E C O N O M I C S B U L L E T I N

On the complementarity between on-the-job training and Ra brief overview

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Abstract

In this paper I briefly review the existing literature on the complementarity between on-the-job training and RI show that the complementarity is studied, on the one hand, within two lines of economic research, labour economics and endogenous growth. On the other hand, from the empirical point of view, some recent papers seem to confirm results of theoretical studies, by arguing that a specific training for RDis quite often a crucial condition for adopting new technologies. I conclude that this issue is treated by different subsets of economic literature which need other improvements, and particularly, an integration

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1 Introduction

In 2000 the Lisbon Strategy was born within European Union; it was revised in 2005, by considering heterogeneous human capital and R&D as crucial elements, in order to facilitate growth rates and to create the most competitive economic area in the world[1].

From some years, economic literature has been studying the links between on-the-job training and R&D activity, because of their increasing relevance for the industrial countries, especially in the last decade:

> "Training is most essential when new technologies are adopted, or in the process of a radical change of environment, for example, the shift from low- to high-skill jobs taking place in most OECD countries today." (Acemoglu, 1997, p. 446).

Complementarity between on-the-job training and R&D is studied by different lines of economic research but, in particular, by endogenous growth and labour economics.

The theory of endogenous growth, especially the one based on the complementarity between human capital and R&D, on the contrary seems not to take into account human capital's heterogeneity, by considering the effects of the complementarity between homogeneous human capital (it is usually assimilated with education) and R&D on economic rate of growth. Just recently, Scicchitano (2006), by introducing the heterogeneity of human capital through education and training, has demonstrates that human capital composition is important in determining the probability of innovation occurring and the growth rate of the economy.

Labor economics, since the 1960s has discuss about human capital's heterogeneity by considering the different components, such as education, on-the-job training, off-the-job training, learning by doing. It studies complementarities between different components of human capital (such as education and training) and between them and R&D; in particular a crucial paper by Acemoglu (1997) analyzes links between training and R&D. Furthermore, an other recent specif subset of empirical studies has given an empirical support to the linkages between training provided by firms and their research activity.

[1] See European Commission (2005*a, b*).

In what follows, I attempt to integrate these recent specific lines of economic literature in order to better define the main aspects of the complementarity between on-the-job training and R&D.

2 The complementarity between training and R&D within:

2.1 Endogenous growth theory: how to solve low development traps

First of all, a line of research in endogenous growth started by a short paper of Nelson and Phelps (1966) studies complementarity between R&D and investments in human capital. Within this approach, human capital is not "simply another factor in growth accounting" [2], because it facilitates technology adoption and diffusion[3] .

In particular, a model developed by Redding (1996), analyzes, within an imperfect labour market, low-skill, low-quality traps, caused by a *strategic* complementarity between homogeneous human capital (chosen by workers) and R&D (provided by firms). Redding uses the Nash Equilibrium solution to solve for a rational expectations equilibrium. He finds two possible equilibrium values for the economy's rate of growth: a first best equilibrium with high growth and R&D and a low development trap with low growth and no research: the trap has the following equation:

$$log\left(\frac{E\left[Y_{t+1}\right]}{Y_t}\right) = g_L^* \equiv \ log\ (1-\delta)\int_0^1 \left(1+\gamma\nu_0^{\theta}\right) di \tag{1}$$

where δ denotes the rate of depreciation of human capital, γ the productivity of education, ν the time spent in education and ϑ the elasticity of

[2] Benhabib and Spiegel (1994)

[3] Many models have studied whether human capital is an ordirary input in the production function, or whether it increases technology diffusion. See for example, Bartel and Lichtenberg (1987), Benhabib and Spiegel (1994, 2005), Krueger and Lindhal (2001), Hall and Jones (1999), Bils and Klenow (2000), Duffy and Papageorgiou (2000), Hanushek and Kimko (2000). Moreover, Lloyd Ellis and Roberst (2002) axamine a model in which skills and technologies are *bounded complements* at the aggregate level.

human capital with respect to time spent in education.

Redding himself notices a restriction of this economic subset of research and particularly of its the model, as it results from the homogeneity of human capital, by writing:

> "For the purpose of the present paper, we make the standard assumption that the education, training and skills of an economy's workforce may be represented by an aggregate stock of human capital H. Hence, the terms education, training, skills and human capital will be used interchangeably. The many interesting issues concerning the heterogeneity of skills are left to one side" (Redding 1996, p. 458).

Recently, Scicchitano (2006) extended Redding (1996), by introducing the heterogeneity of the human capital, through both education and on-the-job training. In the paper two different types of training are modeled: a *technology-general training* (T-G T), adopted even without R&D and provided for all workers, and *a technology-specific training* (T-S T), provided just for those workers engaged in R&D and, if and only if, firms engage in research. In the model the expected second period output for a firm which provide T-G T is:

$$\begin{aligned} E\left[y_{2,t}^{T-GT}(i)\right] &= A_{1,m}h_{1,t}(1+\tau)\left(1+\gamma\nu^{\theta}\right)\left\{\sigma\left[\lambda\mu+(1-\mu)\right]+(1-\sigma)\right\} \\ &\quad -C(\tau) \end{aligned} \tag{2}$$

where A shows the productivity, h the human capital inherited from the preceding generation, τ the training, σ the fraction of workers engaged for R&D activity, λ the effect of R&D on productivity, μ the probability of research success, $C(\tau)$ the training cost for workers engaged in no research. This equation shows that when firms provide T-G T, all workers receive training, independently of their activity (research or not) and independently of research success.

Otherwise, when firms offer a T-S T the expected second period output is:

$$E\left[y_2^{T-ST}(i)\right] = A_{1,m}\left(1+\gamma\nu^{\theta}\right)h_{1,t}\left\{\sigma\left[\lambda\mu\left(1+\tau\right)+\left(1-\mu\right)\right]+\left(1-\sigma\right)\right\} \quad (3)$$

By this equation we can observe that T-S T is just provided when firms engage in research activity and just to workers engaged in R&D.

The paper concludes, differently from the previous study, that complementarity between heterogeneous human capital and R&D generates four different equilibria of the economy's rate of growth. In the Redding's model the absence of the R&D was a necessary and sufficient condition for the low development trap; in the Scicchitano's model the lack of innovations becomes necessary but not a sufficient condition, because also a T-S T is necessary. Moreover, even without innovations, a T-G T avoids the low development trap; this occurs because if firms are able to train workers independently of research activity, job-training can increase human capital accumulation and support economic growth even when there is no R&D.

2.2 Theoretical and empirical labour economics: training and R&D within an imperfect labour market

A second subset of economic research analyses investment in heterogeneous human capital within competitive and/or imperfect labor markets. The original paper by Becker (1964) has showed that human capital is not only education, because it displays on-the-job training even within firms; additionally, he has introduced the distinction, used quite often later, between general training, which a worker can use both inside and outside the firm which trains him and specific training adopted only within the same firm. Becker's analysis is developed within competitive labour markets; recently Acemoglu (1997) and Acemoglu and Pischke (1998, 1999a, 1999b) have introduced many labour market's imperfections, such as switching, turnover and search costs. These papers conclude that, the actual labour markets, by their imperfections, "make technologically general skills de facto specific" (Acemoglu and Pischke 1999b, p.540).

The most relevant paper is provided by Acemoglu (1997); it studies the complementarity between innovation and training within imperfect labour markets. In the model every worker i in the firm j has the following productivity:

$$y + \alpha\left(\gamma_j, \tau_i\right) \tag{4}$$

where firms' decision whether or not to invest in R&D depends upon γ: when γ is equal to (0) 1 firms (do not) adopt a new technology. τ denotes the effect of training. Furthermore, the basic assumption is

$$\alpha\left(0, \tau\right) = \alpha_0 \tau \quad \text{and} \quad \alpha\left(1, \tau\right) = \alpha_1 \tau \qquad \forall \tau \text{ and } \alpha_0 \leq \alpha_1 \tag{5}$$

which denotes complementarity between training and innovations.

Acemoglu (1997) demonstrates that the combination of imperfections in the labour market and complementarity between innovation and training causes inefficiency in training provision and a multiplicity of equilibria in the labour market. It should be also noted that the complementarity considered by Acemoglu (1997) is different from that used by Scicchitano (2006). In the first model when firms do not use new technologies, they can provide training; in the second model there is a *strict* complementarity between T-S T and R&D: without T-S T firms are not able to invest in R&D and without research activity firms do not provide on-the-job training.

Moreover, some empirical studies investigate links between training and R&D within labour market of different industrial countries. They point out that some firms are able to provide training for all workers (low-skilled and high-skilled) and *independently of* their research activity. On the contrary, other firms provide training only for high-skilled workers engaged in research activity and only when they engage in successful R&D.

In particular, many papers find an empirical evidence about complementarity between training and R&D. Ballot et al. (2001) analyze some French and Swedish firms and evaluate the effect of firm-sponsored training and R&D purchase on productivity. They find an interesting complementarity between training and research activity and notice that, particularly for French firms, there is a stronger direct link between R&D and specific training provided for managers and engineers; this provides evidence that specific training is more important for skilled labors. Also Baldwin et al. (1996), Baldwin (1999), and Baldwin and Peters (2001) confirm that one of the most important factors which presses firms to adopt specific training is the introduction of new technologies, which need adequate skills, not available in the labor market. They notice that specific training is more common among large enterprises; in fact, they are more able to adopt sophisticated technologies, which need

specific training in the firm. Hashimoto (1981) notices that, for Japanese firms, specific training seems to be the main condition which allows to adopt new technologies. Furthermore, Ok and Tergeist (2002) show that, for OECD countries, younger, better-educated workers and workers engaged in highly skilled occupations are more likely to enter training programs. They find also that training reduces the erosion of skills with age: decline of adult literacy with age is faster where training participation is low. Moreover, training improves the efficiency of investments in new technology, because it avoids the skill obsolescence which is concomitant of technological change (Arnal et al. 2001).

Substantially, this recent empirical literature argues that (I) workers with high levels of education and engaged in high-skilled occupations are more likely to receive further training, (II) training is able to support the workers' accumulation of human capital by avoiding the skill obsolescence which comes with age and technological change, (III) firms which offer specific training for technologies are more likely to introduce new technologies. Furthermore, complementarity between training and R&D is usually found when firms (I) operate in economic activities in which the introduction, diffusion and use of new technologies are more likely, (II) adopt sophisticated and creative technologies, which need specific professional skills, (III) use own technologies, (IV) have medium-large dimensions.

3 Conclusions

In this paper we have discussed about complementarity between on-the-job training and R&D. We have noted that this is a relevant topic for the actual economic policy of industrial countris and particularly of European Union; we have also pointed out that different complementarities exist, as they result from different lines of economic literature.

This topic is in particular analyzed, from the theoretical point of view, by two subsets of economic literature which do not generally meet. Within labour economics the main consequence of the complementarity is the inefficiency in the supply of training; otherwise, the theory of endogenous growth points out that complementarity between human capital and R&D causes the multiplicity of equilibria in growth rate and the low development traps. Furthermore, endogenous growth generally identifies human capital with education, by neglecting the effects of its heterogeneity and particularly of

training:

> "An interesting issue which is however completely ignored by the macro literature concerns the role of training in economic growth, and the connected relationship between the level of education and subsequent investments in human capital accumulation on the job. [...] The macro literature focuses on measures of human capital which ignore formal (and informal) on-the-job training, nor has it explored to date the possibility for education to have an indirect positive effect on economic growth by fostering training" (Sianesi and Van Reenen, 2002, pp.35-36 and 39).

Just recently Scicchitano (2006) has demonstrated that human capital's heterogeneity could avoid low development traps when research activity is absent.

From the empirical point of view, some recent papers seem to confirm results of theoretical studies, by arguing that, in many industrial countries, a specific training for R&D is quite often a crucial condition for adopting new technologies.

In conclusion, the complementarity between training and R&D is becoming a relevant condition for industrial countries' growth rate: this review has pointed out that this issue is treated by different economic literatures which need other improvements and particularly an integration.

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