A Note on Productive Learning

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Abstract

We use a standard production function to identify the impact of learning-by-doing on the productivity of labour, human capital and physical capital. Using data from a representative sample of 1,000 UK businesses, we observe that learning effects on labour and human capital productivity are highest when firms are very young. By contrast, learning has the greatest effect on the productivity of physical capital the older a firm becomes.

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1 Introduction

This paper presents a decomposition of the effects of learning-by-doing (LBD) using data from a recent survey of 1,000 UK businesses. In doing so, we hope to build upon the US empirical work of Bahk and Gort (1993), who tested for LBD effects in a sample of manufacturing plants across fifteen industries between 1973 and 1986, and earlier theoretical contributions from, for example, Jovanovic (1982) and Killingsworth (1982). The analytical point of focus is on firm-specific LBD. To this end we use a production function approach in order to isolate the effects of learning on two types of human capital, general and firm-specific, as well as physical capital learning. Of great interest to us is how learning effects accumulate, and potentially at least peak and diminish, over time.

Empirically, we use data from a cross-sectional survey carried out in the summer of 2003. The data is representative of the UK business population in terms of size and broad sectoral distributions. In order to maintain consistency with earlier work in this area, we define LBD as the accumulation of knowledge and skills through the production of goods and services, not through investment in human capital development (Bahk and Gort, 1993). Further, and crucially, the costs of LBD are implicitly lower than knowledge, skills acquisition from other sources (eg investment in training). This gives older firms a comparative advantage over new firms as more time has elapsed in which, relatively, costless human capital formation has occurred (Killingsworth, 1982). Jovanovic (1982) explores another interesting avenue in the context of how entrepreneurial ability affects the survival and subsequent growth of new firms. In his model, the ability of the entrepreneur is revealed over time as she learns more about her skills in a business environment. Those with low levels of entrepreneurial ability exit the market. Here LBD is learning about oneself, on the assumption that, ex ante, all new entrepreneurs perceive that they have the requisite ability to survive and prosper.

Another issue is that of who appropriates the returns to LBD. It is often assumed that wage rates reflect the employee's general human capital (Becker, 1964). Returns not captured by the employee are added to the firms stock of organisational capital, although this effect can manifest itself through various channels, notably process and/or quality improvements. This can be linked to the concept of complementarities raised in a theoretical paper by Meyer et al (1993) and empirically supported in studies by Macduffie and Krafcik (1992) and Ichniowski et al (1993) in the sense that increasing the focus on one strategic component also raises the returns to increasing the focus on other strategies, for example product and process innovation.

2 Methodology

The approach we take here is to view LBD as a productivity-augmenting factor, which enters the production function as a separate argument, rather than as a shift parameter. Thus, in its most basic form we can assume a production function of the form:

$$Yit = F\ (Lit, Kit, Mit, Xit) \qquad (1)$$

Where, Y denotes output, L the labour input, K the capital stock, M intermediate goods and services, and X the stock of knowledge. The i's refer to firms and the t's to time. For

this study, the empirical proxy we use to capture the accumulated stock of knowledge, X, is age of firm. The production function specified is a KLEMS measure that allows gross output, Y, to be determined by inputs of capital, labour, energy, materials and services. The unit of analysis is the firm. A further assumption we make is that technology is widely diffused. This allows us to adopt a cross-sectional framework in which LBDF is the only source of disembodied technical change given that, holding our three factor inputs constant across firms, it is the only explanation for observed differences in productivity across firms. Yet to bring our empirical estimation in line with our discussion regarding separate arguments for input augmenting technical change in the production function, we assume that the labour input is most appropriately defined in terms of pure labour input (headcount) and human capital (proxied by the wage rate). Equation (1) can now be re-written for estimation purposes as:

$$\log Yi = \beta 1 + \beta 2 \log Li + \beta 3 \log Wi + \beta 4 \log Ki + \beta 5 \log Mi + \beta 6\, t \quad (2)$$

Where Y is gross output, L is pure labour, W is human capital, K is physical capital and M is intermediate goods and services. t is chronological time. The subscript i denotes the firm.

3 Results

The main question we are seeking to empirically identify is which of the factor inputs become more productive as learning occurs? Further, what is the speed of LBD knowledge accumulation and does it decay at some point? Thus we need to observe how the coefficients on each factor input are affected by learning. Our approach is to examine these effects using time elapsed since the birth of the firm. In this context we assume that each factor input comprises two elements. The first is independent of learning and the second shifts in the coefficients from time-dependency arising from firm-specific learning. Here the impact of LBDF is captured by time-dependent shifts in the factor input coefficients.

Table 1: Production Function Estimation: All Industry Cross -Section for 2003

Firm Age (years)	Constant	Pure Labour	Human Capital	Physical Capital	Materials	Adj Rsq	N obs
1-3	1.95	0.73	0.65	0.08	0.17	0.94	106
	(4.30)	(14.09)	(12.38)	(2.77)	(6.29)		
4-13	2.56	0.61	0.48	0.11	0.26	0.94	195
	(7.13)	(13.95)	(12.27)	(3.91)	(8.41)		
14-23	2.57	0.54	0.42	0.16	0.27	0.95	131
	(9.62)	(8.96)	(4.65)	(7.18)	(6.05)		

Notes: figures in parentheses are t-statistics

Table 1 presents the results for three age bands of firm. Firms older than 23 years were excluded, as the survey questionnaire was open ended for ages beyond this, thus making interpretation more difficult. Data is cross-sectional. We observe that the R squared values are very high, and all factor input coefficients have fairly large t-values. Turning to the

factor input coefficients, we note that the elasticity of output with respect to pure labour and human capital show that the marginal products per £ are higher for pure labour (measured here by full-time equivalent employees). In the youngest firms, the evidence is more consistent with the optimal input allocation rule as the pure labour and human capital coefficients are much closer at 0.73 and 0.65 respectively.

Taken over different age classes of firm the decomposition effects of LBD are interesting. For pure labour LBD effects are highest when the firm is very young and diminish in a fairly linear fashion thereafter. The human capital learning effect is also highest in the youngest firms. But the rate of decay thereafter is decreasing, but at a declining rate over time. For physical capital these findings are reversed. The learning effect is increasing, and at an increasing rate over time. For intermediate goods and services, learning effects increase substantially after three years in business but level out after thirteen.

If, as is normally assumed, labour learning is typically associated with performing specific manual tasks, then it is likely that the skills and competencies of workers are enhanced through experience and repetition. Organisational learning is also best captured through the two labour related coefficients. Our results imply that the time- interval through which such gains are captured are relatively short. Capital learning, which is about increasing knowledge about the characteristics of available physical capital, is fundamentally concerned with expanding understanding about the characteristics of given plant & machinery, and the organisation of the processes and systems by which they are employed most efficiently. Our evidence suggests that capital learning has a much longer time horizon.

4 Conclusion

We used data from a recent survey of UK businesses to test for learning-by-doing effects at the level of the firm. Using a production function approach, with the arguments labour, human capital, physical capital and intermediate goods and services, we proxy firm-specific learning effects by time elapsed since firm birth. We then decompose these learning effects into labour learning, organisational learning, and capital learning.

The models are estimated using individual firm level data and in cross-sections for three age classes of firm, namely 0-3 years, 4-13 years and 13-24 years. Our results suggest that organisational learning, captured through the labour components, is greatest in the first three years after birth. By contrast, capital learning extends over a much longer time period, and appears to be increasing over time. This suggests that new entrants to the market are at a relative disadvantage vis-à-vis physical capital productivity. By contrast, however, new entrants appear to have a relative advantage in terms of organisational and labour learning, which occurs very rapidly after birth. These latter effects are consistent with the Jovanovic (1982) model in which high quality entrepreneurs, typically with labour intensive production techniques, are able to learn and compete with more bureaucratic and formally managed incumbent firms as the learning effects attributable to the labour function are captured so quickly.

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