its multifarious nature.

There are two major difficulties with obtaining an estimate of σ using Equation (2). The first is that it implicitly assumes instantaneous adjustment of labour demands to changes in wages. Military labour, however, takes time to adjust because it take time to train recruits, military employment contracts are relatively long, and there is a need to maintain an appropriate mix of experience and rank. To account for this, (2) is taken to be the desired relative demand for labour (L^*) in a partial adjustment process:

$$L_t = L_{t-1} + \lambda \left(L_t^* - L_{t-1} \right) \tag{3}$$

with the adjustment parameter $\lambda \in [0, 1]$ and expected to lie in the upper half of its permissible range. Equations (2) and (3) yield the basic estimating equation:

$$L_t = \alpha + \beta_1 \mathrm{ln} L_{t-1} + \beta_2 W_t \tag{4}$$

Equation 4 allows estimates of the short-run ($\lambda\sigma = -\beta_2$) and long-run ($\sigma = \beta_2 / \left(\beta_1 - 1\right)$) elasticities of substitution between military and civilian labour to be obtained.

The second difficulty is the likely endogeneity of the relative wage for military labour, W_t. As the relative numbers of military and civilian labour employed by the MOD and the wage premium for military labour are simultaneously determined by supply and demand, the relative wage of military labour on the right hand side of (4) is likely to be endogenous. To account for the endogeneity of the relative wage two instruments based on the relative supply of military labour are proposed. If valid instruments, these allow Instrumental Variables estimation to obtain consistent (if not unbiased in finite samples) estimates of (4). Both instruments are related to the relative supply of military labour, and are suggested by the key challenges to recruitment and retention facing NATO members (NATO, 2007). The first is the proportion of the labour force eligible for military service, the second is the number of young people in full time education. They are detailed in Section 3. The identifying assumption is that shifts in each are independent of expected shifts in the relative demand for military labour.

3 Data and instruments

The data used to estimate the long- and short-run elasticities of substitution between military and civilian labour are time-series for the UK over the period 1970 to 2008.[7] The ratio of military to civilian labour employed, L, is represented by the ratio of the reported strength of the UK regular armed forces to the number of MOD civilian employees, both as at 1st April each year.[8] The measure of civilian labour required in Section 2 (L_C in Equation (1)) is total inputs of civilian labour into production of defence. This includes both civilian labour employed directly by the MOD and indirect inputs on civilian labour used in the production of contracted-out defence activities. Data on the number of staff involved in the production of contracted out defence activities does not exist, so the number of civilians directly employed by the MOD is used here as a proxy for total civilian labour inputs. The omitted civilian labour inputs from contracted-out activities is likely to become increasingly important towards the end of the sample. In order to account for this increasing importance a trend is added to Equation (4) when estimated. It also allows for the possibility of a trending component in the efficiency parameter, A, of the labour aggregation function within Equation (1).

[7] The data are taken from various issues of the Annual Abstract of Statistics (Office for National Statistics, various years), UK Defence Statistics (Ministry of Defence, various years) and the Statement on the Defence Estimates Vol II (Secretary of State for Defence, various years), Education and Training Statistics UK and its predecessor Education Statistics UK (Department for Education, various years). Where different issues contain different figures the later (presumably revised) figures are preferred.

[8] Strength of the regular armed forces excludes personnel locally entered overseas (such as Gurkhas), mobilized reservists and reservists on Full Time Reserve Service. MOD civilian employees are both UK based and locally engaged. In 2004 the MOD changed the way it counted its civilian staff. Consequently, the number of civilian employees reported since 2004 is not comparable with earlier years. To avoid discontinuity, the numbers of civilian employees in years 2004-2008 have been calculated by inflating the reported 2003 figure by the annual percentage increase in MOD Level 0 civilian staff.

The ratio of military to civilian wages, W, is represented by the ratio of MOD expenditure on military and civilian personnel. Expenditure on personnel is preferred to basic wages because it better reflects the total costs of employing each type of labour. The MOD will alter its relative demand for military labour not only in response to changes in relative wages, but also to changes in the other costs of employing military rather than civilian staff. In addition to basic wages, the overall costs of employing military labour include employment include the costs of allowances paid, recruitment, retention, retirement and death benefits, training, housing, etc. (Sandler and Hartley, 1995). Whilst some of these additional employment costs are also paid for civilian labour, they are likley to be higher for military labour: the overall employment costs of military labour may be as much as double basic wage costs (Warner and Negrusa, 2006).

The instruments used to account for the endogeneity of relative wages are both based on the relative supply of military and civilian labour to the MOD. The first is the proportion of the labour force of a suitable age to be recruited into the armed forces. Only the relatively young have the capacity to develop the requisite fitness to serve in the armed forces so the pool of potential recruits for military labour is only a fraction of the entire labour force. Civilian labour employed by the MOD (or indeed private firms) may be any age, and may be drawn from the entire labour force. This is reflected in the age distributions of the MOD's military and civilian labour: on 1st April 2011 50.2% of armed forces personnel were aged 19-29 compared with only 9.7% of MOD civilians, and only 2.5% were aged 50 and over compared with 42.5% of MOD civilians (Ministry of Defence, 2011). The armed forces are also overwhelmingly male - on 1st April 2011 90.4% of full-time armed forces personnel were male. In contrast, only 52.7% of MOD full-time civilian employees were male (Ministry of Defence, 2011). Given this, the variable used to represent the proportion of the working age population eligible for military recruitment, POP, is the UK population of males aged 15-29 divided by the total working age population (males aged 15-64 and females aged 15-59). The justification for POP being a valid instrument is that the smaller the proportion of the labour force eligible for joining the armed forces then, for any given level of military labour, the greater the proportion of the pool of potential recruits that must be recruited to maintain a given level of military labour. Since the UK has an all volunteer force, recruiting a greater proportion of the pool of potential recruits requires a higher wage premium to be paid to military labour. The factors determining POP are demographic and outside the MOD's control, so the identifying assumption that changes in POP are independent of changes in the relative demand for military labour seems reasonable.

The second instrument proposed is the numbers of young people in full-time education, EDU. This is represented by the number of students (in millions) in full time Further or Higher Education in the UK plus the number of school pupils aged (as at 31st August each year) 15 or over. The rationale for EDU being an appropriate instrument is that the armed forces tend to recruit mainly those with fewer educational qualifications. The armed forces traditionally recruit school leavers (with the possible exception of officers who make up only 17% of strength) and large numbers of unskilled and lower educated workers. An increase in the numbers of young people pursuing Further and Higher Education reduces this pool of potential recruits targeted by the armed forces (National Audit Office, 2006).

Furthermore, the educational qualifications of military labour are considerably below the national average. Although the the MOD does not routinely collect information on the educational background of its personnel (National Audit Office, 2006), around 45% of young people in the UK leave school with 5 GCSEs graded A-C whereas Army recruits average only 0.9 GCSEs graded A-C (House of Commons Defence Select Committee, 2005). Many recruits opt for a career in the armed forces as a last resort - when they have exhausted their alternative career options.[9] Pursuing education for longer opens up a greater range of alternative careers. If the proportion of potential recruits remaining in education increases, since when they qualify they are less likely to opt for a military career, the relative supply of military labour will fall.

Although government policy has driven the increase in Further and Higher Education

[9] A survey of British Army recruits (albeit with a small sample and in only one city) showed that 40% joined as a last resort (House of Commons Defence Select Committee, 2005, Ev 255-256).

participation rates in the UK since the 1980s, these policies have not been driven by the MOD. It seems reasonable to assume that changes in the numbers of young people in education are independent of the MOD's relative demand for military labour.

4 Empirical results

Table 1 reports the results of estimating Equation (4) with a trend added. OLS results are reported in the second column, and separate just-identified IV estimates for each of the instruments in the third and fourth columns. POP and EDU are used in separate models to minimize concerns as to their potential weakness since just-identified IV estimates are median unbiased (Angrist and Pischke, 2009). OLS estimates are presented both for comparison and because it is not certain that the wage ratio is endogenous. Military wages in the UK are (in practice if not in principle) set independently by the Armed Forces Pay Review Body (AFPRB). In the market for civilian labour, the MOD is a relatively small employer in the market and might be thought of as facing a perfectly elastic supply of civilian labour. If this is the case then the wages of MOD civilians are exogenously determined in the overall labour market. If both civilian and military wages are exogenous then OLS will be a consistent and unbiased estimator.

In Table 1 the serial correlation tests suggest the models suffer from serially correlated errors (though provide only weak evidence for the OLS and POP estimates). This may well be due to misspecified dynamics with the partial adjustment process applied to the basic relative demand (2) not fully capturing the MOD's difficulties of adjusting levels of military labour. Although not reported, richer dynamic structures have been estimated allowing a second lag of the dependent variable, L_{t-2}, and an Autoregressive Distributed Lag, ADL(2,2), model. Allowing for further lags was felt to compromise (the already small) sample size too far. For each model the restrictions necessary to obtain the specification in Table 1 cannot be rejected at any conventional level. Because of this, all test statistics in Tables 1 and 3 are robust to serial correlation.

Table 1: Estimates of the relative demand for military labour

Instrument	–	*POP*		*EDU*	
Estimator	OLS	IV	FULLER	IV	FULLER
Constant	0.05***	0.06***	0.06***	0.10***	0.09***
	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)
Trend	0.006***	0.007***	0.007***	0.011***	0.011***
	(0.002)	(0.003)	(0.002)	(0.004)	(0.003)
L_{t-1}	0.75***	0.70***	0.70***	0.56***	0.58***
	(0.09)	(0.11)	(0.11)	(0.16)	(0.14)
W_t	-0.18***	-0.24**	-0.23**	-0.42**	-0.39***
	(0.07)	(0.10)	(0.10)	(0.17)	(0.15)
Long run elasticity	-0.704***	-0.794***	-0.790***	-0.958***	-0.941***
	(0.238)	(0.240)	(0.239)	(0.236)	(0.232)
N	39	39	39	39	39
$AC_1 - \chi^2(2)$	3.07*	3.67*	3.62*	9.73***	9.03***
$AC_2 - \chi^2(2)$	3.82	4.48	4.44	9.75***	9.07**
$HET_1 - \chi^2(1)$	0.01	0.001	0.0004	0.08	0.06
$HET_2 - \chi^2(3)$	3.44	0.24	0.26	0.62	0.61
RESET $- \chi^2(3)$	8.42**	2.93	3.01	3.12	3.37
Endogeneity $- \chi^2(1)$	–	0.77		4.41**	

Notes: Newey-West serial correlation robust standard errors reported in parentheses using bandwidth $3 \simeq T^{\frac{1}{3}}$ (Baum *et al.*, 2007). Significance levels denoted by * $p<0.10$, ** $p<0.05$, *** $p<0.01$. RESET tests based on serial correlation robust VCE: for OLS test is Ramsey type test, for IV is Pesaran and Taylor's (Pesaran and Taylor, 1999) test; both use the square, cube and fourth power of the (forecast for IV) predicted values. Serial correlation tests based on standard VCE: for OLS are Breusch-Godfrey test for 1 and 2 lags, for IV are Cumby and Huizinga tests. Heteroskedasticity tests are Koenker's test for OLS using fitted values (HET_1) and all regressors excluding constant as indicator variables (HET_2); for IV the corresponding tests are Pagan-Hall tests using the level of the fitted values of the dependent variable (constructed using the first stage instruments) and all exogenous variables except the constant (included and excluded instruments). The Endogeneity test is a Durbin-Wu-Hausman test.

Table 2: Tests for structural break at the end of the Cold War

	OLS	IV	
Break in:		*POP*	*EDU*
1990	7.47	4.70	0.61
1992	1.90	0.21	0.81
1994	3.02	1.64	1.94

Notes: Significance levels denoted by * p<0.10, ** p<0.05, *** p<0.01. All test statistics distributed as $\chi^2(4)$.

Since the sample straddles the end of the Cold War, the possibility of a structural break at the end of the Cold War must be considered, especially since evidence of a break has been found in similar samples (MacDonald, 2006). Whilst a structural break may be suspected, it is not a foregone conclusion since the end of the Cold War resulted in a reduction in the volume of defence produced rather than a shift in the fundamental technology of defence. Table 2 shows the results of applying Chow type tests of parameter stability allowing for a break in each of the models considered over a range of feasible break points. None suggests the presence of a structural break at the end of the Cold War in any of the models in Table 1.

Although formal testing of the assumptions used in Section 2 to derive the relative demand (4) is not possible without data on capital, an informal check may be provided by including in the relative demand a measure of defence output and testing its significance. Logged real military expenditures (frequently used as a proxy for output (MacDonald, 2006; Ridge and Smith, 1991; Smith *et al.*, 1987)) is not significant at any conventional level when added to any of the models in Table 1. This provides some reassurance, since significance would suggest that the true technology was nonhomothetic making a separable CES production function inappropriate.

The validity and strength of *POP* and *EDU* as instruments for relative wages must also be addressed. This is especially important given the small sample used here, since if they are not strongly correlated with the relative wage, W, any IV estimates relying upon them may be seriously and give misleading estimates of significance.

Table 3 reports the first stage results for the IV models in Table 1. The first stage coefficients on each of the instruments are both significant and of the expected signs: for POP a fall in the proportion of the population eligible for military service causes an increase in the relative wages for military labour; for EDU an increase in the numbers. The magnitudes of the coefficients in Table 3 also seem reasonable. The significant statistics for the (robust to non-iid errors) Kleibergen and Paap (2006) tests of underidentification suggests both models are identified.

For the model using POP as an instrument, the F-statistic for excluded instruments of 25.94 exceeds the Stock and Yago (2005) critical value for 10% maximal size (16.38). On this basis POP does not appear to be a weak instrument. However, the F-statistic for EDU of 8.725 suggests EDU is a weak instrument for the wage ratio – the Stock and Yogo critical values indicate a true rejection rate of more than 15% and suggest that EDU is weak enough to cause significant biases in the estimated coefficients. Given this, estimation using POP as an instrument is preferred to using EDU.

Focusing on the results of the OLS and POP models in Table 1, the apparent absence of conditional heteroskedasticity justifies the use of IV over a more general estimator such as GMM.[10] The estimated coefficients on L_{t-1} are in the upper half of the permissible $[0, 1]$ range as expected. The coefficient of primary interest is that on W_t – the short run elasticity of substitution between military and civilian labour. These are of the expected sign, significant in both models and relatively similar. The estimated long-run elasticities are also significant and relatively similar (at least not significantly different). The results suggest that a 1% increase in the relative wages of military labour causes a 0.2% fall in the military proportion of MOD labour and that over time this rises to around 0.75%. For neither model can a hypothesis that the elasticity of substitution between military and civilian labour is equal to one be rejected. An elasticity of one would be consistent with the MOD having a fixed proportion of expenditure allocated to personnel which it switches between military and

[10] Under conditional homoskedasticity both IV and GMM are consistent and asymptotically efficient, but GMM may have poor small sample properties (Baum *et al.*, 2003).

Table 3: First Stage and Reduced Form Estimates

	First stage estimates		Reduced form estimates	
Dependent variable	W_t		L_t	
Instrument	*POP*	*EDU*	*POP*	*EDU*
Constant	1.63***	-0.51**	-0.32***	0.31***
	(0.28)	(0.24)	(0.15)	(0.10)
Trend	0.008**	-0.02	0.005***	0.021***
	(0.004)	(0.02)	(0.002)	(0.006)
L_{t-1}	-0.48***	0.06	0.82***	0.54***
	(0.15)	(0.32)	(0.08)	(0.14)
POP	-7.48***		1.77**	
	(1.47)		(0.76)	
EDU		0.44***		-0.19***
		(0.15)		(0.06)
N	39	39	39	39
RSS	0.133	0.204	0.0428	0.0389
Adjusted R^2	0.761	0.633	0.977	0.979
Kleibergen-Paap – $\chi^2(1)$	9.89***	6.34**		
F-statistic – $F_{1,35}$ (excluded instruments)	25.94	8.73		

Notes: All statistics robust to serial correlation using Newey-West VCE with bandwidth $3 \simeq T^{1/3}$(Baum *et al.*, 2007). Serial correlation robust standard errors in parenthesis. Significance levels denoted by * p<0.10, ** p<0.05, *** p<0.01. Kleibergen-Paap (2006) is test of underidentification.

civilian staff in response to changes in relative prices.

For the *POP* model, a Durbin-Wu-Hausman test cannot reject a hypothesis that the relative wage is exogenous (because the estimates are so similar). If true, OLS estimation is consistent and unbiased and the OLS estimates should be preferred on efficiency grounds. That the two models produce such similar results is reassuring.

The significant RESET statistic of the OLS results is a little troubling, but not surprising given the simple form adopted for the relative demand used here. Whilst there is a possibility that it is picking up endogeneity (since the very similar *POP* estimates do not have a significant statistic in the analogous test) or serial correlation (Leung and Yu, 2001), it is most likely to reflect some missing nonlinearities or general misspecification. It suggests that the results in Table 1 are to treated cautiously and interpreted as a broad indication of the substitution possibilities between labour types in the military production function.

It is difficult to interpret the estimated elasticity precisely because it has been estimated for directly employed MOD labour and not the total civilian labour (MOD and private contractor employed) used in the production of defence demanded by L_C in equation 2. The rise in the MOD's reliance on outsourced provision over the sample period means that the estimate produced above is an underestimate of the true elasticity, but the magnitude of the difference between the estimated and true values of σ is unknown. What is certain is that some cases of successful substitution are not captured (e.g. the successful use of civilian labour in the provision of support for fast jets (National Audit Office, 2007)). This difference suggests that the estimated elasticity is best interpreted as estimating the scope for substitution over and above that caused by outsourcing arrangements already entered into. It suggests that there is some (probably limited) scope for further efficient outsourcing of military activities in the UK.

The dataset used also imposes some further limitations: Firstly, the estimates are obtained from a small sample of only 39 observations. Not only is the sample small, but the sample period encompasses several large changes in the strategic environment facing the UK. Although the end of the Cold War does not seem to affect parameter stability, the sample size makes it impossible to investigate the full range of possible structural breaks and the possibility that the elasticity of substitution has changed over the sample period.

Secondly, the number of directly employed MOD civilians fell sharply during the 1980s due to the programme of privatisations, such as that of the Royal Dockyards. This fall may account for the trending nature of L_M/L_C, but is unrelated to relative wages. Thirdly, military wages are set by the AFPRB at the level of comparable civilian occupations plus some X-factor. This means that there is not a large amount of variability in the wage ratio, and reduces the precision of the estimates obtained.

Finally, there are some limitations due to the derivation of the relative demand for military labour used to estimate the elasticity. Separability and constant returns have been discussed above and partially addressed by testing the significance of military spending. However, cost-minimisation by the MOD is also required in the the derivation of the relative demand (2). The military are commonly perceived as being inefficient, at least anecdotal (for instance in equipment procurement). Indeed, the most common justification for contracting-out is that the private sector can produce efficiently, whereas the public sector cannot. If the MOD was not at all concerned about cost one would expect an elasticity of (close to) zero because it would define fixed roles for each type of labour with no substitution in response to changes in relative prices. Our results do not support this, as they suggest some substitution occurs within the MOD. However, if private firms are able to use labour more flexibly – which is frequently cited as one of their advantages – they will have greater substitution possibilities than the MOD. This would cause our estimates, based solely on the MOD's past behaviour, to underestimate the scope for substitution of civilian labour for military labour, and so to underestimate the scope for outsourcing military activities.

5 Conclusion

This article uses time series data for the UK over the period 1970–2008 to estimate the elasticity of substitution between military and civilian labour within the MOD based on the relative demand for military labour. The long run elasticity is found to be significantly different to zero. The best point estimate is about 0.75 and the elasticity is likely to be between 0.5 and 1, though a value of 1 cannot be rejected. The article argues that the elasticity can be used to infer the likely scope for efficient outsourcing of military activities. The estimated elasticity of 0.75 suggests that there remains some limited scope for further efficient outsourcing of MOD activities in the UK. It does not, however, suggest precisely which activities should be outsourced.

Although both OLS estimates and IV estimates using the proportion of the population eligible for military service as an instrument produce very similar estimates, the results have a number of caveats: i) they are based on a small sample size and this restricts the form of the relative demand estimated to be relatively simple; ii) the data used for estimation may not be close enough to the theoretical variables required to allow accurate estimates to be obtained; and iii) the approach adopted here relies on a number assumptions which may not be valid. The latter two caveats mean that the estimated elasticity may understate substitution possibilities and so the potential for outsourcing.

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