LEI DELSEN EN MARK SCHONEWILLE*

Human Capital and Labour Productivity

Integration of Institutions and Endogenous Growth

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* Lei Delsen is an assistant professor and Mark Schonewille is an assistant researcher, both at the Department of Applied Economics of the faculty of Policy Sciences, University of Nijmegen, the Netherlands.

Abstract

This paper is part of a project that attempts to reveal the way labour market institutions, human capital and labour productivity are interconnected. First we discuss two approaches in the human capital theory, stressing some difficulties that could be solved if the approaches are combined. It is argued that the Nelson-Phelps approach could be improved by adding elements from the Lucas model. We think that the production factor of human capital needs a more detailed description than usual in empirical research, e.g. further schooling and training, experience and external effects. Empirical tests show that the frequently obtained conclusion that investments in higher education are too low are doubtful. The tests also show the importance of further education and training, especially on-the-job training.

The data used for this paper are provided by, among others, The Data Archive of the University of Essex, United Kingdom. The author bears full responsibility for all empirical results presented in section 6 of the paper. The paper and an example of the data are available on the internet at http://marksch.cjb.net

Please, send any comments to:
Mark Schonewille
University of Nijmegen
Faculty of Policy Science
P.O. Box 9108
6500 HK Nijmegen
The Netherlands
e-mail: m.schonewille@bw.kun.nl

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1 Introduction

Human capital plays an important role in economic growth. Macro-economic analyses focus on the effect of the level of human capital (Nelson and Phelps, 1966) or its growth rate (Lucas, 1988). In these macro-economic models human capital is mainly narrowed down to formal education[1] (see also: Barro and Sala-i-Martin, 1995). In micro-economic analyses, apart from schooling, on-the-job training and experience (Becker, 1964; Mincer, 1974) are also considered as components of human capital of major significance.

In this paper, a sector model is developed, that reveals the effects of different components of human capital on labour productivity. A sector model allows for distinguishing general and industry-specific human capital, because many activities are specific to an industry rather than to one firm in particular. At the level of the firm, it is relatively difficult to distinguish these two types of human capital, because several firms within the same industry often use a particular production technique. In order to allow for a distinction between specific and general human capital, even though this is a theoretical distinction, a sectoral model is to be preferred to a micro- as well as a macro- oriented model.

The Human Capital theory is mainly inspired by a micro-economic study by Becker (1964). He formulated his proposition that firms invest in specific skills while employees are mainly interested in general knowledge. Furthermore, he stated that those who invest in human capital act rationally, that external effects do not exist and that market failures, *e.g.*, as a consequence of poaching, do not occur. The human capital theory still builds on this work, but now it also pays attention to external effects and market failures.

Becker’s model explains investments in human capital, but it is static and therefore not eligible as a starting-point for developing an endogenous growth model. A macroeconomic approach, however, does allow for this: endogenous growth models usually study, often optimum, growth of aggregate production at macro level. Fundamental to our model are two articles by Nelson and Phelps (1966) and Lucas (1988). They describe the influence of the level and the growth of human capital endowments at macro level, respectively. They find important determinants of human capital growth at both micro and macro level. So, the proper middle course is a sector approach, combining Becker’s ideas on the one hand and the endogenous growth theory on the other. Whereas the literature often focuses exclusively on one source of human capital in particular, our sector model studies the effects of several sources together.

The paper is organised as follows. In section 2, the Nelson-Phelps and Lucas approaches are discussed. A model based on the Nelson-Phelps approach and describing the effects of initial education has already been developed and empirically tested by Cörvers (1997). Cörvers’ model is elaborated in section 3. Section 4 gives an outline of

[1] Barro and Sala-i-Martin (1995, Ch. 5) assume that the production of human capital relies heavily on educated people as an input. Furthermore, their discussion of the Lucas model suggests that production of commodities and human capital are strictly separated, while in a world where training is a possibility, this distinction is not always that obvious.

the Lucas model, and section 5 shows how Cörvers' model can be extended using Lucas' work (1988). This enables us to include additional sources of human capital, besides initial education, and allows for external effects. In the section 6 and 7, we will make a first attempt to apply the model to the United Kingdom and give our conclusions and some suggestions for further research.

2 Two Approaches in the Human Capital Theory

Currently, two important approaches in the human capital theory can be distinguished (Aghion and Howitt 1998, Ch. 10): the Nelson-Phelps approach and the Lucas approach. Aghion and Howitt conclude that human capital is an important factor in economic growth and find two different effects: one effect comes from the *level* and another from the *accumulation* of human capital.

According to the Nelson-Phelps approach, growth depends on human capital endowments that have already been accumulated rather than on current human capital accumulation. The more human capital *per capita* a country has created, the higher the rate of innovation. The production factor of physical capital, *i.e.* past innovations, is the only factor used in the production of final commodities. Evidently, if the productivity of physical capital increases as a consequence of innovations, production can grow too. So, the level of human capital affects production growth. Differences in growth rates between countries would be caused by differences in the level of the human capital stock. A single additional investment resulting in an increase of the human capital stock may cause a catch-up effect[2], because the higher rate of innovation will bring about a permanent increase in production growth. This is why Aghion and Howitt (1988) argue that, in the Nelson-Phelps approach, the level of the human capital stock is mainly determined by the extent to which the labour force has obtained more than average qualifications, *i.e.* the skewness of the distribution of skills over workers. In other words, higher educated employees are responsible for innovations and thus for economic growth.

The Lucas approach mainly studies the significance of human capital accumulation to economic growth. According to Lucas (1988), there are two sources of human capital exist: education and learning by doing[3]. In his model, education is measured by the amount of time not used in production. Meanwhile, human capital can also be

[2] While, in the textbook Solow model, steady state growth may diverge over countries, endogenous growth could exhibit convergence. In a growth model with human capital, countries may even bypass current leaders in economic growth.

[3] Lucas (1988) suggests that learning by doing can be interpreted in to ways: on the one hand as a well deliberated choice not to invest time in education but to expect an increase in individual knowledge during the production process. On the other hand as an external effect the individual cannot control. Lucas chooses to elaborate the latter.

accumulated in the production process, because this causes learning by doing. In view of this approach, the human capital stock is considered to be an ordinary production factor, just like labour and capital. So, there is a direct relation between the level of production and the human capital stock, while production growth depends on the growth of the human capital stock.

The significance of external effects in endogenous growth attracted special attention after two articles had been published by Romer (1986; also see 1990) and Lucas (1988). In both articles, knowledge is of crucial importance. The Romer model regards the way growth is generated differently from the Lucas model. In the Romer model, knowledge is used in innovation, just as in the model developed by Nelson and Phelps (1966), but the latter do not include external effects. This means that human capital is an input in the production of innovations, also called production techniques, blueprints or intermediary inputs (also see: Verspagen 1993, pp. 41-44). Therefore, investments in human capital only have an indirect, dynamic, effect on growth, because they increase labour productivity only through technological development. In the Lucas model, however, the human capital stock and production are directly connected with each other, as are the growth rates of the two magnitudes.

Lucas endogenises growth by assuming that effectiveness and productivity of investments in human capital depend on the human capital stock, which has been created in the past, and time that is invested in new human capital. Thus, investment of time becomes more beneficial the more human capital has been accumulated. Besides this direct connection between human capital and labour productivity, there is an indirect connection, for individual investments in human capital induce positive external effects that contribute to endogenous growth. These external effects take the form of learning by doing and therefore depend on both schooling and output: the longer workers have participated in schooling, the more knowledge is obtained in the production process.

In the Lucas model, endogenising growth starts from a number of assumptions. First, private investments in schooling and training increase labour productivity. Second, the young build on the knowledge of the old: knowledge is passed on and enlarged. Third, children can acquire new skills more easily if their parents' stock of human capital is larger. This means that human capital growth is partly due to the level of social human capital *per capita* and that acquiring new skills is accompanied by external effects. Fourth, human capital is created by investing time $1-u$. Consequently, individuals have to choose between investing time $1-u$ in human capital or using u in production. Fifth, human capital productivity increases with the size of its stock because of external effects[4]. Finally,

[4] Lucas (1988) argues that social human capital causes external effects because accumulating it is a social activity. The environment of the individuals, consisting of their family, friends, the neighbourhood and colleagues, largely determines his abilities to adopt new knowledge. At country level, differences in environment are evident, as are differences in human capital accumulated in the past.

Lucas supposes that all individuals born in period *t* are identical to each other, yet different from all older individuals.

If human capital investments take the form of schooling, they will induce two different effects. One is the static effect, which means that schooling causes an increase in the productivity of employees who invest in schooling. The second effect is a dynamic one: schooling causes an increase in the productivity of the entire labour force. As individuals do not take account of this effect when deciding on their investments in human capital, the effect is an externality. Yet, the dynamic effect as apparent in the Lucas model differs from that in the Nelson-Phelps approach. The dynamics of the Lucas model is reflected by the connection of human capital growth in period *t*, which depends on the level of human capital, with production in the past. So, in the Lucas model this second effect is dynamic in the sense that it occurs over time.

In the Nelson-Phelps model, however, "dynamics" occur within one period: labour productivity growth in period *t* depends on the level of human capital and the rate of innovation in the very same period. Therefore, this approach does not appear to reveal real dynamic effects. It is Lucas who offers real opportunities to endogenise economic growth, since in the extreme case human capital growth depends exclusively on time and individuals' preferences. The smaller time preferences are, the more consumption will be postponed and the larger the human capital stock will be. In the Nelson-Phelps model, the composition of human capital endowments is exogenously determined rather than endogenously, as in the Lucas-model. This is why the Nelson-Phelps model does not allow for actual endogenous growth. So, the Lucas model is an important supplement to the work of Nelson and Phelps (1966).

The learning by doing mechanism can simply be described as a dynamic process (Torvik 1995, p. 194). Human capital growth due to learning by doing during period *t* is assumed to depend on production during period *t-1*. The idea is that producing a car induces new insights and new knowledge, which are beneficial for future production. Now, we can define learning by doing as the component of human capital that is the result of past production.

The Lucas model is based on an individual utility function. He assumes that individuals maximise their utility and hence choose between consumption and production. The smaller an individuals' time preferences are, the more they will postpone consumption and the more time they will use in production. Obviously, time is an important factor in the creation of human capital, because time can be spend either to attend initial education and continuing training or to produce output. Moreover, Lucas states that external effects are due to human capital. At industry level, learning by doing may be considered as a phenomenon fully external to the individual firm. The extent to which learning by doing, *i.e.* human capital accumulation due to production, occurs can be described by an increasing function of industry size.

While the Lucas approach mainly studies international growth divergence, the Nelson-Phelps approach particularly offers opportunities to endogenise technological change. Lucas finds a connection between growth divergence and differences in human capital growth; Nelson and Phelps argue that technological development is the result of the level of human capital endowments. Hitherto, empirical research has not been able to reject or accept one of these hypotheses in general. Benhabib and Spiegel (1994) show that the level of human capital does not directly affect growth, but they do show that there are some indirect effects, which depend on the rate of innovation and the adoption of new innovations[5]. We can conclude from their work, that growth does not specifically depend on the rate of human capital accumulation, but rather on the current level of human capital endowments.

In the view of Barro and Sala-i-Martin (1995, p. 433), a connection between human capital accumulation and GDP growth does indeed exist, for they discovered a positive relation between public spending on education and GDP growth, the latter being interpreted as a quality improvement of education. If a quality improvement of education were accompanied by faster human capital accumulation, this would imply that there is a connection between human capital and labour productivity. Along this line of argument, higher spending on education, human capital accumulation and economic growth are directly connected.

So far, we have discussed the assumptions and conclusions of two different approaches of the human capital theory. Both approaches study their own specific issues. The two major issues are: 1) is growth primarily caused by either the level or growth of the human capital stock? and 2) which mixture of human capital is best to obtain high economic growth? Both the Lucas and the Nelson-Phelps approach offer good starting-points to study these questions more closely. Besides, the papers written by Benhabib and Spiegel (1994) and Barro and Sala-i-Martin (1995) suggest that accepting one approach does not necessarily lead to rejecting the other. A new model combining both approaches might therefore produce interesting results.

In the next two sections, we will formalise both approaches. Subsequently, a new model is developed that combines both approaches discussed here. The latter explains productivity growth by the level as well as the accumulation of human capital.

3 Formalising the Nelson-Phelps approach

The human capital model as developed by Cörvers (1996) and applied by the same author (1997) can briefly be summarised as follows. His model, assuming exogenously given labour, starts with a standard Cobb-Douglas function:

$$Y_i = AK_i^a L_i^{*b}$$

[5] Actually, Benhabib and Spiegel (1994) discuss the research effect and the diffusion effect, to which we come back in the next section.

where production Y of an individual firm is the result of the production factors physical capital K, efficiency units of labour L^* and the efficiency parameter A. Labour efficiency units are presumed to consist of the number of workers in a firm, or the number of hours worked, and three levels of initial education. These levels are lower, intermediate and higher education. So, an equation for efficiency units of labour looks like

$$L_i^* = L_i \cdot L_{1i}^{q_1} L_{2i}^{q_2} L_{3i}^{q_3}$$

In this equation, L_i is the number of employees in firm i and $L_s^{q_s}$ is the number of employees with education level s=1, 2 and 3, respectively.

Parameters q_s reflect the contribution of the respective education levels to the efficiency units of labour. It is assumed that producers are homogeneous, *i.e.* are of equal size and use similar production techniques. The next step, not shown here, is to divide both sides of the equation by labour L, which gives us the expression for labour productivity. Now, we can derive the industry production function, by multiplying numerator and denominator with the number of firms N in a particular industry[6] and adding subscript i=1,2,3...n for each firm.

$$\frac{Y}{L} = \frac{N \cdot AK_i^a L_i^{*b}}{N \cdot L_i} = \frac{AK^a L_i^b L_{i1}^{q_1} L_{i2}^{q_2} L_{i3}^{q_3}}{L_i}$$

From now on, we will ignore the subscript i Rewriting the equation and after dividing numerator and denominator by L we get

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^a L^{a+b-1} L_1^{bq_1} L_2^{bq_2} L_3^{bq_3}$$

which can be rewritten once more by substituting $1\text{-}L_2\text{-}L_3$ for L_1. The result is

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^a L^{a+b-1} (1 - L_2 - L_3)^{b(1-q_2-q_3)} L_2^{bq_2} L_3^{bq_3}$$

According to this equation, or the logarithmic version, the level of labour productivity depends on the relative shares of the three educational levels in the labour force of the industry. The equation thus illustrates the worker effect –more labour can produce more output as long as the marginal product is positive– and the allocation effect –better qualified labour is able to use available inputs and techniques more efficiently. This production function can be used to calculate the static effects of human capital. Later on,

[6] Here, equal firms sizes are assumed. In the model in section 6, the symbol N is to be interpreted as the number of industries rather than firms.

we will extend the function by including external effects in the same way as Lucas (1988) does. This will allow us to take learning by doing into account.

The second step in the Cörvers model is to formalise the diffusion and the research effect. These effects determine labour productivity growth. The diffusion effect is the result of the skills level of employees: the higher their qualifications, the easier they can apply new techniques in the production process and the faster labour productivity is able to grow. The research effect consists of productivity growth induced by research and development (R&D). The larger the number of intermediate and higher educated workers in an industry, the faster the R&D process proceeds.

The two effects are reflected by efficiency parameter A. The growth equation of A is derived by writing the standard production equation in logarithmic terms and rewriting the result using growth variables. The growth equation for the efficiency parameter now looks as follows:

$$\dot{A} = \left(\frac{\dot{Y}}{L}\right) - a\left(\frac{\dot{K}}{L}\right) - (a + b - 1)\dot{\bar{L}} - b(1 - q_2 - q_3)d(1 - L_2 - L_3)/dt - bq_2\dot{L}_2 - bq_3\dot{L}_3$$

where $\dot{\bar{L}}$ denotes growth of the exogenously determined labour force of an industry. According to this equation, the growth of the efficiency parameter equals labour productivity growth minus the growth of each separate production factor, including human capital (Cörvers (1997)). This equation shows the dynamic effects, but it cannot show how labour productivity is affected. Therefore, it is to be preferred to adjust the model in such a way that it allows for external effects, instead of endogenising A.

The worker, research, allocation and diffusion effect all result from a particular level of the human capital stock. Fully in accordance with the Nelson-Phelps approach, labour productivity growth is explained by human capital endowments.

An important limitation of Cörvers' model is that it measures the human capital stock as the relative shares of the three components of initial education in the labour force. Because of this, the significance of initial education is overstated. Adding more sources of human capital, as Lucas does, might mitigate this bias. In the next section, we will show that the model developed by Lucas offers a way out of these difficulties. However, his model does not specify external effects very accurately. So, if we want to gain new insights into these external effects, we still need to use Cörvers' model. A combination of the Lucas and the Nelson-Phelps models seems to be a good candidate for describing effects of investments in human capital.

4 Formalising the Lucas approach

Lucas' production function is built on the neo-classical theory, although it does allow for external effects. The function is of the form

$$Y = AK^a (uhL)^b$$

in which the national product Y depends on the technology parameter A, also called the efficiency parameter; the physical capital stock K; time used in production u, which also measures investment of time 1-u in human capital; the level of the human capital stock h; and labour supply L measured as hours or years. uhL is replaced by a term indicating efficiency units of labour L^*. We also assume, as Lucas does, constant returns to scale, which means that $a+b=1$. Next, Lucas adds a term that allows for external effects. This yields the production function

$$Y = AK(t)^b L^*(t)^{1-b} h_a(t)^g$$

where h_a is the amount of human capital per capita, also called social human capital. Note that h and h_a are different in nature. We have also included a time index t. In the production function, efficiency units of labour L^* are defined as

$$L^* = u(t)h(t)L(t)$$

In the Lucas production function, external effects are the result of a contribution of individuals' investments to the average level of human capital in an economy. In other words, when one individual obtains higher qualifications, he does not only increase his own productivity but also that of the entire labour force.

Subsequently, the growth rate of human capital is defined as

$$\dot{h}(t) = h(t)^z d(1 - u(t))$$

where *h(t)* denotes the level of human capital endowments in period *t*, *1-u(t)* is investments of time in human capital and *d* equals productivity of time, *i.e.* the actual contribution of additional learning efforts to the human capital stock.

In our view, the article by Lucas can be interpreted in two different ways. In fact, Lucas discusses two ways of accumulating human capital: 1) investing time in schooling and training and 2) learning by doing. Lucas himself suggests that learning by doing can occur in two ways as well. First, individual employees can consciously choose to use part of their time in production in order to preserve or obtain more experience. In this case, external effects would not appear in the model, which would not be able to explain under-investments in human capital. Second, learning by doing can be interpreted as a fully exogenous effect[7]. The version of the model explicitly discussed by Lucas includes learning by doing as an exogenous phenomenon only. Here, Lucas considers two industries: a technologically advanced industry and one using basic technologies. This

[7] See also note 1.

means that human capital is specific[8] for each industry *i*, which is illustrated in the next equation.

$$\dot{h}_i(t) = h_i(t) d_i u_i(t)$$

According to this equation, human capital is industry specific and depends on production, *i.e.* time used in the production process. The larger production is, the faster human capital accumulation can occur. Furthermore, Lucas assumes that human capital growth in t depends on the level of human capital already present in the economy. This would mean that a relatively high labour productivity in a particular industry is due to human capital created in the past, or due to past labour investments in human capital. Therefore, we could write

$$h_t - h_{t-1} = du_{t-1} \quad \text{or} \quad h_{a,t} = du_{t-1}$$

where h_t is the level of human capital in period *t*, *ht-1* its level in period *t-1*; *d* is the marginal contribution of time to human capital; and ha denotes human capital growth per working hour. The technology parameter , unspecified other effects which are connected to market failures, *e.g.* poaching and the hold-up problem, and other sources of human capital, *e.g.* experience and company provided education, altogether form the unexplained part of total factor productivity *A*. When we substitute, as a last step, *L** for efficiency units of labour, we get

$$Y = AK^a L^{*b} u^{gd_u} h_a^{gd_h}$$

In this equation, production depends on technology *A*, physical capital *K*, efficiency units of labour *L** and external effects h_a with their respective coefficients. External effects are separated into two components, one of which is explained by learning by doing, denoted by u with coefficient d_u, and an unexplained part h_a with coefficient d_h.

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[8] Each industry builds a unique set of human capital, which is the result of past production. Since technology of an industry is a combination of labour, physical capital and human capital, the technological process in every industry is unique. Comparing similar industries in international perspective, printing services (Acemoglu and Pischke 1997) or biscuit factories (Prais (1995)) for instance, one will observe that these industries still differ. The reason for this is that in different countries different institutions bring about a different mixture of human capital. By necessity, German car factories use a production process which is different from that of Dutch or British factories. Because human capital growth depends on the human capital stock created in the past and because the latter is of a unique nature in each industry, this growth is industry-specific. Learning by doing in turn depends on the technology used in the production process. As a consequence, human capital exhibits industry specificity as well as process specificity.

This model exhibits strong similarity with the model of Cörvers, but now it reflects both static and dynamic effects.

5 Comments and a new model

Keeping in mind the preceding sections, we may adjust Cörvers' model in such a way that the labour productivity equation takes account of both dynamic and static effects. The question still remains, how to measure the level of human capital, which has been specified by Cörvers as the relative shares of initial education levels in industry employment. There are several ways to do this. Besides distinguishing several levels, it is possible to make a classification according to vocational and general skills or formal and informal education. In constructing the model, there will always be a continuous search for useful classifications. We will start our search, using the following human capital components. First, we recognise initial education, consisting of lower, intermediate and higher levels. Then further education is included, which refers to company provided education and on-the-job training. Finally there is knowledge due to production, specified as learning by doing on the one hand and experience on the other.

This list of components is far from exhaustive, but it allows us to illustrate the relative significance of human capital investments by employees and employers. All human capital components in this model are included irrespectively of the actual financial source, which can also be a subsidy from the government. Furthermore, it is now possible to include external effects H in the model. H is defined as a function that assumes that external effects are due to learning by doing. We use an upper case symbol for external effects, because it is not necessarily similar to Lucas' h_a, as the empirical model will reveal.

The productivity equation, which is based on Cörvers' model and is extended with external effects, looks like the following equation:

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{a} L^{a+b-1}(1-L_2-L_3)^{b(1-q_2-q_3)} L_2^{bq_2} L_3^{bq_3} H(\cdot)$$

Now, $H(\cdot)$ can be specified in several ways. Educational levels L_s, $s=1, 2, 3,$ also can assume several shapes. Following Cörvers, we choose to define L_s as the highest qualification of an employee obtained in initial education. Subsequently, we adopt Lucas' suggestion to specify H(·) as learning by doing, although we don't use time in production but the amount produced in an industry. For each industry, the equation

$$\frac{Y_{i,t}}{L_{i,t}} = A\left(\frac{K_i}{L^i}\right)^{a} L_i^{a+b-1}(1-L_{2,i}-L_{3,i})^{b(1-q_2-q_3)} L_{2,i}^{bq_2} L_{3,i}^{bq_3} Y_{i,t-1}{}^{l}$$

holds. Here, $Y_{i,t-1}$ is production of industry *i* in period *t-1*. Then we extend the model with human capital investments by employees of an industry. In order to do this, we need to measure employees' expenditures on company training by industry. This concerns formal company training instead of learning by doing. In the model[9], human capital investments by employees are denoted by L_4, which does not reflect a relative share in industry employment, but measures the total amount of accumulated industry specific training. The latter also brings about some amount of unintended general skills. Finally we add a variable *X* to the model, denoting average experience of the employees of a particular industry. This avoids overestimating the relative significance of other human capital components.

The extended model, including company training, looks as follows:

$$\frac{Y_i}{L_i} = A\left(\frac{K_i}{L^i}\right)^a L_i^{a+b-1}(1-L_{2,i}-L_{3,i})^{b(1-q_2-q_3)} L_{2,i}^{bq_2} L_{3,i}^{bq_3} L_{4,i}^{bq_4} X_i^{bq_x} Y_i^{\,l}$$

and in logarithmic form

$$\ln\frac{Y_{i,t}}{L_{i,t}} = \ln A + a\ln\frac{K_i}{L_i} + (a+b-1)\ln L_i + b(1-q_2-q_3)\ln(1-L_{2,i}-L_{3,i}) +$$
$$+ bq_2\ln L_{2,i} + bq_3\ln L_{3,i} + bq\ln L_{4,i} + bq_X X + l\,Y_{i,t-1}$$

In this last equation, all variables are measured in period *t*, except for production that causes the external effect of learning by doing and is measured in the preceding period *t-1*.

6 Applying the model to the United Kingdom

Currently, the model developed in this paper is still at an experimental stage. This means that all we can do is to apply the model to some rough data derived from several sources[10]. Contrary to the equations in the last section, the model below contains four, rather than three, levels of initial education. This has a very important effect, since it appears that the highest qualifications do not contribute positively to labour productivity. We also rewrote the model one more time, in order to simplify it's application to the data and to avoid the harmful effects of high correlations[11]. So, the model actually tested looks slightly different, again.

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[9] In the empirical model in section 6, we distinguish four levels of initial education. The appendix gives an extension with on-the-job training, *i.e.* investments in human capital by employers.

[10] See the Appendix A.2 for more information on the data sources.

[11] The danger of correlation between the variables of the model is revealed in appendix A.1.

$$\ln \frac{Y_{i,t}}{L_{i,t}} = \ln A + a \ln K_i + (b - 1)\ln L_i + bq_1)\ln(1 - L_{2,i} - L_{3,i} - L_{4,i}) +$$
$$+ bq_2 \ln L_{2,i} + bq_3 \ln L_{3,i} + bq_4 \ln L_{4,i} + t_1 T^{Off}_{it-1} + t_2 T^{On}_{it-1} + tq_X \ln X + q_{age} \ln Age + l Y_{i,t-1}$$

where *i* denotes individual industries; *A* is a constant, *K* refers to physical capital, *L* is sector employment measured by hours; L_s equals the share in employment of the respective initial education levels s; T^{Off} and T^{On} denote off-the-job and on-the-job training respectively; *X* is years of continuous employment of individuals in industry *i* on average; *Age* is average age; *Y* equals gross value added of industry *i*; *t* refers to a period; and the other symbols are coefficients. After this equation had been tested, it is easy to calculate the actual coefficients and to check whether the model exhibits constant returns to scale.

Table 1 Loglinear models without continuing vocational education

Model	1	2	3	4	5
Constant	-8.80*	-8.22**		-5.45	-12.25**
Total capital endowments[a]	0.28**	0.27**	0.25**	0.27**	0.60**
Labour[b]	-0.61**	-0.71**	-0.71**	-0.70**	-.62**
Education					
Lower[c]	0.43	0.41	0.23		0.51
Intermediate	2.65**	2.58*	1.91*	1.93**	2.62**
Higher	1.02**	1.09**	1.13**	1.08**	1.52**
Degree	-0.66*	-0.64	-0.72*	-0.83	-.74**
Training					
Off the job training (t-1)					-0.31*
On the job training (t-1)					0.17*
Experience[d]		-0.75	-0.81	-0.93	
Age		-0.04	-1.36	0.28	
R^2 adjusted	0.75	0.79	0.79	0.79	

Note: * indicates a 90% significance level; ** indicates a 95% significance level or better.

[a] Total capital endowments are measured as a moving average in order to serve as a proxy for the physical capital stock with depreciation.

[b] Labour employed in production, measured as number of workers times average hours worked.

[c] In those models that include all four education levels, lower education enters the regression equation as 1 minus the shares in employment of the other three levels.

[d] Experience is corrected for the age effect. Coefficients are not significant due to causality problems.

Table 1 contains the results of the loglinear model as developed in the last section. Model 1 in table 1 is similar to the one tested by Cörvers (1997). At first sight, this is just another very good model with highly significant coefficients. The reason that the coefficient for lower education is not significant, is that this component has been composed of the relative shares of the other three education levels in order to avoid interdependencies. Since lower education is not significant, this approach is successful to some extent only.

Still, if we leave lower education out of the model, in particular the coefficient of intermediate education seems to have been over-estimated somewhat, although ignoring the constant that refers to the *A* in the model, seems to reduce this coefficient in exactly the same way, so models 3 and 4 of table 1 are not very different with respect to the education coefficients.

Each of the four models clearly suggests that over-education is a possibility. Increasing the quality of labour by attracting workers with a degree, or similar qualifications, will even decrease the level of productivity. Furthermore, while Cörvers concludes that in the Netherlands one should invest more in high skilled labour[12], which includes both the high education level and degrees used in our model, we can conclude now that in the UK there is under-investment in intermediate skills, rather than higher and scientific education. It also appears that experience and age do not affect the model significantly. Experience and age ought to affect labour productivity moderately in a positive and a negative way respectively, but this does not happen in the model, because labour seems to be less flexible in a high productive industry than in a less productive one. We will come back to this issue in another paper. Model 4 is just a straight loglinear equation without any special features and shows that there is not much danger in ignoring the constant or adding a term for lower education.

Model 1 in table 2 shows what happens, if training variables are used rather than education variables. The problem here is that on- and off-the-job training show some correlation, while the two are highly auto-correlated. Apparently, it was not a very good idea to use weekly training hours as a proxy. Instead, we might try to use participation rates.

Inspired by Lucas, we tried to use output as a measure for learning by doing. Using Gross Value Added (GVA) as a proxy causes very strong multicollinearity and so does productivity in period *t-1*. Yet, productivity in period *t-2* seems to be a possible proxy with a significant coefficient, as is shown in model 3. Obviously, this incurs some other problems, since this is not in accordance with the theoretical model.

[12] Figures of the Research Centre for Education and the Labour Market (1996, tables 3.26-3.28) show that over the years 1995-2000 demand for highly technically skilled labour due to industrial growth amounts to an additional 20 to 30 per cent, while demand for intermediate technically skilled labour will grow with a moderate 5 to 10 per cent. Demand due to replacement of retired workers will also grow. Growth of demand for intermediate and highly skilled labour seems to develop in a rather similar way. Therefore, we expect somewhat different results once the model is applied to the Netherlands. Still, we do not tend to conclude that in the Netherlands investments in high education levels are too low, because on average the amount of highly skilled school leavers is relatively large as well.

Table 2 Loglinear models with continuing vocational education

Model	1	2	3	4	5
Constant	-3.2**	-0.16	-12.1	-13	
Total capital endowments[a]	0.76**	0.29**	0.5**	0.61**	0.54**
Labour[b]	-0.92** [f]	-0.67**	-0.52**	-0.62**	-0.63**
Education					
Lower[c]		-0.24		0.38	0.77
Intermediate		2.34**	1.5**	2.48*	2.37*
Higher		1.27**	1.38**	1.54**	1.53**
Degree		-.91*	-0.78**	-0.81	-0.65
Training[d]					
Off the job	-9.4**				
Off the job (t-1)	9.55**		-0.42**	-0.34	-0.23
Off the job (t-2)	0.74**				
On the job	2.26**				
On the job (t-1)	-5.3**		0.2**	0.18	0.17
On the job (t-2)	-0.64**				
Total		-0.32			
Total (t-1)		-0.2			
Total (t-2)					
Experience[e]		-1.37*	-0.58*	-0.12	0.33
Age		2.76	1.5	0.47	-3.07
Productivity (t-2)			0.14*		
R^2 adjusted	0.99	0.81	0.97	0.96	0.96

Note: * indicates a 90% significance level; ** indicates a 95% significance level or better.

[a, b and c] See notes of table 1.

[d] Training is measured as weekly hours.

[e] See note d of table 1.

[f] Labour measured as number of workers.

So, we cannot simply apply the proposal of Lucas to use past output as a source of human capital growth. Although output is a reliable measure of the size of an industry, it is questionable whether it generates new human capital by itself. As an alternative, we might use the average number of workers in a firm, for in a larger firm more people interact with each other and might come up with new ideas more easily. In a large firm, it may also be easier to find someone to solve difficulties with new techniques. Another alternative is the number of firms in an industry, as a relatively small number of firms may have high labour productivity, if there are increasing returns to scale.

Yet, model 3 might be interpreted in a different way, such as to explain “long” term productivity growth. It seems to suggest that on- and off-the-job training serve well as explanatory variables for growth. This is very well understandable, since especially on-the-job training allows workers to get acquainted with new technologies that will foster labour productivity. Since training always takes one or two years to become effective, training in *t-1* or *t-2* may explain productivity in period *t*. The significant coefficients of training in model 3 support this hypothesis, but the data do not yet allow us to elaborate further on the intertemporal effects of training.

Third, we noticed that a lag of two years seems to give best results. A possible interpretation of this is that learning by doing takes some time. Whereas Torvik (1995) suggest that this learning process would take about one year, there is no reason not to believe that learning by doing takes a longer period. As a fourth and very important result, the models show that lower education may very well contribute positively to labour productivity. In fact, its contribution is even higher than that of the most advanced component of human capital, *i.e.* workers with a degree.

Model 2 in table 2 shows a remarkable, though not significant, effect of training that also illustrates that training takes some time in order to become effective. Training in period t affects productivity negatively, because most trainees are away from the job during the training. For example, in 1994, about 55 per cent of employees receiving training, were offered a training course by their own employer. Part of these employees received their training off-the-job; the other 45 per cent was engaged in some form of off-the-job training as well[13]. So, a majority of trainees received off-the-job training, thereby causing a temporal decrease in labour productivity.

We included model 5 in table 2, because it is almost entirely in accordance with our hypotheses, although we had to remove the constant A in order to obtain this. Now, experience contributes positively to productivity while age has the opposite effect. Still, note that the causality problem is not solved. Moreover, these coefficients don't need to be positive, because there may be an optimal job tenure and even an optimal age.

Finally, not that in model 5 of table 1 and models 3 and 4 of table 2, the coefficients for total capital endowments a and labour 1-b are such that $a + b = 1$, so we have constant returns to scale. While in the original Nelson-Phelps model the number of workers in a firm or industry is not important under constant returns to scale, we think that firm size might enter the production function as a proxy for externalities.

7 Conclusions

This paper shows that Cörvers' applied a useful model in a somewhat naive way. First, the Nelson-Phelps approach probably overstates the importance of human capital, because externalities are not included in the model. Although the results are not that strong, we have shown that output in the past generates a positive externality, even if all human capital components are included[14]. Second, it is illegible to measure human capital as

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[13] Estimates by the author, based on own calculations from the UK Quarterly Labour Force.

[14] Recently, Ellery (1998) published a paper, which shows that a model inspired by Lucas (1988) might *(cont.)*

initial education only. While models focusing on initial education seem to indicate that investments in higher education are too small, the model presented in this paper reveal relatively high contributions of lower and intermediate education to labour productivity.

A third flaw in human capital theory is measuring external effects. Lucas inspired many theorists to model the effect of learning by doing. However, doing so is far from easy. Torvik's (1995) suggestion to use past production as a proxy for learning by doing yields unsatisfactory results, since output coefficients are either nil or small. Therefore, in a next version of the paper we will attempt to measure external effects or learning by doing, to adjust experience for the age effect and to elaborate under- or over-investments in particular human capital components[15].

The human capital component of higher initial education is a source of productivity growth, according to the Nelson-Phelps model, as stated in section 2. However, the models tested in this paper show that investments in intermediate initial education may be more profitable in order to obtain a high productivity level. This means that workers with at least higher qualifications are responsible for the dynamic research effect, but contribute relatively little to the productivity level. The same group of workers is supposed to take care of the efficient allocation of inputs, which also fosters the level labour productivity. So, higher initial educated workers and employees with a degree induce no more than moderate static effects while the dynamic effects are relatively important.

We can also conclude that lower and, in particular, intermediate skilled workers generate the larger part of the static worker effect, since they have a relatively high contribution to the level of productivity.

We think that the most sound conclusion is the one concerning on- and off-the-job training. It is mere logic to suggest that training enhances diffusion of new technology, since the purpose of training often is to get employees acquainted with new techniques of production, new machines, new kinds of raw materials, and all other new features in the production process. In our view, this especially holds for on-the-job training, because in all models the productivity level is positively correlated with on-the-job training one year ago. Contrary to on-the-job training. off-the-job training may serve objectives other than labour productivity, *e.g.* career prospects or a need for intellectual challenges. Therefore, it

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overstate the effect of human capital as well. Maybe, this problem is, together with high correlation of labour productivity and output, of course, a reason why we have a hard job to obtain strong results with respect to external effects.

[15] Note that the model presented in this paper is of an experimental nature. This is why the figures in tables 1 and 2 only serve to illustrate the limitations of existing models. It is impossible to draw any conclusions from this table as to policies needed to allocate investments in human capital more efficiently. Neither are any of these models able to reveal adequately the quantitative effects of phenomenons like poaching on *e.g.* experience. We will pay attention to these difficulties in later versions of the paper.

is not remarkable that the negative effect of off-the-job training is even stronger than the positive effect of on-the-job training.

With respect to initial education, there seems to be some under-investment in intermediary initial education. Yet, we have to be cautious in concluding that the UK government should start a policy to promote participation in intermediate education, since investments in higher qualifications are of great importance, considering long term productivity growth. Policy makers need to take into account this trade-off between short-term and long-term objectives and it is very difficult to formulate some advice on national education policies.

Training is an issue that is not that difficult to deal with. It seems to be important that on-the-job training occurs in order to facilitate productivity growth due to diffusion of new technologies. At the same time, off-the-job training may be important for other reasons, but it apparently has a negative effect on labour productivity. It would be understandable if employers tend to reduce off-the-job training, but this might have other negative effects. A national policy concerning training should serve an increase in participation in on-the-job training, by initiating an apprenticeship system after the German style, for example. Still, in our opinion, off-the-job training should not be neglected.

In summary, the importance of external effects is not quite clear, so we cannot support efforts to provide incentives to increasing investments in human capital in general. Yet, our paper shows that a well-balanced allocation of investment sources over different components of human capital is a good aim to strive for, indeed.

In the near future, we intend to adjust the empirical model by inserting different proxies for externalities. We also feel that using participation rates in training rather than training hours might yield stronger results, although participation rates do not denote actual investment costs. Furthermore, there is a productivity growth model waiting for empirical application, in order to distinguish the research- and diffusion-effects more clearly. We will also add empirical tests concerning the Netherlands and Germany. This should enable us to assign differences in productivity to the institutional structure of an economy. It is also to be expected, that more research on the interdependencies between the components of human capital will allow for major improvements of the model.

A.1 Correlations

The correlation coefficients in table A.1 reveal some important problems that occur in the empirical tests of the model in section 6. We are especially concerned with the variables of lower education, age and experience. It appears that these variable are highly correlated with the other variables used in the model, thereby affecting the significance of the tests.

Table A.1 Correlation coefficients

	Capital	Labour	Lower	Interm.	Higher
Gross value added	0,79	0,03	0,04	0,15	-0,24
Capital	1,00	0,01	-0,22	0,31	-0,16
Labour		1,00	0,03	-0,02	-0,20
Lower			1,00	-0,77	-0,49
Intermediate				1,00	-0,11
Higher					1,00
Degree					
On-the-job training					
Off-the-job training					
Experience					
Age					

	Degree	On-the-job	Off-the-job	Experience	Age
Gross value added	-0,18	-0,12	-0,16	-0,45	-0,31
Capital	0,13	-0,14	-0,08	-0,46	-0,55
Labour	0,07	-0,12	-0,07	-0,37	-0,25
Lower	-0,81	-0,10	-0,41	0,31	0,53
Intermediate	0,28	0,04	0,24	-0,53	-0,69
Higher	0,69	0,08	0,22	0,38	0,19
Degree	1,00	0,12	0,43	-0,10	-0,26
On-the-job training		1,00	0,77	0,06	0,27
Off-the-job training			1,00	-0,14	0,03

We mentioned the problems with experience and age. Clearly, there is a very high correlation between these two variables. Age is also highly correlated with most other variables. We still need to find a solution for these interdependencies.

A.2 The Data

The data are derived from several sources: the UK Labour Force Survey, the UK National Accounts and the Eurostat Labour Force Survey provided most of the variables. We managed to include 10 out of 14 UK industries. So, not the entire economy is covered by the data. The industries under consideration are:

Agriculture
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale, retail and repair
Transport and communication
Financial intermediation, real estate and business
Public administration
Health and Social Care

The variables other than *industry* are defined as follows. *Productivity* is measured as the ratio of Gross Value Added to labour. Capital equals moving average of gross capital accumulation over three years. As soon as the time series gets longer, this variable will be adjusted to reflect the effect of depreciation a little more realistic. *Labour* is the average number of hours worked times the number of employees in an industry. *Lower, intermediate, higher* and *degree* denote the shares of the respective education levels in employment, calculated as percentages of the number of workers rather than employment. This might need some adjustment as well. *On*- and *off-the-job training* are measured as average weekly hours invested in employees' training courses.

For each industry, *experience* is calculated as the average ratio of continuous employment in a firm and individuals' age. Regressions of experience on age showed that an age correction was necessary. This correction consists of a multiplication of experience and $c \cdot Age^{-1}$, where c is a coefficient. Ignoring this coefficient affects the constant in the productivity model, but not any of the coefficients.

As a final remark, note that the data file is still in progress. We will try to improve the data in the near future.

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