Discussion Papers in Economics

ENTREPRENEURSHIP, SPILLOVERS AND PRODUCTIVITY GROWTH IN THE SMALL FIRM SECTOR OF UK MANUFACTURING

By
Hany El Shamy
(University of Surrey)
&
Paul Temple
(University of Surrey)

DP 07/08

Department of Economics
University of Surrey
Guildford
Surrey GU2 7XH, UK
Telephone +44 (0)1483 689380
Facsimile +44 (0)1483 689548
Web www.econ.surrey.ac.uk
ISSN: 1749-5075

31 July 2008

Entrepreneurship, Spillovers and Productivity Growth in the Small Firm Sector of UK Manufacturing

by
Hany El Shamy¶
Paul Temple¶*

Abstract

This paper considers the sources of technological change and productivity growth in the small firm sector of UK manufacturing over the period 1973-2002, focusing on the mechanisms by which spillovers occur between the large firms which perform the bulk of R&D and smaller firms which are the recipients. It is argued that the current volume of domestic R&D generates profitable and high productivity opportunities for smaller firms. However this mechanism ignores the ways in which R&D also contributes to the more general knowledge base available to small firms as codified information which frequently takes the measurable form of industrial standards. A simple model of labour demand among small manufacturing is developed which employs two measures of technological activity intended to capture both these channels. A co-integrating relationship based upon an augmented labour demand equation is established for UK manufacturing, showing the relevance of both channels for the explanation of productivity growth in the small firm sector.

Key Words: Small firms; productivity; technological change; R&D; standards.

JEL codes: J23, L25, L26, O32

* The authors wish to thank Stephen Drinkwater and Lester Hunt for their helpful comments.

¶ Department of Economics, University of Surrey, Guildford, GU2 7XH, UK; Corresponding author: p.temple@surrey.ac.uk

1. Introduction

At least some of the stylized facts concerning the history of UK manufacturing over the last fifty years are well known. First and foremost is the decline of manufacturing as a source of employment - for over more than four decades. At its peak in 1966, manufacturing employees in Britain totalled just short of 8 ½ million – nearly 37% of the total. Today the figure (for employee jobs in 2007) is just 2.8 million, a little short of 11% of the total available. The decline has been more or less continuous and indeed seems to have accelerated in the relatively quiescent macro-economic climate of the past decade or so: in 1992, the share of jobs in manufacturing was close to 18% a decline of 53% in just 15 years.

As a second stylised fact it is widely recognised that the decline in employment partly reflects more rapid productivity growth in manufacturing than in the economy more generally. Focusing on the last 15 years, we find that manufacturing output grew at a sluggish 0.8% per annum between 1992 and 2007, which, combined with substantial job loss over the same period, amounts to labour productivity gains of 3.3% per annum. This compares with a whole economy figure of 2.1% per annum.

Nowadays discussion of the implications of these phenomena is somewhat muted and most commentators are more sanguine than in the hey-day of debates about 'de-industrialisation' in the 1970s. However a third stylised fact sometimes gives pause for thought. That is the slow growth in business R&D spending – the lion's share of which continues to be conducted within manufacturing industry. The latest available data suggests that – using GDP at market prices as a deflator – the growth in the volume of R&D spending in manufacturing exceeded output growth (a little) at 1.1% per annum between 1992 and 2006. Using OECD data we were however able to construct a series for the longer period. Figure 1 shows the volume of business spending over the longer period from 1973-2002. It shows a long period of stagnation between the early 1980s and the mid-1990s, after which there was some recovery.

Probably less well known than the three stylised facts discussed above has been a remarkable shift in the share of employment in manufacturing toward smaller firms. Compared to the remorseless fall in employment among large firms, employment in the small firm sector has declined far less. As shown in Figure 2, between 1973 and 2002, the sector comprising firms employing more than 500 employees employed more than 4 million workers

Figure 1

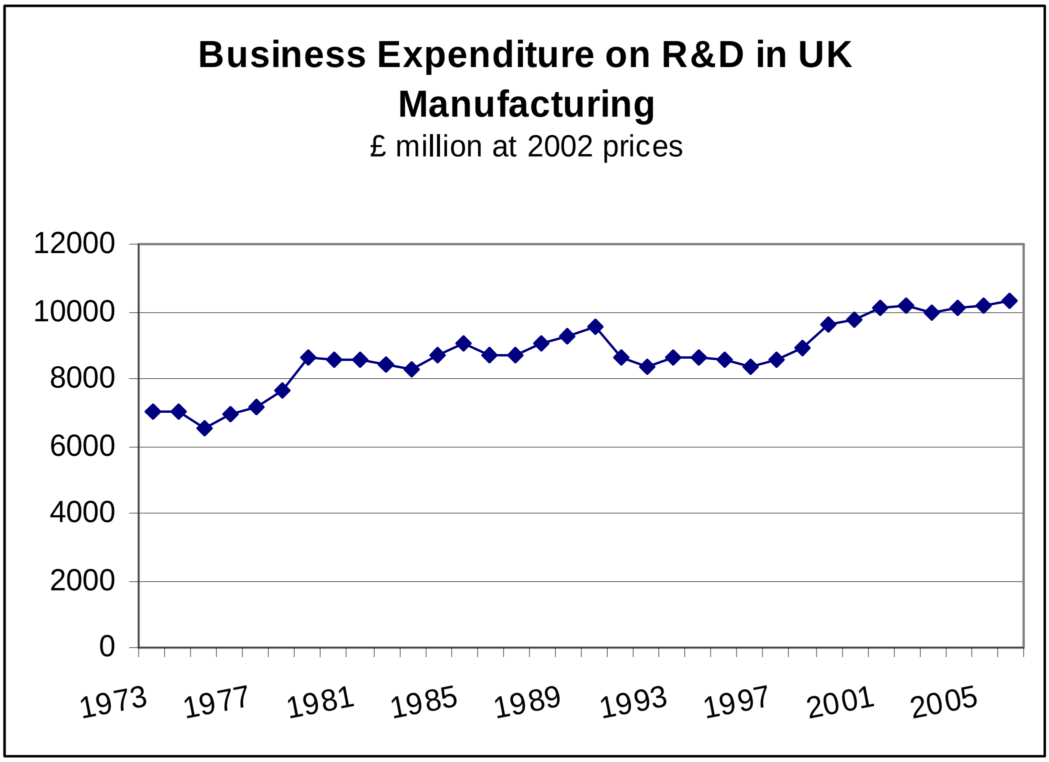
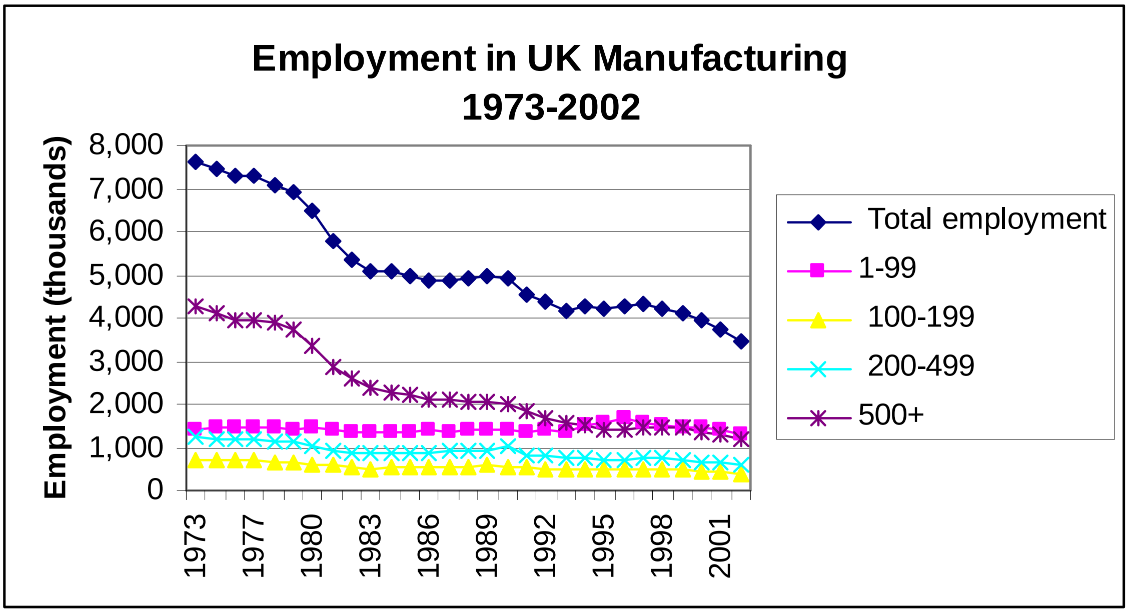


Figure 2



in 1973 compared to just a little more than 1 million in 2002 – close to the total loss of jobs in UK manufacturing over that period. By contrast, in generating more than 1 million jobs, employment among small firms of fewer than 100 employees is very similar today to the level of 1973.

What is the relationship between the stylised facts? More particularly from the point of view of the current paper, how does the R&D 'slowdown' - reflecting business decisions made mainly by larger firms - impact upon output, employment and productivity among smaller firms? Part of the interest in this question stems from what it tells us about the nature of technology spillovers – not least between large firms which conduct most formal R&D and smaller firms. In order to consider the underlying relationships we develop a simple labour demand model of how R&D impacts upon employment and productivity, augmenting the direct role of R&D with industrial standards.

The paper is organised as follows. The next section considers the relationship between technological change and productivity growth in the small firm sector. Section 3 develops a simple labour demand model of how R&D impacts upon employment and productivity among small firms. Section 4 augments the model to consider the role of both domestic R&D and industrial standards, establishing a co-integrating relationship between the variables. Section 5 provides some concluding discussion.

2. R&D, Technological Change and Productivity Growth in the Small Firm Sector

There is now a long history of studies which have attempted to ascertain the sources of technological change and their links to economic growth. Many of these have been based upon a production function approach, in which an indicator of technological input is been used, alongside conventional inputs, in a deterministic relationship to outputs. One frequently used input is R&D. Here we concentrate on R&D and what a production function approach - augmented to include R&D - can tell us about the technological spillovers which impact upon small firms.

As an input measure, R&D fits neatly into the production function approach. Typically, growth accounting techniques have been used to obtain a measure of technological change – total factor productivity (TFP) – which are then used as a dependent variable with R&D considered as a measure of input into innovation. There are basically two ways in which this can be done. The first is to use R&D to create a measure of 'knowledge capital' (R say) which acts multiplicatively on output Q.

$$Q = A(t)\, R^{\lambda} K^{\alpha} L^{\beta} \tag{1}$$

where λ is a constant the elasticity of output with respect to knowledge capital. If we have constant returns to scale returns to scale,
and $A(t) = A_0 R^{\lambda}$ then:

$$T = A_0 R^{\lambda} e^{\mu t} \tag{2}$$

Where T is the *level* of TFP and $e^{\mu t}$ is used to capture unobserved influences which are however trended, and A_0 and μ are constants. Taking logs:

$$\log (T) = \log A_0 + \lambda \log R + \mu t \tag{3}$$

Differentiating with respect to time we get the proportionate *rate of change* of TFP as:

$$\Delta T/T = \lambda \Delta R/R + \mu \tag{4}$$

Using the fact that $\lambda = (\Delta Y/Y)/(\Delta R/R)$, this last equation can be rewritten as:

$$\Delta T/T = (\Delta Y/\Delta R)(R/Y)(\Delta R/R) + \mu = \varrho \Delta R/Y + \mu \tag{5}$$

Where $\varrho = \Delta Y/\Delta R$

(5) provides the basis for a second type of estimating equation in which the coefficient ϱ on $\Delta R/Y$ (the ratio of the increment of knowledge capital to output) can be interpreted as a 'rate of return' to current investment in R&D.

Equations (3) and (5) have both featured in the empirical implementation literature. They have been found applied at various levels from the individual firm to whole economies, with different levels of aggregation permitting attempts to measure technological spillovers (for the classic discussion see Griliches 1992).

Estimation and interpretation of an equation such as (3) or (5) involves several difficulties. There is of course the nature of the indicator itself. R&D

activities comprise creative work "intended to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications" (Freeman, 1982). The popularity of R&D in econometric estimation stems from the ready availability of the data and the consistency of definition, since - for statistical purposes - both R&D personnel and R&D expenditures by firms are defined according to the OECD's Frascati Manual (7th edition OECD 2002), which defines R&D in terms of the production of new knowledge or the new application of existing knowledge (Smith 2005). It therefore excludes many activities – such as design, market research or training activities which may be relevant to technological change, especially in the small firm sector; almost by definition R&D measures are 'biased' toward larger firms which are more likely to have formal specialised R&D departments. The definition is relatively straightforward to apply in the context of the formal R&D departments which tend to exist only in the case of large firms.

Patel and Pavitt (1995) observe other limitations to R&D data. First there is a bias toward science-based industries – in chemicals and electrical and electronic industries – where formal R&D departments are more common. In engineering, production engineering and design department may be more important as generators of technology. The second issue the authors raise arises from the fact that R&D expenditures give little indication as to their *direction* – toward product versus process innovation for example. Here Patel and Pavitt (1995) note the limitations of breakdowns of R&D activities by industry, observing that R&D is allocated according to the principal activities of the firm engaging in R&D. This ignores the fact that much R&D is based around the development of *processes* and associated equipment in many industries. Therefore the share of inventive and technological activity based around mechanical and production engineering is underestimated by the share of R&D undertaken by the mechanical engineering sector of the economy. Similarly in IT, much software development takes place (like production engineering) outside formal R&D departments (Patel and Pavitt 1995).

To understand some of the problems associated with the interpretation of this type of approach relevant for this paper however, consider implementing (3) at the level of a subset of firms constituting an 'industry'. A stock of knowledge at the industrial can be constructed constituting the knowledge available at the level of the industry – mainly (as discussed above) – as a result of R&D investments by the larger firms in the industry.

Now consider an equation such as (3) implemented for just the small firms in a particular industry. The industry stock of knowledge can reasonably be regarded as ‘outside’ knowledge capital, for an equation which ‘augments’ (3):

$$log\,(T) = log\,A_0 + \lambda_1\, log\, R_{OWN} + \lambda_2\, log\, R_{OUTSIDE} + \mu t \qquad (6)$$

What can an econometric estimation of an equation such as (6) tell us about spillovers toward small firms? As it stands, at least three important points need to be made.

First, as noted above, R&D statistics are biased toward larger firms with formal R&D departments. Similar activities by smaller firms are likely to go under-recorded or not recorded at all. In the extreme case only large firms perform R&D will be recorded in the official statistics. Importantly however, knowledge investments by both sets of firms are responding to the technological opportunities in part at least created by a much wider knowledge base. Econometric estimates of productivity among small firm sector will falsely be attributed to spillover effects (to outside R&D) rather than design or other ‘non-R&D’ investments made by smaller firms in response to the underlying technological opportunities.

The second point concerning the implementation and interpretation of either (3) or (5) is the issue of the depreciation of knowledge. TFP growth in (5) can only be interpreted as a function of R&D intensity (R&D as a proportion of output) if the rate of depreciation is close to zero. In the case of (3) we need explicitly to consider the rate of ‘depreciation’ of knowledge capital. What do we know about such depreciation? The concept of the depreciation of knowledge is a subject that has so far been little explored, outside the recognition that there is a difference between the ‘private’ and ‘social’ rate of depreciation. For a firm creating knowledge, and treating it as an investment good, knowledge can depreciate quite rapidly. How fast depends upon a range of considerations dependent upon whether the knowledge is used by rival firms or is utilised by other firms in the supply chain, or even by quite unrelated firms. However, as the knowledge becomes more generally available among rival firms it no longer serves competitive advantage. While not assisting profitability of course, it still continues to assist productivity – the private rate of depreciation is faster than the social rate of depreciation. An equation such as (5) presumably only captures the social rate of depreciation. Preferably, it would be useful to have indicators of technological activity which reflect both high productivity/value added ‘entrepreneurial’ opportunities created by current R&D spending, and the absorption of new knowledge into a more generally available knowledge stock.

Both of the links between R&D spending and small firm productivity correspond to models of the product cycle (e.g. Vernon 1966; Abernathy, Utterback 1978, in which early stages of product development are characterised by uncertainty and firms experiment with a variety of designs). The knowledge involved in these early stages is highly tacit in character, while the flexibility required over inputs favours entrepreneurial activity by small firms. Of course this is not the only way in which knowledge may transfer between the performers of formal R&D and smaller firms. The standardization of technology requires that it be codified. Shared information lowers transactions costs. Some of this information is of course internalised within the firm and used (as in Vernon's model) as a means of technology transfer *within* the firm. Much on the other hand becomes part of the codified knowledge base which is incorporated in publicly available technical documents known as standards. As an indicator of technological activity these are discussed further in section 4.

A final and more practical point concerns the measurement of TFP among different size classes of firms. This requires knowledge of both inputs and outputs. On the output side, the degree of heterogeneity that exists between large and small firms make the use of a common deflator to measure output extremely hazardous. On the input side, at least as far as the UK is concerned, indicators of capital inputs simply do not exist across the size classes, nor do estimates of the capital stock, widely used as a proxy for capital inputs. Despite the arduous attempts of one of the authors to supply these missing data, it is useful (in the opinion of both authors) and maybe preferable, to consider a different approach in which the dependent variable at least is measured with more precision. Such a variable is the level of employment. Within orthodox economics at any rate, one way forward is then to explain employment using a labour demand equation, featuring, in addition to output and the real wage, explanatory variables intended to measure technological change.

3. A Model of Labour Demand

Rather than model and estimate an augmented production function for small firms, we argue that an alternative approach is to consider a model of employment in the small firm sector of UK manufacturing, using a standard labour demand approach (as surveyed for example in Hammermesh 1996).

A reasonably general specification of labour demand for current purposes based upon the constant elasticity of substitution (CES) production function is as follows. This particular specification allows for non-constant returns to scale; the lower case letters indicate the use of logarithms and the time subscript is suppressed:

$$l = \alpha_0 + \alpha_1 wa + \alpha_2 q + +\alpha_3 rd + \alpha_4 t + \mu \qquad (7)$$

Here, *l* is the level of employment, *wa* is the real product wage, and *q* is net output evaluated at constant prices in the small firm sector (firms employing less than 100 employees), *rd* is our indicator of the UK knowledge stock available in manufacturing,; *t* is a time trend which allows for unobservable influences on *l* but which is usually regarded as the result of Hicks neutral technological change. In a dynamic setting, consideration needs to be given to the lags involved. Employment is generally an autoregressive process and so a lagged dependent variable may be appropriate, although in the context of the small firms sector and the high rate of churn among small firms, it may be that responses to changes in the determinants of labour demand may be relatively rapid in this context and with the annual data to hand. However, the main interest is in the long-run and whether we can detect an influence of technological change on the level of employment.

The simplest model of employment and labour demand with technological change proxied by a time trend provides a natural starting point and a base line model. Table 1 displays some relevant summary data for the variables used in the following analysis and required by the basic theory.

Table 1

Summary Statistics:
Output, employment and real product wage among small firms in UK Manufacturing

data period 1973-2002
(annual data)

		mean	Standard deviation	minimum	maximum	change over period	average change over period
log of employment	*l*	7.26	0.05	7.18	7.42	-0.05	0.00
log of net output at constant prices	*q*	10.54	0.26	10.14	10.97	0.76	0.03
log of real product wage	*wa*	9.53	0.26	9.13	10.00	0.87	0.03

As can be seen from the final column, employment fell slightly over the period for which there are data, real output grew at around 2.6% per annum, while the real product wage grew reasonably strongly – at around 3% per annum.

Modern time series analysis begins with the idea of stationarity and the order of integration of the underlying variables. The regression technique of ordinary least squares provides consistent parameter estimates only if the variables are all stationary. However, it is possible for some vector combination of non-stationary variables to be stationary. This vector combination is then said to be co-integrated. Co-integration analysis is particularly relevant in the current context because it allows for the study of long-run relationships without the need to discuss particular short-run dynamic specifications, and it is the long-run relationship between knowledge largely produced by large firms and technological change among small firms that is the primary object of interest.

The concept of stationarity allows for the possibility of a deterministic time trend. Of the variables in Table 2, no clear trend can be seen for *l,* while *q* and *wa* may exhibit a deterministic time trend. Tests of stationarity using the standard augmented Dickey-Fuller (ADF) test are reported in the Appendix to this paper. They allow for up to three lags and for a trend in the case of *q* and *wa.* Also included are the adjusted R^2 and the Akaike Information Criterion (AIC) for comparative purposes. Implemented in STATA®, the results suggest that we cannot reject the hypothesis of a unit root in any of the three variables. For the variables to be considered stationary, we need to be able to reject the hypothesis of a unit root in the first differences of these variables. ADF test results for Δl, Δq , and Δwa are also shown in the Appendix. While the results are not completely clear-cut, the conclusion that the first differences of these variables are stationary seems reasonable.

Accepting that *l*, *q,* and *wa* are essentially I(1) variables, we can proceed to see whether a co integrating relationship exists between them as suggested by simple labour demand models with Hicks neutral technological change. A simple regression of *l*, *q,* and *wa* with the addition of a time trend (*yr*) yields the following result:

$$l = 9.293 + 0.727q - 0.629wa - 0.002yr \qquad (8)$$

Residual based tests suggest that this simple model does not cointegrate[1]. More important perhaps is the question of whether the result makes economic sense. It implies that technological change contributed nothing to employment change in the small firm sector since the coefficient on the time trend – although correctly signed – seems too small. One possible reason for the result is the mis-measurement of technological change. This is

[1] Results available from authors on request.

considered in the next section by providing alternative measures of technological change.

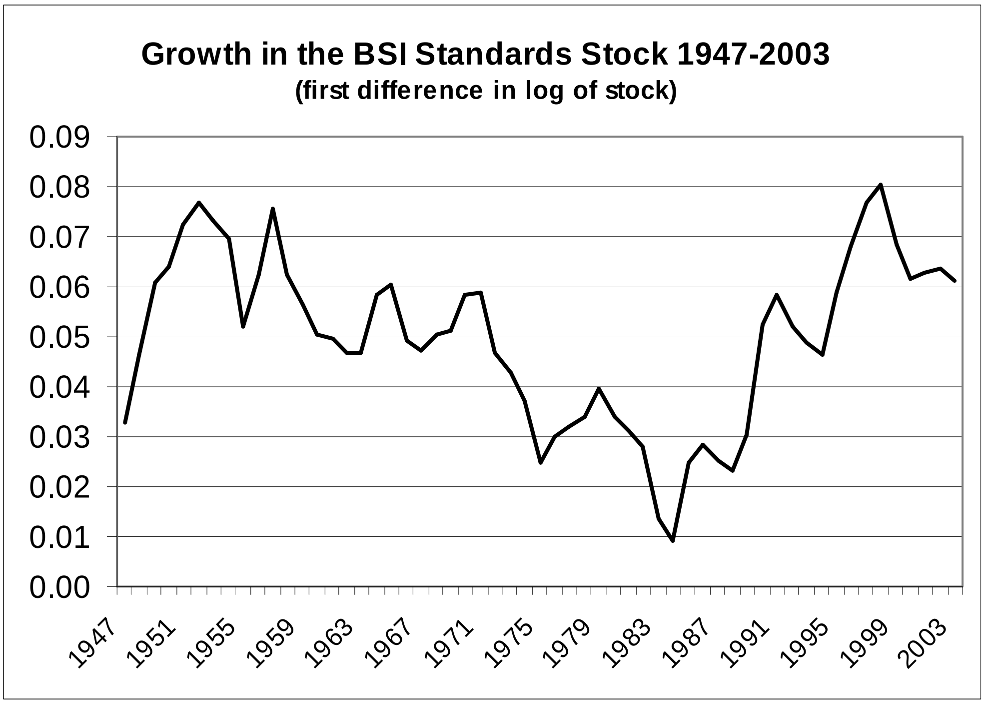
4. A Model of Labour Demand Augmented by Two Measures of Technological Activity

Our earlier discussion suggested that a measure of the entrepreneurial opportunities for small firms arising from technological activity could be proxied by *current* volumes of R&D spending – denoted here by *rdv*. However, simply including a proxy for these opportunities ignores the process by which R&D – and indeed other activities, including the knowledge generating activities of small firms – creates a more generally available knowledge stock for which the social rate of depreciation is rather low. There is a danger that these longer term consequences of R&D are being missed. For that reason this section considers an additional measure of technological activity that may be able to capture this effect. This measure – essentially a count of technical standards similar to the patent counts sometimes used in the literature – aims at capturing an important channel for the transfer of technology to the small firm sector. This channel is that of 'codified information' – i.e. information that takes the form of readily accessible knowledge in the form (here) of technical information – test procedures, product and process specifications - that communicate elements of a shared technological base. This information frequently takes the form of publicly available industrial 'standards' – published documents which carry the information, and which therefore provide a means of measuring the size and importance of this channel at the level of aggregate manufacturing.

There is now a long literature on the economics of standards. Economists observe that standards can be usefully defined standards in terms of what standards actually do (Temple and Williams, 2002), i.e. in terms of their economic function. These are now well recognised in the literature and a definitive treatment of the main functions (variety reduction, interoperability, minimum quality) of individual standards can be found in Blind (2004). At the aggregate level considered here however, standards both provide information which emanates from both domestic and international sources, but also serve to reduce transactions costs.

Technical documents in the form of industrial standards have different origins, but a major provider in the advanced economies and especially in the UK and Europe are national standards bodies (NSBs). In the UK, the NSB is the British Standards Institution (BSI). An important feature of this channel is that these documents (like patents) can be counted in ways that can be used for econometric analysis. Such a count was conducted by Temple et al (2004) as part of a project researching the 'Empirical Economics of Standards' for the Department of Trade and Industry in London (DTI 2005). The estimates were used to try and establish a co-integrating relationship between productivity, capital and standards at the level of the whole economy for the period 1948 – 2002 (reported in Temple et al 2004). In 1946 there were 1403 standards at mid-year. The catalogue had grown by 2003 to 23,737 an average annual rate of growth of 5.2%. The first difference in the log of the stock – i.e. roughly the proportionate rate of growth in the stock - is shown in Figure 3. A rather rapid growth is evident in both the 1950s and 1960s with a noticeable slowdown from the mid 1970s to the mid 1980s. Here – unlike the R&D stocks – we know rather more about the stock's determination. The fast growth in later years reflects the importance of European harmonization of standards – often in support of EU Directives. An important feature of the standards stock is therefore its international character, reflecting wider technological opportunities than simply domestic R&D.

Figure 3



Because of the longer period over which we have data for standards, tests for a unit root in the standards data are more powerful – although as Perron (1989) notes, there is a greater possibility of a regime change. ADF tests on both the log levels (*std*) and the first differences of the log of BSI standards stock (*dstd*) are reported in the Appendix. They suggest that the first difference may not be stationary, unless a dummy for the period of slow growth between 1974 and 1985 is incorporated. This however allows us to proceed to the co-integration analysis incorporating both measures of technical activity. The final specification for labour demand in the small firm sector of UK manufacturing therefore incorporates both *rdv* and *std* – the BSI standards stock calculated in mid-year. Allowing for a time trend to pick up 'unobservable' influences on labour demand in the small firm sector, the new specification becomes (using the notation already defined):

$$l = \alpha_0 + \alpha_1 q + \alpha_2 wa + \alpha_3 rdv + \alpha_4 std + \alpha_5 yr + \alpha_6 dummies + \mu_t \qquad (9)$$

Given the clear break in the process generating the standards data this specification allows for a possible structural break in the co-integrating relationship, using step dummies. Table 2 shows both the cointegrating regression and residual based ADF tests for 4 variations on (9). All ADF

Table 2

Long Run Employment in Small Firm Sector Co-integration Analysis 1973-2002					
Specification		(A)	(B)	(C)	(D)
Dependent Variable		***l***	***l***	***l***	***l***
(log of employment)		Coefficient	Coefficient	Coefficient	Coefficient
Independent variable					
Output	*q*	0.6463	0.6431	0.6914	0.7103
Real product wage	*wa*	-0.5247	-0.5282	-0.5126	-0.5491
R&D volume	*rdv*	-0.2567	-0.2571	-0.2746	-0.1756
Standards stock	*std*			-0.0938	-0.0983
time trend	*yr*		0.0002	0.0023	
Post 1989 dummy	*yr90*				0.0402
constant		7.770	7.4279	3.7242	7.4892
CRDW		1.185	1.189	1.364	1.635
Mackinnon approx p-value at favoured lag length		0.0573	0.0529	0.0214	0.0003
ADF test statistic		-2.807	-2.839	-3.176	-4.431
Significance		*	*	**	***
1% critical value		-3.736	-3.736	-3.736	-3.736
5% critical value		-2.994	-2.994	-2.994	-2.994

tests allow for up to 2 lags, which is the preferred lag length in all specification, as determined by the adjusted AIC criterion. Neither the first variation (A) – in which current volumes of R&D replace the time trend in equation (7) – nor the second variation (B) which includes both variables – appear to offer satisfactory evidence of co-integration on the basis of ADF tests on the residuals. In neither instance does the ADF statistic on the residuals allow for a rejection of the null of a unit root at the 5% level of significance. Only variations such as (C), which includes the standards stock appear to cointegrate. There is however some unexplained upward movement in employment after 1989, and experimentation with a variety of dummies allowing for a structural break meant that our preferred relationship was (D), in which a time trend is replaced by a dummy for the period between 1990 and 2002, and which suggests an upward adjustment of about 4% in small firm employment in the later period.

In the Engel-Granger two step approach, the dynamic counterpart to the postulated cointegrating relationship should provide additional evidence of cointegration. Equation (10) shows an unrestricted ECM counterpart to our preferred specification (D) in Table 2. The estimates suggest that standards play little role in the very short run- impacting on labour demand only via the lagged error-correction term (ECM_{-1}) which is significant at the 1% level. The fact that standards impact only in the longer run is of course consistent with our earlier discussion. The diagnostics all seem reasonable.

$$\underset{}{\Delta l} = \underset{(0.065)}{0.676\Delta q} - \underset{(0.071)}{0.560\,\Delta wa} - \underset{(0.066)}{0.227\,\Delta\, rdv} - \underset{(0.221)}{0.861\,ECM_{-1}} \quad (10)$$

Standard Errors in parentheses

Adjusted $R^2 = 0.842$
DW = 1.903
Chi^2 Joint Skewness/Kurtosis test of normality Pr > $chi^2 = 0.18$

One can of course use the estimated long-run elasticities to provide estimates of the contribution of different factors to long-run productivity growth. Table 3 is based upon specification (D) in Table 2 and shows the contribution of the different factors embodied in (9) for the long run growth of labour productivity, which increased by around 3.0% per annum over the whole period. It can be seen that a strong contribution from real product wage (leading to higher capital intensities) and increasing returns. While R&D is important in the early part of the period, its contribution is strictly limited over the period since 1979. Since 1990, standards have been contributing far more strongly than domestic R&D spending to the growth in productivity of the small firm sector.

Table 3

Long Run Impact on Labour Productivity Among Small Firms approximate contributions to change in productivity (% pa)					
	impacts				
	returns to scale	real product wages	domestic knowledge capital	standards	unobserved factors
period					
1973-2002	0.8	1.6	0.2	0.4	0.1
1973-1979	0.9	1.1	0.6	0.3	0.0
1979-1990	0.8	1.9	0.2	0.3	0.4
1990-2002	0.7	1.5	0.1	0.6	0.0

5. Concluding Discussion

The econometric analysis of spillover effects has usually been conducted in a framework based upon the neo-classical concept of the production function, augmented by R&D, which as an input creates 'knowledge'. This approach creates a variety of difficulties which are amplified when it comes to studying spillovers between the major 'doers' of formal R&D – the large firms – and small firms. A particular problem identified in the paper is the question of the rate of depreciation of knowledge. As far as small firms are concerned a rather high private rate of depreciation needs to be attached to the current R&D spending of larger firms, since these create temporary high value added opportunities. On the other hand much of this knowledge feeds into channels which are generally available, perhaps in the form of codified information. In the econometric analysis of labour demand, we proxied this channel by the number of standards available to firms in the catalogue of the BSI. We noted that this channel does not depend so heavily upon 'domestic' R&D, and will reflect the global pattern of R&D, providing a plausible channel for international R&D spillovers. When both the proxies are used to augment a labour demand equation for the level of employment among small firms, we find that a long–run co-integrating can be established which illustrates the relevance of both channels.

References

Abernathy, W.J. and J.M. Utterback, "Patterns of Innovation in Industry," Technology Review, Vol. 80, No. 7, June-July 1978,

Blind, K. (2004).The Economics of Standards: Theory, Evidence and Policy, Cheltenham: Edward Elgar

DTI (2005) The Empirical Economics of Standards, DTI Economics Paper No 12, London: Department of Trade and Industry

Freeman, C. (1982). The Economics of Industrial Innovation, London: Frances Pinter.

Griliches, Z. (1992) "The Search for R&D Spillovers," The Scandinavian Journal of Economics, 94 (Supplement), S29-S47

Griliches, Z. and F. Lichtenberg, (1984) 'R&D and Productivity Growth at the Industry Level: Is There Still a Relationship?', in Griliches, Z. ed. R&D, Patents and Productivity, Chicago: University of Chicago Press.

Hamermesh, D. S. (1993). Labor Demand, New Jersey, Princeton University Press.

OECD (2002). The Measurement of Scientific and Technological Activities., Paris, OECD.

Patel, P. and K. Pavitt (1995). "Patterns of technological activity." in (P. Stoneman (ed)) The Handbook of the Economics of Innovation and Technological Change.. Oxford, Blackwells.

Perron, P. (1989) "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis, *Econometrica*, Vol. 57(6), pp. 1361-1401

Smith, K. (2005). "Measuring Innovation." in (J. Fagerberg, C. Mowery and R. R. Nelson (eds)) The Oxford Handbook of Innovation.. Oxford, Oxford University Press.

Temple, P. and G. Williams (2002). The Benefits of Standards, European Committee for Standardisation. CEN: Brussels

Temple, P., R. Witt and C.Spencer (2004). "Institutions and long-run growth in the UK: the role of standards." Discussion Paper, 10/04, University of Surrey, Depatment of Economics.

Vernon, R. (1966) "International Investment and International Trade in the Product Cycle, The Quarterly Journal of Economics, Vol. 80(2), pp. 190-207

Data and Results Appendix

Data Sources

l	Log of total employment from ACoP for the period 1973-97 and from ABI for the period 1998-2002
q	Log of net output from ACoP for the period 1973-97 and from ABI for the period 1998-2002 but it is deflated by PLLU (output price index in UK manufacturing)
wa	Log of wages included National Insurance contribution deflated by PPI. The orginal data of wages are collected from ACoP for the period 1973-97 and from ABI for the period 1998-2002.
std	Log of stock of technical standards from PERINORM© database, produced by a consortium of the BSI, DIN, and AFNOR, the national standards bodies of the UK, Germany and France respectively and available on CD-ROM.
rd	Log of R&D data is that for business expenditure on R&D (BERD) for total manufacturing taken from the OECD's ANBERD dataset which is consistent with the Structural Analysis of Industries (STAN) data also available from the OECD web-site.

Table A1
Results of ADF tests
Levels of l, q ,and wa
1973-2002

	variable	no lag	1 lag	2 lags	3 lags
	l	no trend	no trend	no trend	no trend
Test- statistic		-1.67	-2.14	-2.49	-1.61
5% critical value		-2.99	-2.99	-2.99	-3.00
Mackinnon approx p-value		0.45	0.23	0.12	0.48
Adjusted R^2		0.06	0.12	0.14	0.15
Akaike Information Criterion*n		-108	-104.92	-100.55	-95.09
	wa	with trend	with trend	with trend	with trend
Test- statistic		-2.74	-2.47	-3.38	-2.60
5% critical value		-3.58	-3.59	-3.59	-3.60
Mackinnon approx p-value		0.22	0.34	0.05	0.28
Adjusted R^2		0.18	0.15	0.28	0.22
Akaike Information Criterion*n		-104	-97.93	-96.76	-89.86
	q	with trend	with trend	with trend	with trend
Test- statistic		-2.87	-2.01	-2.77	-2.76
5% critical value		-3.58	-3.59	-3.59	-3.60
Mackinnon approx p-value		0.17	0.60	0.21	0.21
Adjusted R^2		0.19	0.19	0.31	0.30
Akaike Information Criterion*n		-95.01	-89.78	-88.96	-83.94

Table A2
Results of ADF tests
First Differences of l, q ,and wa
1973-2002

	variable	no lag	1 lag	2 lags	3 lags
	Δl	no trend	no trend	no trend	no trend
Test- statistic		-4.00	-2.67	-3.46	-1.55
5% critical value		-2.99	-2.99	-3.00	-3.00
Mackinnon approx p-value		0.00	0.08	0.01	0.51
Adjusted R^2		0.36	0.35	0.43	0.46
Akaike Information Criterion*n		-102	-96.09	-94.06	-90.4
	Δwa	no trend	no trend	no trend	no trend
Test- statistic		-6.13	-3.26	-3.67	-3.40
5% critical value		-2.99	-2.99	-3.00	-3.00
Mackinnon approx p-value		0.00	0.02	0.00	0.01
Adjusted R^2		0.58	0.57	0.60	0.63
Akaike Information Criterion*n		-95.1	-89.06	-85.85	-83.55
	Δq	no trend	no trend	no trend	no trend
Test- statistic		-7.35	-2.74	-2.7	-2.53
5% critical value		-2.99	-2.99	-3.00	-3.00
Mackinnon approx p-value		0.00	0.07	0.07	0.11
Adjusted R^2		0.66	0.67	0.67	0.66
Akaike Information Criterion*n		-89.4	-84.71	-79.57	-74.49

Table A3

Results of ADF tests
rdv
1973-2002

variable	no lag	1 lag	2 lags	3 lags
Levels of rdv	with trend	with trend	with trend	with trend
Test- statistic	-1.86	-2.27	-3.00	-2.57
5% critical value	-3.58	-3.59	-3.59	-3.60
Mackinnon approx p-value	0.67	0.45	0.13	0.30
adjusted R^2	0.05	0.09	0.22	0.15
Akaike Information Criterion*n	-95.75	-91.61	-95.15	-88.67
first differences of rdv (lrdv)	no trend	no trend	no trend	no trend
Test- statistic	-4.54	-4.18	-3.08	-3.26
5% critical value	-2.99	-2.99	-3.00	-3.00
Mackinnon approx p-value	0.00	0.00	0.03	0.02
adjusted R^2	0.42	0.46	0.35	0.36
Akaike Information Criterion*n	-90.15	-88.97	-85.05	-80.58

Table A4
Results of ADF tests
Std
1973-2002

	1 lag	2 lags	3 lags
level of *std*	with trend	with trend	with trend
Test- statistic	-3.52	-2.41	-2.97
5% critical value	-3.49	-3.50	-3.50
Mackinnon approx p-value	0.04	0.37	0.14
Adjusted R^2	0.81	0.82	0.84
Akaike Information Criterion*n	-386.82	-380.00	-377.73
First differences of *std (dstd)*	no trend	no trend	no trend
Test- statistic	-2.35	-1.68	-1.78
5% critical value	-2.93	-2.93	-2.93
Mackinnon approx p-value	0.16	0.44	0.39
Adjusted R^2	0.11	0.12	0.11
Akaike Information Criterion*n	-375.04	-369.62	-360.35
Residuals of dstd	no trend	no trend	no trend
Test- statistic	-4.15	-3.28	-3.32
5% critical value	-2.93	-2.93	-2.93
Mackinnon approx p-value	0.00	0.02	0.01
Adjusted R^2	0.22	0.17	0.17
Akaike Information Criterion*n	-379.97	-370.81	-362.14

Here the second set of results allow for a mean shift for the period 1974-89 in the process generating the standards data. An ADF test on the residuals of the corresponding regression suggests that we can reject the unit root hypothesis for *dstd*.