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Extended Abstract

Human capital accumulation and R&D are certainly two of the most important engines of growth and, strangely enough, in the last few years only few attempts have been made in order to integrate them within a unified and homogeneous framework. Stokey (1988) and Young (1993), for example, build theoretical models in which the interaction between endogenous technological change and human capital formation is explicitly taken into account. However, in these papers skills accumulation happens through *learning-by-doing* and *on-the-job-training* in the production activity rather than a separate formation (or education) sector. Grossman and Helpman (1991, Ch. 5.2) also endogenise both human capital and technical change. In their set-up, though, education sector does require no skilled labour and incentives to accumulate human capital depend, in equilibrium, only on an exogenously specified schooling technology and agents' time preference. The same criticism applies also to Bucci (2001), where the shares of human capital devoted to formation and research sectors are exogenously given. Eicher (1996) addresses a very interesting puzzle one faces when analysing the technology-skills relationship. Indeed, from a theoretical point of view, although technical change may increase the demand for human capital, and consequently the wage premium of skilled over unskilled workers, a higher level of education should lead to a higher supply of skilled labour and then to a fall in the wage differential. In Eicher's 1996 paper, skilled labour is assumed to be an input in education, research, and in the *absorption* of innovations into production. As a consequence, the absorption of new technologies requires the withdrawal of human capital from research and education, so that, at the end, higher rates of technological change lower relative supply of skilled labour and increase the relative wage.

An extensive and well established research line (both theoretical and empirical) suggests that technology and skills are, in a sense, complements. The most immediate consequence of the existence of such complementarities is represented by the rise of poverty traps and multiple steady states (Redding, 1996). However, in Redding's OLG model (and unlike the approach we take here) pecuniary externalities are introduced both in the accumulation of human and knowledge capital.

More recently, Arnold (1998) has integrated the basic Grossman and Helpman model (1991, Ch.3) with the Lucas model (1988) in such a way that two predictions of endogenous growth theory (widely rejected by empirical evidence) are eliminated. These are the *scale effect* prediction and the prediction that long-run growth may display persistent effects of government policies. Blackburn *et al.* (2000) extend Arnold's model in the direction of a more complete micro foundation of the R&D process, even though they obtain basically the same results.

This paper aims at analysing those factors potentially able to influence the *inter-sectoral allocation of human capital* within an integrated model of endogenous technological change and human capital accumulation *à la Romer (1990)-Grossman and Helpman (1991, Ch.3)-Lucas (1988).* In this work we also study simple correlations among the shares of human capital devoted to each sector employing this input and the long-run growth rate. All this is not done neither by Arnold (1998) nor by Blackburn *et al.* (2000), even though the theoretical framework we consider here is very close to theirs.

A recent paper that attempts to study the determinants of the steady-state share of resources devoted to R&D and its correlation with the long-run growth rate is represented by Jones and Williams (2000). However, in this paper, there is no human capital; capital goods and research are produced through foregone consumption and, accordingly, the inter-sectoral competition for the final output as an input concerns solely these two sectors.

Formally, we consider an economy with three different productive sectors. There exists an undifferentiated consumption good, which is produced using a fixed supply input and capital goods (intermediate inputs). These are available, at time t, in n_t different varieties. In order to produce such inputs, intermediate firms employ only human capital. Technical progress takes place as a continuous expansion, through purposive Research and Development activity, of the set of available horizontally differentiated intermediates. Unlike the traditional *R&D-based growth models*, we assume that the supply of human capital may grow over time. In this connection, following the path breaking papers by Uzawa (1965) and Lucas (1988), we postulate the existence of a representative household that chooses plans for consumption, asset holdings and human capital. For the sake of simplicity, we also assume that the representative household of this economy has unit measure and owns the fixed supply input which is used exclusively to produce the homogeneous final good. On the other hand, human capital is an homogeneous input and can be employed to produce intermediates, to invent new varieties of capital goods (research) and to create new human capital.

We find that the ratio of human to technological capital does depend on the parameter measuring the productivity of research human capital (the higher the research human capital productivity, the higher the amount of resources invested in this sector, the higher the number of available capital goods, the lower this ratio). Overall, the result comes out that, contrary to Jones and Williams (2000), where the steady state share of R&D (s_n) is monotonically increasing in the steady state growth rate (g), the relationship between s_n and g is not monotonic in our context. The result stated by Jones and Williams remains true when (and only when) the productivity parameter of the human capital accumulation process is not sufficiently high. Indeed, when this parameter is high, then s_n is negatively correlated with g. Hence, the hypothesis one can infer is that when human capital (the real engine of growth in our approach) is particularly productive in the education sector, further increases in the productivity parameter of the resources devoted to formation push the investment in education up and reduce the investment (in terms of human capital) in the other two sectors competing for the same input. All this implies an increase both in the steady-state growth rate of the economy and the ratio of human to knowledge capital. Finally, as for the impact of monopoly power on the other main variables of the model, we notice that an increase in the market power enjoyed by intermediate local monopolists increases s_n without any ambiguity. Indeed, variations in the mark-up term do not have any growth effect, whereas they do influence the allocation of human capital between the capital goods and research sectors. This result is explained as follows: when the monopoly power enjoyed by local intermediate producers decreases, the perspective of lower and lower profits represents a disincentive to R&D investment (s_n decreases). At the same time, the higher elasticity of substitution among intermediates increases the degree of competition within the capital goods market and, then, the aggregate intermediate output and the human capital demand coming from this sector.

We also get that growth does not display any scale effect and the only policies able to influence the long-run growth rate are those concerning human capital production.

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