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Author(s)	:	Bas Jacobs
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Simulating the Lisbon skills targets in WorldScan

This paper explains the theoretical background, the analytical methods, calibrations, assumptions and computations of the skill inputs for the WorldScan analysis on the skills targets of the Lisbon agenda. The Lisbon skills targets are implemented in WorldScan using most recent theoretical and empirical research in human capital theory. In particular, a satellite model for WorldScan is developed which disaggregates high skilled labour in S&E and non-S&E workers, and low skilled labour in workers with primary education (or less), lower secondary education, and higher secondary levels of education. In addition, workers can acquire skills through on-the-job training. The quality of the workforce may also increase by a higher quality of initial education. Finally, a stylised cohort model is developed to capture the time-lag between changes in policies and the eventual impact on the labour force. In implementing the skills targets we take heterogeneity between various EU countries into account with respect to the following skill variables: initial average levels of education, the returns to education, graduation rates in upper-secondary education, participation in on-the-job training, and the graduation shares in S&E education.

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1 Introduction

This document explains the theoretical background, analytical methods, calibrations, assumptions and computations of the skill inputs for the WorldScan analysis on the skills targets of the Lisbon agenda. These computations are carried out for the Competitiveness Report of DG Enterprise. The chapter analyses five targets of the Lisbon agenda by means of what-if simulations with the WorldScan model. The Lisbon agreement concerns targets on skills. The Lisbon agenda mentions the following goals in this respect:

1. By 2010, an EU average rate of no more than 10% early school leavers should be achieved.
2. By 2010, at least 85% of 22 year olds in the European Union should have completed upper secondary education.
3. By 2000, the percentage of low-achieving 15 year olds in reading literacy in the European Union should have decreased by at least 20% compared to the year 2000.
4. By 2010, the European Union average level of participation in Lifelong Learning should be at least 12.5% of the adult working age population (25-64 age group).
5. The total number of graduates in mathematics, science and technology in the European Union should increase by at least 15% by 2010 while at the same time the level of gender imbalance should decrease.

The current state of affairs in the EU countries can be found in Commission Staff Working Paper: Progress towards the common objectives in education and training, SEC(2004) 73.

Currently, WorldScan (WS) uses production functions with two skill levels, which correspond with:

- Low skilled: ISC levels 01 + 2 + 34, so all up to and including completed secondary education.
- High skilled: ISC levels 5 + 6: tertiary education.

Effects on productivity and wages result from shifts between low and high skilled labour. However the above targets induce no shifts between skill levels in WS. Targets 1 - 3 concern shifts within the low skilled category, target 5 concerns a shift within the high skilled category and target 4 may relate to both categories but will hardly induce any shifts between categories.

To compute the impact of reaching the targets on education and training we developed a small, independent 'satellite model' to WorldScan, which incorporates various aspects of skill-formation needed to simulate the targets. This extension allows for three disaggregated skill groups at the lower education level and distinguishes between two types of higher educated workers: non-science&engineering (S&E) and science&engineering workers. Furthermore, the satellite model captures on-the-job-training and the quality of education in a rudimentary, but consistent, fashion. And, finally, a simple flow-approach to the labour market is introduced to capture the time-lags of policy changes on aggregate macro-economic outcomes.

In particular, we first apply nested CES sub-production functions within each aggregate skill group to capture the heterogeneity in skill-levels. Subcategories of labour are nested in the low and high skilled categories. We allow for three types of lower education (ISC01, ISC2, ISC34) and two types of higher education (ISC56: non-S&E and S&E students). These sub-production functions are calibrated on the basis of substitution elasticities and returns to education that are found in the literature. It was not to explicitly include these lower level CES functions in the full WS-model due to time limitations. Our WorldScan skill 'sub-block' allows for simulations of each of the Lisbon-targets. We compute the difference between the current state of affairs in each of the EU member state and the Lisbon targets. We then use the developed methodology to compute inputs for the WorldScan model for each country.

Second, we incorporate on-the-job training to capture life-long learning effects. We use a short-cut to incorporate on-the-job training by allowing for growth in the number of efficiency units of human capital. Changes in life-long-learning patterns translate in higher growth rates of human capital stocks. Furthermore, we capture 'skill-begets-skill' effects of human capital gathered on the job (cf. Heckman, 2000).

Third, the quality of formal education may improve so that the levels of human capital of future cohorts entering the labour market increase compared to current cohorts. We simply use an index for educational quality which we adjust as a consequence of the literacy target.

The fourth and last aspect of implementation is the time lag between formal education and the skill structure of the labour force. It takes many years before the skill structure of the labour force has adjusted to the higher educated cohorts that leave formal education. To take this into account a stylised cohort model is used to compute the impact of reaching the targets in 2010 on the skill structure of the labour force in the period 2010-2040. Moreover, we allow countries to 'catch up' towards steady state levels of education in the work force. For example, the graduation rates in higher education are typically still above the fractions of higher educated workers in the population. Hence, the share of higher educated works in the population still increases in the absence of the Lisbon targets. We acknowledge an important caveat at the outset. Our simplified demographic structure is a crude approximation to reality because we assume that all cohorts are equally sized. Although the simulations of the skills model are somewhat sensitive to the underlying demographic assumptions, this approximation affects the baseline time-paths and the Lisbon time-paths for the workforce equally. As such, the demographical assumptions will not create a systematic bias when comparing the Lisbon simulations with those of the baseline.

Further, the implementation has a regional dimension as well. European Commission (2004) shows that countries differ with respect to their initial position vis-à-vis the targets. At the same time, European Commission (2004) emphasises that the targets apply to the EU as a whole and not to individual countries. In accordance with the other Lisbon simulations we follow a general rule to compute country specific targets. We set an upper limit above the Lisbon-target, which is above the highest initial level observed for all countries as individual countries sometimes exceed the targets in the baseline years. We then set the target for a country proportional to the distance of the initial value and the upper limit. This is the same procedure that has also been applied for the employment and the R&D target. In this way countries that are at the largest distance from the target have to make the largest effort. At the same time, because the upper limit exceeds the target, countries that have reached or exceeded the target are still assumed to make some (although generally small) effort. The only exception to this rule is the target on mathematics, science and technology graduates. European Commission (2004b) specifies this target as a percentage change and we uniformly apply that change to all countries.

Differences between countries' levels of education generate differences in returns to education. Returns to education are high (low) in countries with a low (high)-skilled labour force (see Harmon et al., 2003, in particular p131). To capture this, we calibrated country specific returns to education that depend on the difference between the average number of years of schooling of a country's labour force and the average number of years of schooling in the EU. One year less (more) schooling compared to the EU average yields one percent higher (lower) return to education. Finally, to calibrate the stylised cohort model we calculate country specific inflow and outflow rates from the population projections in the WorldScan base path. That has been done for each country according to two criteria. Firstly, population growth in the stylised model has to equal the average rate of population growth until 2040 in the base run. Secondly, the outflow rate in the stylised model has to equal the average outflow rate out of the population between 25 and 64 years of age in the base projection of WorldScan.

The satellite model calculates a time path of the increase of labour efficiency that originates from Europe reaching the skill targets in 2010 by combining disaggregated skill categories, on-the-job training and quality of education with a stylised cohort model. This increase in labour efficiency is subsequently inserted in the WorldScan model, which computes the general equilibrium effects of the education and training policies.

The what-if character of the simulations implies that we do not explicitly deal with the policies required to reach the targets. Nevertheless, some simulations still capture the most important costs of achieving the skills targets, namely the opportunity costs of increasing levels of education and the opportunity costs of acquiring more skills on the job. In particular, raising the number of better skilled workers in the population automatically implies that there are less low skilled workers available. Also, increasing training efforts will automatically imply lower labour earnings in the short run as workers spend less time being productive when they spent their time accumulating human capital. However, we ignore the direct and institutional costs associated with larger levels of investment in formal schooling and training. In addition, the policy costs are not taken into account of increasing literacy levels and of shifting the composition of graduates from non-S&E to S&E fields. The economic costs of reaching the skill-targets are likely to be too low in the simulations. Further, a large number of uncertain parameters are involved in the simulations. Wherever possible we have chosen the most plausible values known from the economic literature. In many instances, parameters are not precisely known and set them at values we consider optimistic. Consequently, the effects of reaching the Lisbon targets are likely to be overestimated. Therefore, one can view our simulations as a rosy picture of reaching the Lisbon targets on skill formation because we are likely to underestimate the costs and overestimate the effects.

This note describes the methods and assumptions used in the simulations. In section 2 we describe the disaggregation procedure. In section 3 we introduce on-the-job training. In section 4 we analyse the cohort effects on the labour market. In section 5 we present the simulations that are used in WorldScan and the results for the skill 'sub-block'.

2 Disaggregating skill-groups

This section explains how the skilled and unskilled groups of aggregate labour are disaggregated to allow for the three types of low skilled labour (ISC01, ISC2 and ISC3) and two types of skilled labour (non-S&E and S&E workers). For convenience we introduce notation first:

- $H^{t,c}$ aggregate skilled workers at time *t* in country *c*.
- $H_i^{t,c}$ skilled workers of type *i* at time *t* in country *c*, *i* = 1,2 (*i* =1: non-S&E graduates (ISC 56), *i* = 2: S&E graduates (ISC 56).
- $L^{t,c}$ aggregate unskilled workers at time *t* in country *c*.
- $L_i^{t,c}$ unskilled workers of type *i* at time *t* in country *c*, *i* = 1, 2, 3 (*i* = 1: only basic education or less (ISC 01), *i* = 2: lower secondary education (ISC 2), *i* = 3: higher secondary education (ISC 3)).
- $w_H^{t,c}$ aggregate skilled wage rate at time *t* in country *c*.
- $w_L^{t,c}$ aggregate unskilled wage rate at time *t* in country *c*.
- $w_{H,i}^{t,c}$ skilled wage rate of type *i* at time *t* in country *c*, *i* = 1, 2.
- $w_{L,i}^{t,c}$ unskilled wage rate of type i at time *t* in country *c*, *i* = 1, 2, 3.
- $\beta_{ij}^{c} \equiv \frac{\ln w_i^c - \ln w_j^c}{s_{ij}}$ constant (over time) 'Mincer' rate of return in country *c* of s_{ij} years more education from type *i* to type *j*.[1]
- $\sigma \equiv -\frac{d\ln\left(H^{n,t} / L^{n,t}\right)}{d\ln\left(w_H^{n,t} / w_L^{n,t}\right)}$ constant (over time and countries) elasticity of substitution between the aggregates of high skilled and low skilled labour.
- $\sigma_H \equiv -\frac{d\ln\left(H_i^{n,t} / H_j^{n,t}\right)}{d\ln\left(w_{H,i}^{n,t} / w_{H,j}^{n,t}\right)}$ constant (over time and countries) elasticity of substitution between the high skill-types *i* and *j* for *i,j* = 1, 2, and $i \neq j$.
- $\sigma_L \equiv -\frac{d\ln\left(L_i^{n,t} / L_j^{n,t}\right)}{d\ln\left(w_{L,i}^{n,t} / w_{L,j}^{n,t}\right)}$ constant (over time and countries and between low skill-types) elasticity of substitution between low skill-types *i* and *j* for *i,j* = 1, 2, 3, and $i \neq j$.

[1] The Mincer return to education equals the internal rate of return of increasing educational levels if direct costs are negligible and lives of individuals are infinite. The depreciation rate of human capital is included in estimates of the return, i.e., it is a net-return. Heckman et al. (1998) moreover suggest that depreciation rates are approximately zero.

We drop time and country indices in the remainder of this section.

Let the aggregate production function be defined over aggregate skilled labour H aggregate unskilled labour L, and other inputs like capital (denoted by the vector $\mathbf{X}$):

$$F(ABH, AL, \mathbf{X}).$$

A is a general efficiency parameter denoting the efficiency of total labour input. B is a parameter denoting skill-biased technical change.[2] In the first stage, firms maximise profits which are equal to total revenues $pF(.)$ minus wage costs (and other outlays on factors of production $C(\mathbf{X})$ where $C(\mathbf{X})$ is the cost function with $C' > 0$, $C'' < 0$

$$\Pi = pF(ABH, AL, X) - w_H H - w_L L - C(\mathbf{X}),$$

where w_H and w_L denote the aggregate skill prices for skilled and unskilled labour respectively.

First-order conditions for profit maximisation give the following factor pricing equations for skilled and unskilled labour:

$$p\frac{\partial F(ABH, AL, \mathbf{X})}{\partial H} = w_H,$$

$$p\frac{\partial F(ABH, AL, \mathbf{X})}{\partial L} = w_L.$$

WorldScan assumes that high and low skilled workers are nested through a CES sub-production function $G(.)$

$$AG(BH, L) \equiv A\left(\alpha_H (BH)^{\rho} + \alpha_L L^{\rho}\right)^{1/\rho},$$

and $\rho \equiv 1 - 1/\sigma$, $\alpha_H + \alpha_L = 1$. Consequently, we can write $F(ABH, L, \mathbf{X}) \equiv F(AG(BH, L), \mathbf{X})$ and

$$p\frac{\partial F(AG(.), \mathbf{X})}{\partial G}\frac{\partial G(BH, L)}{\partial H} = w_H,$$

$$p\frac{\partial F(AG(.), \mathbf{X})}{\partial G}\frac{\partial G(BH, L)}{\partial L} = w_L.$$

The correct share parameters α_H and α_L are generally unknown. If we know the share parameters and the elasticity of substitution we can fully specify the sub-production function $G(.)$. We apply the ‘Mincer’ rates of return to various types of education to identify the share-parameters in general equilibrium up to the elasticity of substitution. We then fix the elasticity of substitution at some reasonable value to fully specify the aggregate sub-production function.

Hence, we can derive the skill-premium between skilled and unskilled labour as

$$\frac{w_H}{w_L} = \frac{\partial G / \partial H}{\partial G / \partial L} = \frac{\alpha_H}{\alpha_L} B^{\rho}\left(\frac{H}{L}\right)^{\rho-1}.$$

[2] We require that the elasticity of substitution between skilled and unskilled labour is larger than one for this to work, i.e., $\sigma > 1$. Only in this case, the income share of skilled workers increases if B increases. This can be checked using routine algebra. $\sigma > 1$ is empirically plausible, see Jacobs (2004).

Taking logs from both sides and recognising the fact that the Mincer return to education equals

$$\ln\left(\frac{w_H}{w_L}\right) = \Delta \ln w_{L,H} = \beta_{L,H} s_{L,H}$$

we find

$$\ln\left(\frac{w_H}{w_L}\right) = \beta_{L,H} s_{L,H} = \ln\left(\frac{\partial G/\partial H}{\partial G/\partial L}\right) = \ln\left(\frac{\alpha_H}{\alpha_L} B^{\rho} \left(\frac{H}{L}\right)^{\rho-1}\right).$$

Rewriting the last expression gives

$$\beta_{L,H} s_{L,H} = \ln\left(\frac{\alpha_H}{1-\alpha_H}\right) + \rho \ln B + (\rho - 1)\ln\left(\frac{H}{L}\right).$$

We can solve this equation to find the shares α_H and α_L in the macro-production function as functions of the substitution elasticity, and the Mincer-returns

$$\alpha_L = \frac{1}{1+\exp \xi},$$

$$\alpha_H = \frac{\exp \xi}{1+\exp \xi},$$

where

$$\xi \equiv \beta_{L,H} s_{L,H} + (1-\rho)\ln\left(\frac{H}{L}\right) - \rho \ln B$$

Note that the shares are dependent on both the relative supplies (H/L) and the level of skill-biased technical change B in the calibration year (B = 1).

In the second stage, firms decide upon optimal quantities of each type of labour within each aggregate skill group. Let the high and low skilled aggregates be nested through a CES production function of the various skill sub-types

$$H \equiv I(H_1, H_2) = \left(\alpha_{H,1} H_1^{\rho_H} + \alpha_{H,2} H_2^{\rho_H}\right)^{1/\rho_H},$$

$$L \equiv J(L_1, L_2, L_3) = \left(\alpha_{L,1} L_1^{\rho_L} + \alpha_{L,2} L_2^{\rho_L} + \alpha_{L,3} L_3^{\rho_L}\right)^{1/\rho_H},$$

where $\rho_H \equiv 1 - 1/\sigma_H$ and $\rho_L \equiv 1 - 1/\sigma_L$. Hence, firms minimise the total wage costs to achieve an labour inputs $I(.)$ and $J(.)$ within each category subject to the aggregate expenditure constraints for each type of labour

$$w_{H,1} H_1 + w_{H,2} H_2 = w_H H,$$

$$w_{L,1} L_1 + w_{L,2} L_2 + w_{L,3} L_3 = w_L L.$$

Again, the parameters $\alpha_{H,i}$ and $\alpha_{L,i}$ are unknown. We apply the same procedure as above to find the shares $\alpha_{H,i}$ i = 1, 2 and $\alpha_{L,i}$, i = 1, 2, 3. First, we derive the shares for the skilled group, then for the unskilled group. If skilled workers are paid their marginal products, then

$$w_H \frac{\partial I}{\partial H_1} = w_{H,1},$$

and

$$w_H \frac{\partial I}{\partial H_2} = w_{H,2}.$$

Hence, the skill-premium follows from

$$\frac{w_{H,2}}{w_{H,1}} = \frac{\partial I / \partial H_2}{\partial I / \partial H_1} = \frac{\alpha_{H,2}}{\alpha_{H,1}} \left(\frac{H_2}{H_1} \right)^{\rho_H - 1},$$

This can be rewritten to find the Mincer returns of increasing education from high-skilled type 1 to high-skilled type 2:

$$\ln\left(\frac{w_{H,2}}{w_{H,1}} \right) = \beta_{H_1,H_2} s_{H_1,H_2} = \ln\left(\frac{\partial I / \partial H_2}{\partial I / \partial H_1} \right) = \ln\left(\frac{\alpha_{H,2}}{\alpha_{H,1}} \left(\frac{H_2}{H_1} \right)^{\rho_H - 1} \right),$$

$$\beta_{H_1,H_2} s_{H_1,H_2} = \ln\left(\frac{\alpha_{H,2}}{\alpha_{H,1}} \right) + (\rho_H - 1) \ln\left(\frac{H_2}{H_1} \right),$$

Since, $\alpha_{H,1} = 1 - \alpha_{H,2}$, we can find

$$\beta_{H_1,H_2} s_{H_1,H_2} = \ln\left(\frac{\alpha_{H,2}}{1 - \alpha_{H,2}} \right) + (\rho_H - 1) \ln\left(\frac{H_2}{H_1} \right),$$

$$\frac{\alpha_{H,2}}{1 - \alpha_{H,2}} = \exp\left(\beta_{H_1,H_2} s_{H_1,H_2} + (1 - \rho_H) \ln\left(\frac{H_2}{H_1} \right) \right),$$

So that

$$\alpha_{H,1} = \frac{1}{1 + \exp \xi_H},$$

$$\alpha_{H,2} = \frac{\exp \xi_H}{1 + \exp \xi_H},$$

where

$$\xi_H \equiv \beta_{H_1,H_2} s_{H_1,H_2} + (1 - \rho_H) \ln\left(\tfrac{H_2}{H_1} \right).$$

Therefore, if the 'Mincer' return β_{H_i,H_j} and the amount of schooling s_{H_i,H_j} needed to become a higher skilled worker is known at this point in time we can identify the share-parameters $\alpha_{H,1}$ and $\alpha_{H,2}$ for an assumed elasticity of substitution ρ_H.

Similarly, if unskilled workers are paid their marginal products, then two skill-premia which follow from

$$\frac{w_{L,2}}{w_{L,1}} = \frac{\partial I / \partial L_2}{\partial I / \partial L_1} = \frac{\alpha_{L,2}}{\alpha_{L,1}} \left(\frac{L_2}{L_1} \right)^{\rho_L - 1},$$

$$\frac{w_{L,3}}{w_{L,2}} = \frac{\partial I / \partial L_3}{\partial I / \partial L_2} = \frac{\alpha_{L,3}}{\alpha_{L,2}} \left(\frac{L_3}{L_2} \right)^{\rho_L - 1}.$$

These can be rewritten to find the Mincer returns of increasing education from low-skilled type 1 to low-skilled type 2 and for low-skilled type 2 to low-skilled type 3.

$$\ln\left(\frac{w_{L,2}}{w_{L,1}}\right) = \beta_{L_1,L_2} s_{L_1,L_2} = \ln\left(\frac{\partial I/\partial L_2}{\partial I/\partial L_1}\right) = \ln\left(\frac{\alpha_{L,2}}{\alpha_{L,1}}\left(\frac{L_2}{L_1}\right)^{\rho_L - 1}\right),$$

$$\ln\left(\frac{w_{L,3}}{w_{L,2}}\right) = \beta_{L_2,L_3} s_{L_2,L_3} = \ln\left(\frac{\partial I/\partial L_3}{\partial I/\partial L_2}\right) = \ln\left(\frac{\alpha_{L,3}}{\alpha_{L,2}}\left(\frac{L_3}{L_2}\right)^{\rho_L - 1}\right),$$

$$\beta_{L_1,L_2} s_{L_1,L_2} = \ln\left(\frac{\alpha_{L,2}}{\alpha_{L,1}}\right) + (\rho_L - 1)\ln\left(\frac{L_2}{L_1}\right),$$

$$\beta_{L_2,L_3} s_{L_2,L_3} = \ln\left(\frac{\alpha_{L,3}}{\alpha_{L,2}}\right) + (\rho_L - 1)\ln\left(\frac{L_3}{L_2}\right).$$

Since, $\alpha_{L,1} = 1 - \alpha_{L,2} - \alpha_{L,3}$, we can find

$$\beta_{L_1,L_2} s_{L_1,L_2} = \ln\left(\frac{\alpha_{L,2}}{1 - \alpha_{L,2} - \alpha_{L,3}}\right) + (\rho_L - 1)\ln\left(\frac{L_2}{L_1}\right),$$

$$\beta_{L_2,L_3} s_{L_2,L_3} = \ln\left(\frac{\alpha_{L,3}}{\alpha_{L,2}}\right) + (\rho_L - 1)\ln\left(\frac{L_3}{L_2}\right),$$

$$\frac{\alpha_{L,2}}{1 - \alpha_{L,2} - \alpha_{L,3}} = \exp\left(\beta_{L_1,L_2} s_{L_1,L_2} + (1 - \rho_L)\ln\left(\frac{L_2}{L_1}\right)\right),$$

$$\frac{\alpha_{L,3}}{\alpha_{L,2}} = \exp\left(\beta_{L_2,L_3} s_{L_2,L_3} + (1 - \rho_L)\ln\left(\frac{L_3}{L_2}\right)\right).$$

So that

$$\alpha_{L,1} = \frac{1}{1 + \exp\xi_{L,1} + \exp\xi_{L,1}\exp\xi_{L,2}},$$

$$\alpha_{L,2} = \frac{\exp\xi_{L,1}}{1 + \exp\xi_{L,1} + \exp\xi_{L,1}\exp\xi_{L,2}},$$

$$\alpha_{L,3} = \frac{\exp\xi_{L,1}\exp\xi_{L,2}}{1 + \exp\xi_{L,1} + \exp\xi_{L,1}\exp\xi_{L,2}},$$

where

$$\xi_{L,1} \equiv \beta_{L_1,L_2} s_{L_1,L_2} + (1 - \rho_L)\ln\left(\frac{L_2}{L_1}\right)$$

and

$$\xi_{L,2} \equiv \beta_{L_2,L_3} s_{L_2,L_3} + (1 - \rho_L)\ln\left(\frac{L_3}{L_2}\right).$$

Therefore, if we know the 'Mincer' return β_{L_i,L_j} and the amount of schooling s_{L_i,L_j} needed to become a better skilled worker, at this point in time we can identify the share-parameters α_{L_i} and α_{L_j} for an assumed elasticity of substitution ρ_L.

In order to calibrate the production parameters we apply country specific Mincer returns for the aggregate production technology, the low skilled sub production function and the skilled sub-production function. We assume that the country average Mincer rate of return, β, is on average 8% per year over all levels of education. This is empirically quite plausible. See also Card (1999), Ashenfelter, Oosterbeek, and Harmon (1999), Harmon, Oosterbeek, and Walker (2003) for excellent reviews. Country and education specific Mincer returns are employed to capture heterogeneity between countries and levels of education. Further, we use different Mincer returns to calibrate the aggregate, the nested lower and nested higher CES production functions.

In particular we assume that the Mincer returns satisfy:

$$\beta^c_{L,i} = \beta^c_L \equiv \beta - \pi\left(e^c_L - \bar{e}_L\right),$$

$$\beta^c_{H,i} = \beta^c_H \equiv \beta - \pi\left(e^c_H - \bar{e}_H\right),$$

$$\beta^c \equiv \beta - \pi\left(e^c - \bar{e}\right),$$

where e^c_L, e^c_H and e^c ($\bar{e}^c_L$, $\bar{e}^c_H$ and $\bar{e}^c$) denote the average number of years of education in country *c* (the EU) of low skilled workers, skilled workers and all workers, respectively. Harmon, Oosterbeek, and Walker (2003) find that each additional year of education on average approximately lowers the Mincer rate of return with 1%, hence we set $\pi \equiv 0.01$. This specification allows for higher returns to education for countries with lower average levels of education like Spain and Portugal. Returns to education are accordingly smaller for highly educated countries like the Scandinavian countries. We approximate the average levels of education in each country using data on the education composition of the workforce and making an assumption on the number of years of schooling it takes to complete each level of education. In particular, ISC01 takes 6 years, ISC2 9 years, ISC34 12 years, ISC56 non-S&E takes 17 years and ISC56 S&E takes 18 years of education. Table 2.1 gives the corresponding values of the Mincer returns used in the calculations.

These figures imply that $s_{L,H} = 5$, $s_{L_1,L_2} = 3$, $s_{L_2 L_3} = 3$, and $s_{H_1,H_2} = 1$. In other words, aggregate high skilled workers have on average 5 years more education than the average low skilled worker. It takes three years of study to get a lower secondary education degree. It takes another three years of study to get a higher secondary education degree. And, there is a difference of one year between non-S&E and S&E education: science and engineering students are enrolled longer for one year than non S&E students. These numbers approximately correspond with education systems in many countries, although we admit that differences may occur. Gathering information on the specific institutional details of all educational systems is currently not doable given the time constraints. Moreover, our main results do not depend very much on the precise values of these enrolment durations.

Table 2.1 WorldScan implementation rates of return

Countries	Mincer agg.	Mincer low	Mincer high
Austria	0.0800	0.0628	0.0972
Belgium-Luxembourg	0.0750	0.0893	0.0657
Denmark	0.0732	0.0733	0.0759
Finland	0.0718	0.0855	0.0663
France	0.0782	0.0984	0.0598
Germany	0.0734	0.0719	0.0815
UK	0.0718	0.0883	0.0635
Greece	0.0913	0.0837	0.0876
Ireland	0.0815	0.0836	0.0779
Italy	0.0924	0.0700	0.1024
The Netherlands	0.0806	0.0784	0.0822
Portugal	0.1179	0.0913	0.1066
Spain	0.0882	0.0945	0.0737
Sweden	0.0703	0.0831	0.0672
Czech Republic	0.0787	0.0548	0.1040
Hungary	0.0785	0.0632	0.0953
Poland	0.0775	0.0689	0.0887
Slovakia	0.0786	0.0541	0.1045
Slovenia	0.0789	0.0643	0.0946
Rest EU	0.0677	0.0853	0.0624
EU25	0.0800	0.0800	0.0800

In addition, we assume that the elasticity of substitution in the aggregate production function is $\sigma = 1.5$. The elasticity of substitution between skilled and unskilled workers at the aggregate level equals about 1-2, see Jacobs (2004) for an extensive review of estimates. At lower aggregation levels we expect that elasticities of substitution are substantially bigger for the low skilled group. Nevertheless, we are not aware of any empirical results that estimate the elasticity of substitution at this disaggregated level. Therefore, we set $\sigma_L = 3$, which is we think a plausible number. Within the high skilled group we think that workers with an S&E education are not very good substitutes for non-S&E graduates. Therefore we set $\sigma_H = 1.2$. The reason for using this low value is that with higher values, the income share of S&E workers becomes implausibly large. We did simulations with both higher and lower elasticities of substitution but these did not importantly affect the results. Note furthermore that workers within education groups are perfect substitutes.

The labour efficiency parameter A is set at 1 for the initial year. A may be affected due to OJT and we return to that below. We assume that the rate of skill-biased technical change at the macro-level B features a constant growth rate $\underline{\tau}$ so that the time path of B follows from

$$B^{t+1} = (1+\tau)B^{t}, \quad B^{o} \equiv 1,$$

where we normalise the number of aggregate efficiency units of skilled labour at time t = 0 to unity. We set τ such that wage inequality between skilled and unskilled workers increases with 1.5% per year if relative supplies *H/L* are constant. Jacobs (2004) summarises empirical estimates for the rate of skill-biased technical change and finds that for the US this generates approximately a 3% increase in wage differentials per year, but for European countries this number seems to be substantially lower. The value of τ follows from log-linearising the aggregate marginal rate of transformation between skilled and unskilled workers (at constant relative supplies)

$$\tau \equiv \frac{dB}{B} = \frac{\frac{dw_H}{w_H} - \frac{dw_L}{w_L}}{1-1/\sigma}.$$

With σ = 1.5 and a relative wage increase of 1.5% per year, τ = 0.045.

In the simulations, we only need to assume that the production function is stable. Having fully specified the model, we can simulate the impulses of exogenous changes in the number of individuals in the subgroups on the aggregate numbers of workers *H* and *L*, cf. the sub 'production' functions. We can also fully capture the general equilibrium responses of changing wages between aggregate skill-groups and within these skill-groups. Hence, we capture all effects on the income distribution of any policy impulse. Moreover, if we assume that supply of various skill groups is completely inelastic then general equilibrium feedback effects of WorldScan to the skill sub-block are not relevant and we can compute all the effects on the income distribution of the sub-groups. This is may be a rather strong assumption, but schooling of individuals does not seem to be very responsive to financial incentives, however, see also Jacobs (2004) for a review of estimates.

3 Training on the job

As a second step, we incorporate on-the-job training in the model. Individuals may not only acquire human capital through formal schooling, but also through training over the life-cycle. See also Heckman et al. (1998). We use a very stylised model to capture on the job-training based on Ben-Porath (1967) and Heckman (1976). Let individual-*n*'s level of human capital be denoted by lower case variables $h_i^{t,n}$ and $l_i^{t,n}$ where *t* denotes time. We follow Heckman et al. (1998) and we assume that

$$h_i^{n,t+1} = h_i^{n,t} + \tilde{A}_{h,i}\left(q_{h,i}^{n,t}\right)^{\alpha_{h,i}}\left(h_i^{n,t}\right)^{\beta_{h,i}}, \quad i = 1,2, \quad \forall n,$$

$$l_i^{n,t+1} = l_i^{n,t} + \tilde{A}_{l,i}\left(q_{l,i}^{n,t}\right)^{\alpha_{l,i}}\left(h_i^{n,t}\right)^{\beta_{l,i}}, \quad i = 1,2,3, \quad \forall n,$$

where $q_{h,i}^{n,t}$ and $q_{l,i}^{n,t}$ denote the fractions of working time invested in training on the job of individual *n* at time *t* with skill *i*, and $\tilde{A}$ is a productivity parameter. As in Ben-Porath (1967) we set $\alpha_{h,i} = \alpha_{l,i} = 1$. Heckman et al. (1998) empirically estimate α and find that α equals .95 for high-school workers and .94 for college graduates. Hence, we do not expect to bias our results to a large extent. Further, we assume that $\beta_{h,i} = \beta_{l,i} = 1$ as well. That is, returns to training investments do not diminish with the level of human capital. Here, Heckman et al. (1998) find estimates of around .85. Although this assumption is a bit more off-track, this assumption allows us to capture changes in OJT very easily through changes in the growth rate of the human capital of each group of worker.[3] As in Heckman et al. (1998) we ignore depreciation of human capital. They argue that depreciation of human capital is not very high because wage profiles do not generally decrease at the end of careers.[4] At the end of working careers, investment in OJT is zero (because the returns are too low) and one would expect that wages would fall if depreciation was indeed important. Our simulations therefore give a plausible upper bound of skill-formation through OJT.

We can aggregate all individual investments at time *t* to obtain aggregates

[3] If β ≠ 1, various cohort and individual (time-) effects in human capital accumulation become inter-twined and we cannot easily aggregate over cohorts and individuals at the same time.

[4] Wages do not even decline at the end of working lives in the US where labour markets are more flexible than in Europe and therefore should permit wage declines of older workers when human capital depreciates.

$$h_i^{t+1} = \sum_n h_i^{n,t+1} = \sum_n h_i^{n,t} + \tilde{A}_{h,i} q_{h,i}^{n,t} h_i^{n,t} =$$

$$\left(1 + \tilde{A}_{h,i} \frac{\sum_n q_{h,i}^{n,t} h_i^{n,t}}{\sum_n h_i^{n,t}}\right) \sum_n h_i^{n,t} = \left(1 + \tilde{A}_{h,i} \chi_{h,i}^t\right) h_i^t, \quad i = 1, 2,$$

$$l_i^{t+1} = \sum_n l_i^{n,t+1} = \sum_n l_i^{n,t} + \tilde{A}_{l,i} q_{l,i}^{n,t} l_i^{n,t} =$$

$$\left(1 + \tilde{A}_{l,i} \frac{\sum_n q_{l,i}^{n,t} l_i^{n,t}}{\sum_n l_i^{n,t}}\right) \sum_n l_i^{n,t} = \left(1 + \tilde{A}_{l,i} \chi_{l,i}^t\right) l_i^t, \quad i = 1, 2, 3,$$

where $\chi_{h,i}^t \equiv \frac{\sum_n q_{h,i}^{n,t} h_i^{n,t}}{\sum_n h_i^{n,t}}$ is the weighted average fraction of time invested in on the job in skilled jobs and similarly for $\chi_{l,i}^t \equiv \frac{\sum_n q_{l,i}^{n,t} l_i^{n,t}}{\sum_n l_i^{n,t}}$. Hence, the growth rates of aggregate human capital over time are given by

$$\gamma_{H,i} \equiv \frac{h_i^{t+1} - h_i^t}{h_i^t} = \tilde{A}_{h,i} \chi_{h,i}^t, \quad i = 1, 2,$$

$$\gamma_{L,i} \equiv \frac{l_i^{t+1} - l_i^t}{l_i^t} = \tilde{A}_{l,i} \chi_{l,i}^t, \quad i = 1, 2, 3.$$

If the average fraction of time spent in training χ remains constant over time we can equate a higher rate of investment in on-the-job training, with a higher growth rate of the number of efficiency units of human capital. This is in the current model also equivalent to a higher rate of population growth for different skill groups. Needless to say, a constant aggregate fraction of time invested in training does not imply that individual training levels are constant over the life-cycle. Indeed, it is generally optimal for individuals to train at the beginning of the life-cycle only (Ben-Porath, 1967; Heckman, 1976; Weiss, 1986).

Growth rates γ_i are not necessarily equal across skill groups, depending on the constants $\tilde{A}_{h,i}$ and $\tilde{A}_{l,i}$ and investment rates $\chi_{l,i}$ and $\chi_{h,i}$. Not much is known on the sizes of the growth rates γ_i. We assume that $\tilde{A} \equiv \tilde{A}_{h,i} = \tilde{A}_{l,i}$ and $\chi \equiv \chi_{l,i} = \chi_{h,i}$ so that each skill-group is *equally* productive in generating human capital through OJT and $\gamma_i = \gamma = const$. In the absence of any solid empirical evidence we do not discriminate between skill-groups. From empirical work we do know that more skilled workers engage more in formal training, but this largely neglects genuine on-the-job training. On the other hand, lower skilled workers -- who have less formal education -- are likely to gather more human capital through combining working and learning. Mincer (1962) and Heckman (1998), respectively, estimate that a fraction ω of 50% to 23% of life-time human capital is gathered through on-the-job training on average over all skill-groups. Consequently, we can say that the average growth rate γ must satisfy:

$$EN^T \equiv \sum_i \left(h_i^T + l_i^T\right) = (1+\gamma)^T \sum_i \left(h_i^O + l_i^O\right) = (1+\gamma)^T EN^O,$$

where EN^t is the total population expressed in number of efficiency units of labour, i.e. the total number of individuals at time t with skill i multiplied by the number of efficiency units at each skill. Therefore we can write:

$$EN^T = \omega EN^T + EN^O \Leftrightarrow EN^T = \frac{EN^O}{(1-\omega)},$$

and, we can infer γ from solving the equation:

$$\gamma = \exp\left(\frac{-\ln(1-\omega)}{T}\right) - 1.$$

For T = 40 years and ω = 0.23 (Heckman et al., 1998) we find γ = 0.66% per year. If T = 40 and ω = 0.50 (Mincer, 1962) we find γ = 1.75% per year. In our base-line we set γ = 1%. This corresponds to an average fraction of life-time human capital generated through on-the-job training of $\omega = 1 - 1/(1+\gamma)^T = .33$. Hence, formal schooling constitutes about 2/3 of total life-time human capital and on-the-job training generates 1/3 of life-time human capital.

Training on the job is not a costless activity. If χ is the fraction of labour time devoted to training on the job, total gross labour earnings will be equal to $(1-\chi)w_h H$ for a skilled worker or $(1-\chi)w_l L$ for an unskilled worker (omitting the other sub and super-scripts). Earnings data will only give figures on earnings after the costs of on the job-training have been deducted. That is, observed yearly wages are $(1-\chi)w_h H$ and not $w_h H$. If on-the-job-training efforts increase (higher χ) then total effective labour inputs decrease. If on-the-job training was zero in the initial situation (χ = 0), then an increase in total on-the-job-training effort to 3% of total time decreases total labour input (and earnings!) also with 3%. If the labour income share in total output equals 0.7, increasing time devoted to training with 3% will decrease national output with about 2.1% initially. Over time, however, stocks of human capital increase and earnings increase as a consequence.

In the simulations we take into account the decrease in labour input (and hence earnings) as a consequence of increases in training efforts. We use a short-cut here. In the baseline we assume that χ = 0.15 as an average over the population, see Heckman et al (1998, fig. 3). If we assume that OJT efforts increase with 3% of total labour time, then total labour input will initially decrease with $\frac{0.03}{0.85} = 3.5\%$ as a consequence of OJT.

Suppose that we allow for OJT in the aggregate production function $F(AG(BH,L),\mathbf{X})$. Since OJT affects all labour types equivalently, we can interpret A as a measure for total effective labour input. Consequently, we can decompose total labour efficiency into a general efficiency term A' and the reduction of labour input due to OJT:

$A \equiv A'(1-\chi)$.

Hence, we can model increased OJT by decreasing aggregate labour efficiency *A* in aggregate production once and for all with with 3.5% from *A* = 1 to *A* = 0.965. Of course, total labour input will recover over time as stocks of human capital increase.

By using χ = 0.15 as a base-line value, we can infer the base-line productivity of training $\tilde{A}$ from solving the human capital growth rate equations for $\gamma = 0.01$ so that $\tilde{A} = 0.01/0.15 = 0.067$. Consequently, we can calculate the new growth rate of human capital through OJT as $\gamma^* = A\chi^*$. In the example of a 3% increase in training time the new growth rate is $\gamma^* = 0.067 * 0.18 = 1.2\%$ per year.

4 Quality of education

Human capital in the work force may not only increase by larger quantities of schooling and training, but also through a better quality of the educational system. Especially the Lisbon target on increasing average literacy scores is aimed at increasing quality of educational output. Since this is the only target which is associated with increasing quality we keep matters as simple as possible and simulate the effects of reaching the target by simply increasing the average quality Q of a unit of human capital generated in formal education from $Q = 1$ to $Q > 1$. We assume that Q is neither varying across education levels nor over time. We argue below that implementing the literacy targets amounts to an across the board increase of educational output over all educational types. Furthermore, the increase in quality is assumed to be once and for all.

5 Labour market

The stock of workers is not only aggregated over skill-types but also over age-groups. Current education policy measures will only affect the flow of each cohort entering the labour market now and in the future, not those who are already in the labour market. Therefore, stocks of workers only adjust very slowly. To capture these effects, we propose a very stylised model of the labour market, see also Jacobs (2004). We ignore country super-scripts, but do allow for time superscripts now.

If we define the in and outflows from the labour force as I^t and O^t, the total population $N^t = H^t + L^t$ evolves through time as

$$N^{t+1} = N^t + I^t - O^t.$$

We assume that population size grows at constant rate g from time t on, hence $N^{t+1} = (1+g)N^t$. Furthermore, we assume that as from t the sizes of new cohorts, as a fraction θ of the total population, are constant. Hence, the number of new workers entering the labour market grows at rate g as well. This implies that the total inflow of workers at time t is given by:

$$I_t = \theta N^t.$$

Moreover, these assumptions imply that the aggregate outflow rates $\delta = \theta - g$ are constant as well:

$$O_t = \delta N^t.$$

The inflow and outflow rates are calibrated such that these match average population growth rates in various countries over the period considered. The data on population growth are provided by UN (2003).

The total stock of human capital of workers in the skill-groups evolves over time according to:

$$H_i^{t+1} = (1+\gamma)H_i^t + Q_i^t IH_i^t - OH_i^t, \quad i = 1,2,$$

$$L_i^{t+1} = (1+\gamma)L_i^t + Q_i^t IL_i^t - OL_i^t, \quad i = 1,2,3,$$

where IH_i^t (OH_i^t) denotes the inflow (outflow) of skilled workers of type i over time. $Q_i^t \geq 1$ is the general efficiency of education denoting the quality of the new inflow of human capital of type i in year t. Q_i^t captures the improvement in the educational process, due to for example, raising literacy scores. We assume that $Q_i^t = Q$. In the baseline we set $Q = 1$.

Note that H_i^t and L_i^t are human capital stocks measured in efficiency units of human capital-adjusted for quality increases, since OJT increases the value of human capital stocks.

The total human capital stocks of skilled workers relative to unskilled workers are probably not yet at their steady state levels. The reason is that the current population still contains a lot of older unskilled workers that are being replaced by better educated younger workers. Nevertheless, we assume that the current graduation rates in education are on their ‘steady state’ levels and will remain constant from now on. (This is just another way of saying that the composition of total investment rate in higher relative to lower education will not change anymore. This may be generated through a micro-economic savings function with a constant savings quote.) If a fraction $\eta_{H,i}$ of each cohort currently graduates in higher education of type *i*, $\eta_{H,1}+\eta_{H,2}=\eta_H$. The corresponding fraction of low skilled workers of each birth cohort are denoted by $\eta_{L,i}$, and by definition that $\eta_{L,1}+\eta_{L,2}+\eta_{L,3}=\eta_L=1-\eta_H$. The number of skilled (unskilled) workers flowing into the labour market is therefore $IH_i^t=\eta_{H,i}\theta N_t$ ($IL_i^t=\eta_{L,i}\theta N_t$). If we assume that the outflow rates for each type worker are the same as in the total population $OH_i^t=\delta H_i^t$ and $OL_i^t=\delta L_i^t$. Consequently, the human capital stocks of skilled and unskilled workers evolve as:

$$H_i^{t+1}=(1+\gamma)H_i^t+\eta_{H,i}Q\theta N^t-\delta H_i^t, \quad i=1,2,$$

$$L_i^{t+1}=(1+\gamma)L_i^t+\eta_{L,i}Q\theta N^t-\delta L_i^t. \quad i=1,2,3.$$

The steady state ratio of skilled and unskilled human capital stocks is given by:

$$\frac{H_i^\infty}{N^\infty}=\frac{Q\eta_{H,i}}{1-\gamma/\theta}, \quad i=1,2,$$

$$\frac{L_i^\infty}{N^\infty}=\frac{Q\eta_{L,i}}{1-\gamma/\theta}, \quad i=1,2,3,$$

and

$$\frac{H^\infty}{L^\infty}=\frac{\eta_H}{1-\eta_H}.$$

Hence, if 1/3 of each cohort currently graduates in higher education, the steady state level of higher educated workers relative to lower educated workers would be one half. If the population does not grow, $\theta=\delta$ and in the steady state 1/3 of all workers should have a higher education degree.

If the stocks are not at steady state levels (measured in efficiency units) we find the following growth rates:

$$g_{H,i}^t\equiv\frac{\theta}{(1+\gamma)}\left(\frac{Q\eta_{H,i}}{H_i^t/N_t}-\frac{\delta}{\theta}\right), \quad i=1,2,$$

$$g_{L,i}^t\equiv\frac{\theta}{(1+\gamma)}\left(\frac{Q\eta_{L,i}}{L_i^t/N_t}-\frac{\delta}{\theta}\right), \quad i=1,2,3.$$

If the inflow rate equals the outflow rate, $\theta = \delta$, i.e., there is no population growth, the stocks H_i^t and L_i^t grow at positive rates as long as the graduation rates $\eta_{H,i}^t$ $\eta_{L,i}^t$ are larger than the current shares H_i^t / N_t and L_i^t / N_t .

Given an initial condition ($H_1^o, H_2^o, L_1^o, L_2^o, L_3^o$) and the graduation rates $(\eta_{H,1}, \eta_{H,2}, \eta_{L,1}, \eta_{L,2}, \eta_{L,3})$ we can generate the base-line time paths as from time *t* = 0 to any *t* of the stocks of skilled and unskilled workers. The graduation rates are well documented and we use the numbers provided by OECD (2005a).

If OJT is included in the model, we need to compute the aggregate stocks of human capital at time *t* = 0 if we want to correctly identify the share parameters of the nested CES functions (the initial condition ($H_1^o, H_2^o, L_1^o, L_2^o, L_3^o$)). We cannot simply equate H_i^t and L_i^t with the aggregate numbers of people with either a high or low skilled education. H_i^t and L_i^t are the aggregate levels of human capital in *efficiency* units. Hence, we need to take into account that workers have already accumulated human capital on-the-job. If H_i^o denotes the aggregate level of human capital in efficiency units at time *t* = 0 then, we can translate the number of workers with skill *i*, NH_i^o and NL_i^o , at time *t* = 0 into human capital stocks H_i^o , L_i^o at *t* = 0 if we assume that the average worker is the worker with average working experience (*T* = 20 if working careers are 40 years) and educational quality remained constant over time (*Q* = 1), i.e.,

$$H_i^o = (1+\gamma)^T NH_i^o, \quad i = 1, 2,$$

$$L_i^o = (1+\gamma)^T NL_i^o, \quad i = 1, 2, 3.$$

However, the initial share of the labour force that has a degree in S&E education (NH_2^o) is difficult to obtain. We assume that the initial share of S&E workers in the work force equals the fraction of S&E graduates currently graduating, i.e.

$$\frac{NH_2^o}{N^o} = \eta_{H,2}.$$

6 Assumptions simulations

Before turning to the simulations we summarise the most important assumptions used in the computations.

1. We use a country specific Mincer return per extra year of education
2. Schooling years from level *i* to *j* are assumed to be $s_{L,H} = 5$, $s_{L_1,L_2} = 3$, $s_{L_2 L_3} = 3$, $s_{H_1,H_2} = 1$.
3. We assume an elasticity of substitution of $\sigma = 1.5$ at the aggregate level between skilled and unskilled workers, an elasticity of substitution the within the low skilled group of $\sigma_L = 3$. The elasticity of substitution between S&E and non-S&E workers is set at $\sigma_H = 1.2$.
4. We assume a rate of skill-biased technical change resulting in growing wage differentials between skilled and unskilled workers of 1.5% per year ($\tau = 0.045$). Since $\sigma = 1.5$, $\tau = 0.045$ generates a skill-bias in skilled wages of 1.5% per year.
5. The average growth rate of the efficiency units of human capital due to OJT is $\gamma = 1\%$ per year across all skill-levels. Increasing OJT efforts are modeled by decreases in aggregate labour efficiency *A*. The baseline fraction of working time devoted to OJT $\chi = 0.15$.
6. The quality-index *Q* of education is assumed to remain constant and equal to $Q = 1$.
7. We assume that the size of each birth cohort relative to the population remains constant at θ. The same holds for the outflow rates of the older people are rate δ. Population grows at a constant rate *g*. The baseline population growth is set on estimated average population growth rates. The same holds for in and outflow rates.
8. We assume that current graduation rates $\eta_{H,i}$ and $\eta_{L,i}$ are at ‘steady state’ levels.
9. We allow for ‘catching up’ towards steady state education levels in the baseline if current fractions of various types of workers in the work force are below/above graduation rates.
10. The average worker in initial situation has accumulated a level of human capital on the job of a worker with half of life-time experience.
11. Informational requirements for the simulations: initial levels of the number of workers at time *t* = 0, NH_i^o and NL_i^o, graduation rates $\eta_{H,i}$ and $\eta_{L,i}$, sizes of birth cohorts θ, and sizes of exit cohorts δ (own calculations).

7 Simulating the Lisbon targets

The following list of targets is formulated. We simulate each of them by changing the parameters of the model. This section explains how.

7.1 Early school leavers

By 2010, an EU average rate of no more than 10% early school leavers should be achieved (European Commission, 2004, p54). This implies that less than 10% of each cohort leaves the educational system with a higher secondary degree. Since this target perfectly overlaps with target number 2, we skipped this target after consulting the EU.

7.2 Secondary school completion

By 2010, at least 85% of 22 year olds in the European Union should have completed upper secondary education (European Commission, 2004, p25). In WorldScan this targed is implemented by imposing the restriction that the average EU fraction of 25-29 year olds should have at least an upper secondary education degree. The data for this target are obtained from OECD (2005a). That is, we define ε as the fraction of the 25-29 year cohort graduates in upper secondray education or more, i.e., $\varepsilon \equiv \eta_{L,3} + \eta_{H,1} + \eta_{H,2}$. We impose an upper limit on this fraction $\varepsilon^{\max} \equiv 0.96$. By adopting the weighting procedure used throughout many of the simulations, the new (denoted with '*') country specific value of the complement of the lower secondary graduation rate can be written as

$$\varepsilon^{c*} \equiv \varepsilon^{c} + \lambda(\varepsilon^{\max} - \varepsilon^{c})$$

where ε^{c} is the base year value for country *c*.

For the EU as a whole we can write

$$\varepsilon^{EU} \equiv \frac{\sum_c \varepsilon^c N^c}{\sum_c N^c},$$

$$\varepsilon^{EU*} \equiv \frac{\sum_c \varepsilon^{c*} N^c}{\sum_c N^c},$$

where N^c is the number of 25-29 year olds with an upper secondary degree in country *c*. Substitution gives

$$\varepsilon^{EU*} = \varepsilon^{EU} + \lambda\left(\varepsilon^{\max} - \varepsilon^{EU}\right).$$

Hence,

$$\lambda = \frac{\varepsilon^{EU*} - \varepsilon^{EU}}{\varepsilon^{\max} - \varepsilon^{EU}}$$

and $\varepsilon^{EU*} = 0.85$ is the EU target. By using the value of λ we can compute for each country the required increase in the fraction of graduates who should complete secondary school.

We assume that the increase of graduates in higher secondary education is initially completely absorbed by lowering graduation rates in lower-secondary education and that the number of graduates without lower secondary education remains constant. Only, in case the target implies that the pool of graduates lower secondary education has completely dried up, we assume that the remaining graduates come from the pool of graduates with primary education and lower. This results in the following expressions for the new graduation rates in each country

$$\eta_{L,3}^{c*} = \eta_{L,1}^{c} + \eta_{L,2}^{c} + \eta_{L,3}^{c} - (1 - \varepsilon^{c*})$$

$$\hat{\eta}_{L,2}^{c} \equiv \eta_{L,2}^{c} - (\eta_{L,3}^{c*} - \eta_{L,3}^{c})$$

$$\eta_{L,2}^{c*} = \max\{\hat{\eta}_{L,2}^{c}, 0\},$$

$$\eta_{L,1}^{c*} = \eta_{L,1}^{c} - (\eta_{L,2}^{c*} - \hat{\eta}_{L,2}^{c})$$

where $\hat{\eta}_{L,2}^{c}$ is an auxiliary variable if there are too few graduates in the lower secondary education and the target has to be reached by drawing from the pool of students with only primary education.

Some countries have relatively large graduation rates in the lowest category with only primary education or less. Policies to improve transitions between skill levels will probably also affect the transition from primary to lower secondary education. Therefore we added a shift from primary to lower secondary graduation rates in the following countries: Greece 2%-points, Ireland 1%-point, Netherlands 1%-point, Portugal 15%-points and Spain 1%-point. Furthermore, in Germany we applied the calculations to the graduation rates of the 30-34 year cohorts (instead of 25-29 year cohorts). The reason is that education tracks in Germany are typically longer than in the rest of Europe. Table 7.1 gives the values used in the calculations.

Table 7.1 Worldscan implementation secondary school completion

	Current share	Lisbon target	Current graduation rates			Lisbon graduation rates		
	≥ upper secondary	≥ upper secondary	ISCO1	ISC2	ISC34	ISC01	ISC2	ISC34
Austria	0.86	0.89	0.02	0.13	0.69	0.02	0.10	0.73
Belgium-Luxembourg	0.82	0.86	0.05	0.13	0.39	0.05	0.09	0.44
Denmark	0.87	0.90	0.01	0.12	0.58	0.01	0.09	0.61
Finland	0.90	0.92	0.01	0.09	0.53	0.01	0.07	0.55
France	0.78	0.84	0.02	0.20	0.28	0.02	0.14	0.34
Germany	0.88	0.91	0.01	0.10	0.62	0.01	0.08	0.64
UK	0.74	0.81	0.01	0.25	0.29	0.01	0.18	0.36
Greece	0.77	0.83	0.10	0.13	0.53	0.08	0.09	0.59
Ireland	0.80	0.85	0.08	0.12	0.42	0.07	0.08	0.47
Italy	0.64	0.74	0.03	0.33	0.52	0.03	0.23	0.62
Netherlands	0.80	0.85	0.05	0.15	0.51	0.04	0.11	0.56
Portugal	0.38	0.57	0.43	0.19	0.21	0.29	0.14	0.39
Spain	0.62	0.73	0.08	0.30	0.21	0.07	0.20	0.32
Sweden	0.92	0.93	0.01	0.07	0.55	0.01	0.06	0.56
Czech Republic	0.93	0.94	0.00	0.07	0.83	0.00	0.06	0.84
Hungary	0.86	0.89	0.01	0.13	0.69	0.01	0.10	0.73
Poland	0.88	0.91	0.01	0.11	0.60	0.01	0.09	0.63
Slovakia	0.96	0.96	0.00	0.04	0.82	0.00	0.04	0.82
Slovenia	0.88	0.91	0.00	0.11	0.68	0.00	0.09	0.71
Rest EU	0.91	0.93	0.01	0.08	0.51	0.01	0.07	0.53
EU25	0.80	0.85	0.03	0.17	0.49	0.03	0.12	0.54

7.3 Achievement in literacy

By 2000, the percentage of low-achieving 15 year olds in reading literacy in the European Union should have decreased by at least 20% compared to the year 2000 (European Commission, 2004, p28). We simulate the effects of increasing literacy by increasing the wage returns of schooling. If literacy improves, the returns to education increase.

The EU bases this target on resulting PISA test scores. The PISA scores on literacy follow -- by construction -- a standard normal distribution with mean μ = 500 and standard deviation σ = 100. Low achieving 15 year olds are individuals with a PISA-score less than about 407. Currently, about 17.2% of the population has a low achievement in literacy. We can compute the increase in the mean score (μ^*) or reduction in the standard deviation of scores (σ^*) that are needed to meet the Lisbon targets.

Let $\Phi(p,\mu,\sigma)$ denote the cumulative normal distribution up to p with mean μ and standard deviation σ. p is the percentile below which students are low achieving. The fraction of low achieving students decreases from p = 0.172 to p^* = 0.137. Consequently, reaching the Lisbon targets follows from solving

$$\Phi(p^*, \mu^*, \sigma^*) = 0.137.$$

If the mean is increased and the standard deviation is held at old levels ($\sigma^* = \sigma$), then with σ = 100 and p^* = 0.137 we find that μ^* = 516. Therefore, average test scores μ need to increase with 3% over the whole student body to generate this reduction in low achievement in literacy. Similarly, we may hold mean scores fixed at μ = 500 and reduce the standard deviation from σ = 100 to σ^* = 85. Hence, a reduction of 15% in the standard deviation is needed to generate the target reduction in low literacy achievement. We prefer to use the first interpretation (an increase in the mean) since a reduction in the standard deviation implies that the fraction of high-performing students is reduced as well. We cannot imagine that this would be EU policy.

An increase of 3% on the average of the test scores equals 16% of one standard deviation ($\Delta\mu = .16\sigma$). From empirical estimates we can infer the wage returns of higher literacy scores as measured in standard deviations. Krueger (2000, p.21-22) summarises some recent empirical research in this field, see Table7.2. Krueger estimates that the wage returns to higher math and literacy scores are in the order of 8-20% per standard deviation increase.

Table 7.2 Returns to literacy

Study	Return per standard deviation increase scores
	%
Murnane, Willet and Levy (1995)	7.7-10.9
Currie and Thomas (1999)	7.6-8
Neal and Johnson (1996)	20

Empirical evidence gives a rather scattered picture. We are inclined to think that a 10% return per standard deviation in tests scores is reasonable. Krueger (2000) uses a value of 8% in his calculations. With a return of 10% per standard deviation in test scores, a $.16\sigma$ increase in the average scores on literacy implies a monetary return of 1.6% in wages. We therefore increase the average quality of human capital of all school-leavers with 1.6% across all schooling types hence Q will rise from $Q^{EU} = 1$ to $Q^{EU*} = 1.016$. Therefore, nothing happens with the skill composition of the work force as a result of an equal increase in the level of human capital over all workers. With a Mincer return of 8% per year of schooling, a 1.6% increase in wages is equivalent to the increase in wages due to 0.2 additional years of schooling on average for all workers as a result of this literacy increase.

In order to implement the country specific targets we we follow the same procedure as before to achieve an increase on average of 1.6% for the EU as a whole. In particular, we again set a max ε^{max} = 0.95, where ε now designates the fraction of each cohort which has a reading proficiency level 1 and above. The data are obtained from OECD (2005b). The new (denoted with ‘*’) country specific value of the reading proficiency target can again be written as

$$\varepsilon^{c*} \equiv \varepsilon^{c} + \lambda(\varepsilon^{\max} - \varepsilon^{c})$$

where ε^c is the old value of reading proficiency above level 1 for country c.

For the EU as a whole we can write

$$\varepsilon^{EU} \equiv \frac{\sum_c \varepsilon^c N^c}{\sum_c N^c},$$

$$\varepsilon^{EU*} \equiv \frac{\sum_c \varepsilon^{c*} N^c}{\sum_c N^c},$$

where N^c is now the number of 25-29 year olds with reading proficiency level above 1 in country c. Substitution gives

$$\varepsilon^{EU*} = \varepsilon^{EU} + \lambda\left(\varepsilon^{\max} - \varepsilon^{EU}\right).$$

Hence,

$$\lambda = \frac{\varepsilon^{EU*} - \varepsilon^{EU}}{\varepsilon^{\max} - \varepsilon^{EU}}$$

and $\varepsilon^{EU*} = 1 - 0.137 = 0.863$ is the EU reading proficiency target. Again, by using the value of λ we can compute for each country the required increase in the fraction of graduates who should complete secondary school. This generates a country specific quality increase of the education system which satisfies

$$Q^{*c} = Q^{c} + 0.016\left(\frac{\varepsilon^{*c} - \varepsilon^{c}}{0.172 - 0.137}\right)$$

where $Q^c = 1$ and the numbers in the denominator correspond to the old and new average EU fractions of the number of pupils with reading proficiency level below 1. Table 7.3 gives the country specific values used in the calculations.

Table 7.3 WorldScan implementation literacy

	Fraction op population Above reading proficiency level 1	Lisbon target Reading proficiency level 1	Quality adjustment
Austria	0.86	0.89	1.010
Belgium-Luxembourg	0.82	0.86	1.016
Denmark	0.82	0.86	1.016
Finland	0.93	0.94	1.002
France	0.85	0.88	1.012
Germany	0.77	0.83	1.021
UK	0.87	0.90	1.010
Greece	0.76	0.82	1.024
Ireland	0.89	0.91	1.007
Italy	0.81	0.86	1.017
Netherlands	0.91	0.92	1.005
Portugal	0.74	0.81	1.026
Spain	0.84	0.88	1.014
Sweden	0.87	0.90	1.009
Czech Republic	0.83	0.87	1.015
Hungary	0.77	0.83	1.022
Poland	0.77	0.83	1.022
Slovakia	0.82	0.86	1.016
Slovenia	0.82	0.86	1.016
Rest EU	0.82	0.86	1.016
EU25	0.82	0.86	1.016

7.4 Life-long learning

By 2010, the European Union average level of participation in Lifelong Learning should be at least 12.5% of the adult working age population (25-64 age group) (European Commission, 2004, p51). Currently, the EU average of workers that participated in training programs in the last month is 8,5% of the work force. If we assume that each training program costs one working day per week, then the current fraction of labour time devoted to training activities equals $4/20*8.5\%=1.7\%$ of total labour time, based on 20 working days per month. This is equivalent to 1.7% of total working time per year. The target implies that the fraction of the workforce participating in training during the last month increases to 12.5% of the work-force. Hence total labour time devoted to training activities has to increase to 2,5% because $4/20*12.5=2.5\%$. Consequently, total labour time devoted to formal training activities increases from 1.7% to 2.5%, which results in the new fraction of training time $\chi^*=0.158$. Therefore, the EU new average growth rate of OJT will become $\gamma^{EU*}=0.067*0.158=1.06\%$ per year. Furthermore, aggregate labour input in the Lisbon scenario will decrease from $A=1$ to

$A^{EU*} = \frac{1-\chi^{EU*}}{1-\chi^{EU}} = \frac{1-0.158}{1-0.15} = 0.99$.

We allow for a country specific implementation of the Lisbon target. First we compute the country specific change in the fraction of the population that participates in life long learning. Data are taken from the European Commision (2004). We set $\varepsilon^{\max} = 0.25$ and the target is $\varepsilon^{EU*} = 0.125$. Now ε denotes the fraction of the population participating in training. Hence,

$$\varepsilon^{c*} \equiv \varepsilon^{c} + \lambda(\varepsilon^{\max} - \varepsilon^{c})$$

where ε^{s} is the old fraction of the population engaging in training in country *c*.

For the EU as a whole we can write

$$\varepsilon^{EU} \equiv \frac{\sum_c \varepsilon^c N^c}{\sum_c N^c},$$

$$\varepsilon^{EU*} \equiv \frac{\sum_c \varepsilon^{c*} N^c}{\sum_c N^c},$$

where N^{c} is now the total population in country *c*. Substitution of the last results gives

$$\varepsilon^{EU*} = \varepsilon^{EU} + \lambda\left(\varepsilon^{\max} - \varepsilon^{EU}\right)$$

The new growth rates of human capital generated through OJT follow from the new country specific fraction of people engaged in training, i.e.,

$$\chi^{c*} \equiv \frac{4}{20}(\varepsilon^{c*} - \varepsilon^{c}) + \chi^{c}$$

$$\gamma^{c*} = \chi^{c*}\tilde{A}$$

$$A^{c*} = \frac{1-\chi^{c*}}{1-\chi^{c}}$$

Table 7.4 gives the country specific values which are used to implement this target.

Table 7.4 WorldScan implementation training

	% of population in training	Lisbon target in training	New fraction time in OJT	New growth rate OJT	Initial decrease labour efficiency
Austria	0.0750	0.1211	0.1592	0.0106	0.9891
Belgium-Luxembourg	0.0670	0.1152	0.1596	0.0106	0.9886
Denmark	0.1840	0.2014	0.1535	0.0102	0.9959
Finland	0.1890	0.2051	0.1532	0.0102	0.9962
France	0.0270	0.0858	0.1618	0.0108	0.9862
Germany	0.0590	0.1094	0.1601	0.0107	0.9882
UK	0.2290	0.2345	0.1511	0.0101	0.9987
Greece	0.0120	0.0747	0.1625	0.0108	0.9852
Ireland	0.0770	0.1226	0.1591	0.0106	0.9893
Italy	0.0460	0.0998	0.1608	0.0107	0.9873
Netherlands	0.1640	0.1867	0.1545	0.0103	0.9947
Portugal	0.0290	0.0873	0.1617	0.0108	0.9863
Spain	0.0500	0.1027	0.1605	0.0107	0.9876
Sweden	0.1840	0.2014	0.1535	0.0102	0.9959
Czech Republic	0.0600	0.1101	0.1600	0.0107	0.9882
Hungary	0.0330	0.0902	0.1614	0.0108	0.9865
Poland	0.0430	0.0976	0.1609	0.0107	0.9872
Slovakia	0.0900	0.1322	0.1584	0.0106	0.9901
Slovenia	0.0880	0.1307	0.1585	0.0106	0.9900
Rest EU	0.0350	0.0917	0.1613	0.0108	0.9867
EU25	0.0803	0.1250	0.1589	0.0106	0.9895

7.5 Science & engineering

The total number of graduates in mathematics, science and technology in the European Union should increase by at least 15% by 2010 while at the same time the level of gender imbalance should decrease (European Commission, 2004, p34). The first target amounts to increasing $\eta_{H,2}$ with 15% on average for all countries. We implement this target by subjecting all countries equally to this target, i.e, $\eta^{*c}_{H,2} = 1.15\eta^{c}_{H,2}$. At the same time the number of students in other types of higher education decreases with $\eta^{*c}_{H,1} = \eta^{c}_{H,1} - (\eta^{c*}_{H,2} - \eta^{c}_{H,2})$. Data are taken from OECD (2004). Table 7.5 shows the numerical implementation of this target in WorldScan.

Table 7.5 WorldScan implementation S&E

	Graduation rate		Lisbon grad. rate	
	Non S&E	S&E	Non S&E	S&E
Austria	0.1154	0.0476	0.1082	0.0547
Belgium-Luxembourg	0.3211	0.1040	0.3055	0.1196
Denmark	0.2420	0.0474	0.2349	0.0545
Finland	0.2489	0.1181	0.2311	0.1358
France	0.3516	0.1523	0.3288	0.1752
Germany	0.1829	0.0868	0.1698	0.0998
UK	0.3145	0.1306	0.2949	0.1502
Greece	0.1782	0.0569	0.1697	0.0654
Ireland	0.2715	0.1055	0.2557	0.1214
Italy	0.0924	0.0295	0.0879	0.0339
Netherlands	0.2458	0.0481	0.2385	0.0553
Portugal	0.1301	0.0433	0.1236	0.0498
Spain	0.3084	0.1026	0.2930	0.1180
Sweden	0.2507	0.1201	0.2327	0.1381
Czech Republic	0.0794	0.0272	0.0753	0.0313
Hungary	0.1485	0.0166	0.1460	0.0191
Poland	0.2493	0.0300	0.2448	0.0345
Slovakia	0.1002	0.0381	0.0944	0.0439
Slovenia	0.1460	0.0556	0.1376	0.0639
Rest EU	0.3603	0.0400	0.3543	0.0460
EU25	0.2547	0.0941	0.2406	0.1082

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