THE LOST RACE BETWEEN SCHOOLING AND TECHNOLOGY*

BY

BAS JACOBS**

Summary

We study the evolution of wage inequality between skilled and unskilled workers in the Netherlands for the years 1969-2020. Our analysis is based on estimates of the production structure in the Netherlands, projections of the relative supply of skilled workers, and projections regarding shifts in relative demand for skilled workers. Wage inequality will increase under plausible assumptions because relative demand for skilled workers will increase more rapidly than the relative supply of skilled workers. We study the potential of education subsidies to higher education in order to stimulate the supply of skilled workers thereby off-setting the increase in projected wage inequality. Our findings suggest that education subsidies are not very effective in combatting increases in wage inequality.

Key words: education, education subsidies, technological change, wage inequality

1 INTRODUCTION

The Netherlands experienced decreasing wage inequality between skilled and unskilled workers in recent decades (see Hartog et al. (1993)). The dominant explanation for this diminished inequality is that the supply of skilled workers, notably higher educated women, increased substantially. Increasing the supply of skilled workers relative to unskilled workers will result in less wage inequality because workers with different skill levels are imperfect substitutes in production.

At the same time, labor demand became increasingly more skill-intensive as a consequence of shifts in relative demand for skilled workers, notably due to technological changes. Leuven and Oosterbeek (2000) have shown that the skill premium has been increasing in recent years. This recent development suggests that the race between education and technology is being lost by schooling, to put it in Tinbergen's (1975) terminology.

* I thank Casper van Ewijk, George Gelauff, James Heckman, Hessel Oosterbeek, Marc Pomp, and Coen Teulings for valuable comments and suggestions. I further thank Barthold Kuipers for support with the data. Any errors are my own.
** Address for correspondence: Department of Economics and Econometrics, University of Amsterdam, Roetersstraat 11, 1018 WB Amsterdam, The Netherlands; Phone: (+31) - 20 - 525 5088, Fax: (+31) - 20 - 525 4310, e-mail: b.jacobs@uva.nl.
Department of Economics and Econometrics, University of Amsterdam, Department of Education and Science, CPB Netherlands Bureau for Economic Policy Analysis.

De Economist **152**, 47–78, 2004.

The first question of this paper is whether the race between technology and schooling is indeed lost by schooling. To answer this question, we estimate a reduced form of a macroeconomic production function à la Katz and Murphy (1992) in order to determine the elasticity of substitution between skilled and unskilled workers and the shifts in relative demand for skilled workers. Our findings are consistent with earlier findings in the literature. Using projections on the future relative supplies of skilled workers, we make a prediction of the evolution of wage inequality in years to come. We come to the conclusion that, under plausible assumptions, and without any changes in policy, wage inequality will increase substantially in coming years.

The second question is whether education policies, i.e., the increase of publicly financed education subsidies, can be used as an instrument in reducing wage inequality as suggested by Tinbergen (1975) and, more recently, by Teulings (2000). The latter author argues that education subsidies are an efficient means to meet redistributional ends. We use our model to compute the necessary increase in the stock of skilled workers to keep wage inequality at its current level. Given some presumed enrollment elasticities, we calculate the reduction in tuition costs required to increase the stock of skilled workers relative to unskilled workers. We suggest that stimulation of the supply of skilled workers is probably a very expensive and therefore ineffective policy in reducing wage inequality. We also discuss some factors that may further reduce the scope of education policy as a redistributive device. We argue that it is doubtful whether education subsidies really have the strong potential of reducing wage inequality as has been suggested.

The set-up of this paper is as follows. First, in section 2 we review the literature on education and inequality in order to position the paper. In section 3 we review some empirical work for the Netherlands. In section 4 we set up a small theoretical model to disentangle the various factors that influence wage inequality and to derive our estimating equation. In section 5 we estimate a macroeconomic production function with skilled and unskilled labor. We make predictions of wage inequality in section 6. In section 7 we analyze the role of education policy in reducing wage inequality. Section 8 contains some arguments that weaken the case for education subsidies for redistributional purposes. And, finally, section 9 is devoted to the conclusions. The appendix contains some theoretical derivations.

2 EDUCATION AND WAGE INEQUALITY

Wage inequality between skilled and unskilled workers has increased in many industrialized countries. Especially the US and the UK have experienced dramatic increases of the skill premium. Similar but less dramatic stories can be told for many European countries (Davis (1992)). Apparently, the steady increase of the relative supply of skilled workers, which compresses wage differentials, has been more than off-set by the increase in relative demand, which increases wage differentials. The economic literature has given a number of explanations for this phenomenon.

The first, and most dominant explanation for the rise in wage inequality is so called skill-biased technological change (see Katz and Murphy (1992), Bound and Johnson (1992), and Berman et al. (1994)). Skilled workers are more complementary with new technologies than unskilled workers. Consequently, new technologies increase the relative demand for skilled workers. There is suggestive evidence that especially the ICT revolution has caused an increase of the skill premium (Krueger (1993), Autor et al. (1998)).

Secondly, increasing international trade, in particular trade with low-wage countries, also offers an explanation for the increased relative demand for skilled workers. The reason is that countries with an abundance of skilled workers will specialize in skill intensive production, whereas low wage countries specialize in labor intensive production. As a direct consequence, relative labor demand for skilled workers increases in the highly developed countries. The empirical importance of international trade to explain increasing wage inequality is strongly disputed however because of the limited volume of international trade (see Wood (1994), Borjas and Ramey (1995), Feenstra and Hanson (1996), and the discussions in Krugman (1993) and Nahuis (2000)).

Thirdly, some recent studies hint at capital skill complementarity, i.e., higher educated workers are more complementary to capital than unskilled workers. This implies that the relative demand for skilled workers increases with the capital intensity of the economy, analogously to skill-biased technical change (Goldin and Katz (1995), Krusell et al. (2000), and Beaudry and Green (2000)). The question still remains whether capital-skill complementarity is indeed empirically relevant, because it is difficult to disentangle from skill-biased technological change. Furthermore, explaining rising wage inequality with capital skill complementarity seems difficult to reconcile with a constant capital share in output (see Heckman et al. (1998)).

Fourthly, changes in labor market institutions may have contributed to increases in overall wage inequality. Lower minimum wages and erosion of union power have caused an increase in wage inequality in the US (DiNardo et al. (1996), Lee (1999), and Teulings (2003)). A number of institutional changes have occurred as well in the Netherlands. These may have contributed to increases in wage inequality, e.g., the freezes in minimum wages and benefits and its associated lowering of the replacement rate which has eroded union power. Other examples are reforms in welfare, unemployment, and disability benefits. The growing importance of part-time jobs and flexible labor contracts have also put pressure on the wage setting power of unions. Labor market institutions may further explain why wage inequality has not been rising so much in most European countries compared to the US. Skill-biased labor demand shifts do not result in larger wage inequality, but in higher unemployment rates amongst the low-skilled if low-skilled workers' incomes are protected by for example minimum wages, strong unions, strong labor market regulations, and so on. See for example Krugman (1995) and David (1998) for the effects of skill-biased labor demand shifts due to increased international trade in the presence of minimum wages.

Although (changes in) labor market institutions may have mattered for overall wage inequality, one has to be careful in drawing firm conclusions on the role of institutions for wage inequality. The reason is that institutional changes may well have been triggered by changed labor market conditions. Many institutional reforms in the Netherlands were to a large extent a response to high unemployment rates in the 1980s. Katz and Autor (1999, p. 1547) note: 'Institutions that go strongly against market forces face a difficult task.' This view finds ample empirical support by Leuven et al. (2000). The latter authors find that the standard labor market model of supply and demand works very well empirically to explain differences in wage inequality for a large number of developed countries.[1]

Furthermore, a number of authors suggest that the relative supply of skilled workers has actually been decreasing in the US, rather than increasing as a consequence of the ageing of the population, lower fertility rates and the inflow of low-skilled migrants (Katz and Murphy (1992), Murphy and Welch (1992), and Borjas et al. (1997)). These developments also increase wage inequality.

Not all wage inequality can be attributed to differences between different skill groups. One can see a steady increase in wage inequality *within* groups of workers with similar skills as well. Further, sectoral shifts in employment have stimulated relative demand for skilled labor.

Nevertheless, Katz and Autor (1999) concluded for the US that only a third of overall wage inequality can be attributed to gender, education, and experience. The bulk of wage inequality remains unexplained and cannot be attributed to observed skill, experience, sector of employment, etc. Skill-biased technological change is therefore regarded as the major candidate to explain this residual wage inequality.[2]

3 INEQUALITY IN THE NETHERLANDS

The evolution of wage inequality between skilled and unskilled workers has been somewhat different in the Netherlands compared to the Anglo-Saxon countries. Firstly, as often suggested, because the institutional setting of the labor market is different compared to other countries. Secondly, and probably more importantly, because the relative supply of skilled workers has increased tremendously in contrast to for example the US.

1 Moreover, Leuven et al. (2000) cast doubt on the findings by Blau and Kahn (1996) who suggested that institutions are the main force driving international differences in wage inequality.

2 One may perhaps draw a parallel to the literature on economic growth where the so called Solow residual is the most important ingredient for economic growth, but remains unexplained.

Stegeman and Waaijers (2000, p.11) present the following 'stylized facts' for the evolution of wage inequality in the Netherlands:

- Overall wage inequality increased in the 1980s, decreased somewhat at the beginning of the 1990s, and increased slightly towards the end of the 1990s.
- Wage differentials between men and women increased in the 1980s and decreased in the 1990s.
- Wage differentials between older and younger workers increased sharply in the 1980s and decreased slightly in the 1990s.
- Young workers with lower education started to earn relatively less compared to young workers with higher education in the 1980s (expansion of wage differentials). The 1990s show the opposite pattern (wage compression).
- Older workers with higher education faced declining wages compared to older workers with lower education (wage compression).
- Within-group wage inequality increased during the 1980s and remained stable during the 1990s.

Stegeman and Waaiers (2000) have two main explanations for the changes in the Dutch wage structure. First, the increase in skilled labor supply of predominantly female workers. Second, (general) skill-biased technological change. Sectoral shifts and labor demand effects only played a minor role.

Findings by Hartog et al. (1993), Leuven and Oosterbeek (2000) and Smits et al. (2001) are consistent with the stylized facts sketched above. In all these studies the private returns to education are estimated and compared over time. The private return measures the percentage increase in wages that results from an additional year of schooling. Therefore, the private return to education is a measure of inequality between workers with different skills: the higher the return, the larger the income differentials between groups of workers with different levels of schooling. The aforementioned authors find that the private return to education is about 11% at the beginning of the 1960s, then steadily declines to about 7% in the 1980s, stabilizes in the early 1990s, and increases again at the end of the 1990s to about 8-9% in recent years.[3]

4 A MODEL OF WAGE INEQUALITY

This section presents a small theoretical model of the labor market with two types of workers that is the basis of our empirical model used later on in this paper.

3 Fase (1969) computes internal rates of return to education based on age-earnings profiles in 1958-1967. Fase largely confirms earlier Dutch findings on the same data by de Wolff and Ruiter (1968) and finds rates of return that are comparable to the ones obtained by Hartog et al. (1991) who use Mincer's wage equation.

We relate wage inequality[4] to the supplies of low and high-skilled workers and to the developments in the demands for low and high-skilled workers. We assume perfect competition in labor and product markets. Workers of different skill are imperfect substitutes in production. We allow for skill-biased technical change and capital skill complementarity. Our set-up allows us to highlight the main determinants of wage inequality as discussed above.

Let production be designated by the following constant returns to scale production function F (.):

$$Y(t) = A(t)\, F(K(t), S(t)\, H(t), L(t))\ , \tag{1}$$

where Y, A, S, K, H, L, and t stand for output, an index for Hicks-neutral technological change, a specific index for skill-biased technical change, the capital stock, the number of high-skilled workers, the number of low-skilled workers, and time, respectively. Following Krusell et al. (2000), we assume that high-skilled labor and capital are nested in the aggregate production function with a constant returns sub-production function G (.), dropping the time indices for convenience:

$$Y = AF(L, G(K, SH))\ . \tag{2}$$

We impose the restriction that the elasticity of substitution between capital and low-skilled labor equals the elasticity of substitution between skilled and unskilled labor (σ). According to Krussell et al. (2000) this is consistent with empirical findings for the US. The elasticity of substitution between capital and skilled labor is denoted ρ. If $\sigma > \rho$, skilled labor is more complementary to capital than unskilled labor.

Perfect competition and constant returns to scale imply that all workers receive their marginal product as wages. Let w_H and w_L denote the wages of skilled and unskilled workers. Consequently, the wage differential between skilled and unskilled workers is:

$$\pi \equiv \frac{w_H}{w_L} = \frac{(\partial F/\partial G)\, S\,(\partial G/\partial H)}{\partial F/\partial L}\ . \tag{3}$$

To find the determinants of wage inequality we (log-)linearize the last equation around an initial equilibrium. This results in the following expression for the change in wage inequality (see the appendix for the relevant algebra):

4 From here on, we use the short-cut wage inequality to denote wage inequality between skilled and unskilled workers.

$$\tilde{\pi} = \underbrace{\frac{1}{\sigma}(\tilde{L} - \tilde{H})}_{\text{substitution}} + \underbrace{\left(1 - \frac{\omega}{\sigma} - \frac{1-\omega}{\rho}\right)\tilde{S}}_{\text{skill-biased technical change}} + \underbrace{\left(\frac{1}{\rho} - \frac{1}{\sigma}\right)(\tilde{K} - \tilde{H})}_{\text{capital-skill complementarity}}, \tag{4}$$

where a tilde denotes a percentage change in a variable, e.g., $\tilde{\pi} \equiv d\pi/\pi, \omega \equiv (\partial G/\partial H)\,SH/G(.)$ is the income share of high-skilled labor income in the sum of wage payments to high-skilled workers and rental payments to capital owners.

The three terms in equation (4) have an intuitive interpretation. The first term gives the standard substitution effect on wages that arises from changes in the relative supply of skilled workers. Increasing the supply of skilled workers relative to unskilled workers ($\tilde{L} - \tilde{H} < 0$) will result in less wage inequality because workers with different skill levels are imperfect substitutes in production. If firms cannot perfectly substitute the increase in supply of skilled workers for unskilled skilled workers, productivity of skilled (unskilled) workers falls (increases) and wage inequality diminishes. If workers are perfect substitutes in production, $\sigma = \infty$, increases in relative supplies of skilled workers ($\tilde{L} - \tilde{H} < 0$) do not affect wage inequality. We would get a similar result if relative wages are determined in world factor markets. One could also interpret $\sigma = \infty$ as a small open economy with perfect factor price equalization. Moreover, increased internationalization may be viewed as an increase in σ. Wage inequality increases as a consequence.

The second term in equation (4) denotes the effect on wage inequality of skill-biased technical change ($\tilde{S} > 0$). Skill-biased technical change results in rising wage inequality because productivity of skilled workers increases relative to unskilled workers.

The last term in equation (4) measures the effect of capital-skill complementarity on wage inequality. An increase in the capital stock ($\tilde{K} > 0$) increases wage inequality because productivity of skilled labor increases relative to unskilled labor.[5] Most analyses hint at skill-biased technical change as the major reason for increases in wage inequality, but equation (4) shows that this may also be due to unmeasured capital-skill complementarity. Krusell et al. (2000) argue that unmeasured trend effects may simply be serving as a proxy for omitted capital-skill complementarity.

A remark on the clearing of the labor markets is in order here. One may argue that minimum wages fix the wage rates for the unskilled workers. Therefore, increases in the supply of unskilled workers do not affect wage inequality, but raises unemployment among the unskilled. However, for the long run we are inclined to think that wages for low-skilled workers are indeed flexible. If this was not the case, one should observe that the number of unemployed unskilled workers

5 If we have a Cobb-Douglas production function, then $\rho = \sigma = 1$, and there is no capital-skill complementarity.

would be steadily increasing over time as the supply of unskilled workers increases. Casual observation suggests that this is implausible. If labor demand for skilled workers keeps up with supply of skilled workers, then minimum wages are not a binding restriction in the demand for low-skilled workers.

Katz and Murphy (1992) based their analysis on a CES production function without capital-skill complementarity, i.e., $F(K, SH, L)$, and $\sigma = \rho$.[6] They further assume a linear time trend in relative demand shifts, i.e., $S(t) = \exp(\gamma t)$. Consequently, the wage differential can be written as:

$$\log \pi = \log\left(\frac{S\partial F/\partial H}{\partial F/\partial L}\right) = -\frac{1}{\sigma}\log\left(\frac{H}{L}\right) + gt + c\,, \tag{5}$$

where the constant c is a function of the labor income shares of skilled and unskilled workers, and $g \equiv (1 - 1/\sigma)\,\gamma$. Katz and Murphy (1992) estimate the last equation on US data using a time series for the period 1963-1987 and obtain the following:

$$\log \pi = -.709 \log(H/L) + .033t + c\,. \tag{6}$$

From this follows that the elasticity of substitution between skilled and unskilled workers $\sigma = 1.41$ and the rate at which demand shifts relative to labor demand increases wage inequality equals 3.3% per year.

Note that it is in general hard to discriminate between the various causes of wage inequality. Increased skill-biased technological change as well as capital-skill complementarity and international trade will affect relative demands for skilled workers and thereby the estimated trend in relative labor demand. In our analysis below we do not attempt to disentangle the various causes. We focus on the aggregate shifts in relative demand for skilled labor. The specification of our estimation equation is based on Katz and Murphy (1992).

5 DATA AND ANALYSIS

We base our analysis on labor statistics ('Arbeidsrekeningen') for the period 1969-1996 collected by CBS (1999).[7] We only use aggregate data because estimation of the elasticity of substitution between skilled and unskilled workers on sectoral level gave implausibly high values. The reason for this finding is probably that sectoral wage differentials are mainly determined by relative supplies of skilled workers throughout the economy. Workers can move relatively easy from one sec-

6 The equation for changes in wage inequality (4), becomes: $\tilde{\pi} = \frac{1}{\sigma}(\tilde{L} - \tilde{H}) + \left(1 - \frac{1}{\sigma}\right)\tilde{S}$.

7 Data for more recent years were not yet available at the time of research. Data are available upon request.

tor to another when there are large wage differentials between sectors. Arbitrage on the labor market ensures that relative wages in all sectors are equalized.[8]

Data are available for four levels of education: workers with primary education (or less), workers with secondary general education, workers with secondary vocational education and workers with either higher vocational or university education. We use two skill groups: lower and higher educated workers. Lower educated workers are all workers with primary or secondary education. Higher educated workers are all workers with higher education.[9]

Our measure for relative supply of skilled workers is simply the ratio of the number of skilled and unskilled workers. We use total labor years, rather than employed persons, as a measure for the supply of each skill group. This is a correct measure for effective labor supply and avoids problems with the number of hours worked. The drawback of this measure is that labor years are sensitive to the business cycle, whereas, for example, total persons in the labor force is not. To check whether business effects are important, we also estimated our regression equation with relative supplies of skilled workers based on the number of persons in the labor force, but this affected our estimates only marginally.[10]

Wage inequality measures are based on gross hourly wages. Relative wages are defined as the ratio of hourly wage rates of skilled and unskilled workers. Wage rates of aggregate skill groups are based on weighted wage rates of the various subgroups. The relative number of labor years have been used as weights.

Because of the short time series available, it is econometrically impossible to allow for a finer disaggregation in skill groups or to allow for the capital stock. Any additional variables would severely limit the reliability of the estimations, as was the case in previous Dutch analyses. For example, Hebbink (1991) estimates 9 or more parameters using a data set containing only 48 observations. We note here that Katz and Murphy (1992) also estimate their equation using 25 observations.

Aggregate time series of the relative supply and wages of skilled workers (in logs) are given in Figure 1. The strong increase in the relative supply of skilled workers is striking. Average growth in relative supply of skilled workers was 4.1% per year in the period 1969-1996. The wage differential between skilled

8 It may be that econometric problems were encountered in earlier Dutch studies because sectoral data were used, see, e.g., Hebbink (1991), Draper and Manders (1996), and Stegeman and Waaiers (2000).

9 Other ways of aggregating skill groups did not affect our results. Katz and Murphy (1992) take weighted supplies within each aggregate skill group where weights are defined as the fraction of time series averages of wages for each subgroup and average wages within each skill group. A similar procedure can be applied to compute the relative wages within each skill group, i.e., by weighting with average labor supplies of each skill group with averages of the aggregate. Some form of the 'Cambridge' controversy is relevant here because, for example, the weights for weighting supplies (wages) are determined by the supplies themselves.

10 Results are available upon request.

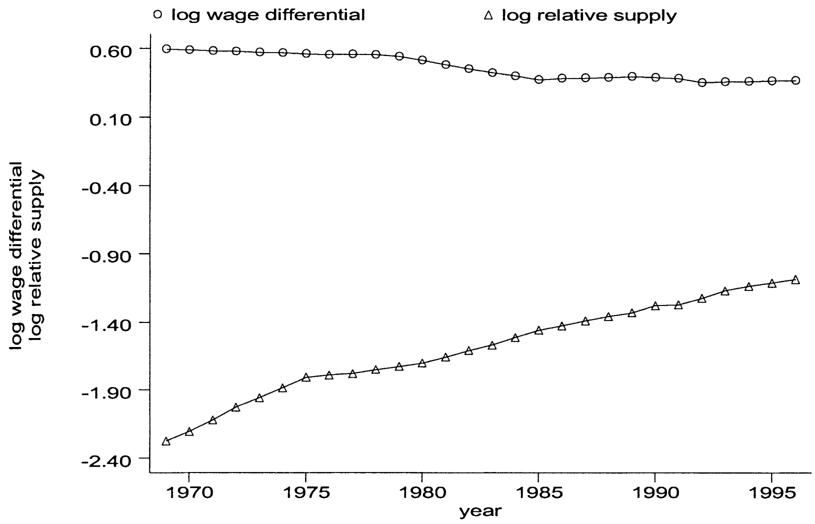

Figure 1 – Log relative supply of skilled workers and log wage differentials

and unskilled workers decreased at an average rate of 1.1% per year in the same period.

At first sight, these time series suggest that there must have been substantial shifts in relative demand for skilled workers to absorb the growth in supply of skilled workers, since differentials decreased at a much slower pace than the relative supply of skilled workers increased.

The data strongly suggest that the time series are not stationary, which may cause estimation problems. Indeed, ADF tests on both relative supplies and relative wages indicate that the presence of a unit root cannot be rejected.[11] We obtain consistent estimates of our parameters only when the estimating equation is co-integrated. We applied ADF statistics on the residuals in our estimations to test for co-integration, i.e., the null-hypothesis of a unit root in the residuals must be rejected.

Following Katz and Murphy (1992), our estimating equation is given by:

$$\log \pi = -\frac{1}{\sigma} \log \left(\frac{H}{L}\right) + gt + c + \varepsilon\,, \tag{7}$$

where c is a constant, g denotes a (linear) time trend which measures shifts in growth of relative demand and σ is the elasticity of substitution between skilled and unskilled workers. Table 1 shows the estimation results.

11 Results are available from the author upon request.

TABLE 1 – ESTIMATION RESULTS ELASTICITY OF SUBSTITUTION AND RELATIVE DEMAND SHIFTS

	g	$-\frac{1}{\sigma}$	σ	p-coint.[†]	R^2_{adj}	N
Not restricted	–	−.253*** (.017)	4	.61	.88	28
Not restricted	−.0112** (.0053)	.0158 (.13)	−63	.86	.89	28
Fixed g						
g = .01	–	−.492*** (.021)	2.0	.29	.95	28
g = .02	–	−.731*** (.025)	1.4	.13	.97	28
g = .03	–	−.970*** (.031)	1.0	.09*	.97	28
g = .04	–	−1.12*** (.036)	.8	.07*	.98	28
Fixed σ						
σ = .5	.0716*** (.0023)	–		.02**	.98	28
σ = 1	.0305*** (.0013)	–		.04**	.95	28
σ = 1.5	.0168*** (.0010)	–		.10*	.91	28
σ = 2	.00995*** (.00088)	–		.22	.82	28
σ = 2.5	.00584*** (.00082)	–		.35	.65	28
σ = 3	.00310*** (.00078)	–		.46	.35	28

Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level, standard errors in parentheses. [†]Test for co-integration based on the MacKinnon p-value for rejection of the null-hypothesis of a unit root in the residuals using an ADF statistic without a trend or lags.

Direct estimation of equation (7) gave non-significant results for the substitution elasticity. Moreover, both the estimates for the elasticity of substitution and the time trend have the wrong sign. The statistical reason for this result is that the time trend is highly collinear with the growth in relative supply of skilled workers (correlation coefficient .99). Figure 1 confirms that relative supply increases almost linearly through time.[12]

As suggested by Katz and Murphy (1992), we proceed by fixing the time trend on a plausible value and estimate the elasticity of substitution, and *vice versa*. This allows us to investigate whether the Dutch data are consistent with empirically plausible values of both parameters encountered in the literature.

Table 2 gives an overview of estimated substitution elasticities as well as the estimated time trends where available. Generally, elasticities are found to lie in the interval (1; 3), cf. Freeman (1986) and Katz and Autor (1999) for overviews of the empirical literature. Freeman (1986, p. 366) draws the conclusion: 'All told, the current evidence suggest a value of the elasticity of substitution between more and less educated labor in the range 1.0-2.0.' Katz and Autor's (1999) reading of the literature also suggests a value around 1.5. Insofar as time trends have been estimated, the coefficients imply a value of the annual growth rate in relative wages of around 3%.

The Dutch study by Draper and Manders (1996) finds plausible estimates. However, studies by Hebbink (1991) and Stegeman and Waaijers (2000) are subject to estimation problems and therefore provide little robust evidence as to what the elasticity of substitution or the time trend is. Hebbink (1991), finds an implausibly high negative value of the rate of skill-biased technical change and very low elasticities of substitution. Stegeman and Waaijers find a very high value of the elasticity of substitution and do not estimate the rate of skill-biased technical change.

First, we fix the time trend at values of 1, 2, 3, and 4% per year. Estimates found in earlier studies are covered in this range of values. Estimation results for the elasticity of substitution – all statistically significant at the 1% level – imply that the coefficient lies exactly in the range of findings from the international literature. Our estimates of the elasticity of substitution range from .8 to 2.0.

If we fix the elasticity of substitution at plausible values between .5 and 3, and estimate the coefficient for the time trend, we also find statistically significant estimates for the time trend in the order of .3 to 7.2% per year. This is also in the ball park of earlier findings, cf. Table 2.

If the elasticity of substitution is smaller than 2 or if the time trend in labor supply is larger than .02, we find that the regression equations are indeed (nearly) co-integrated for the most plausible parameter values. In order to gain more confidence in our estimations, we also estimated the regression equation in first-differences.[13] Again, simultaneous estimation of the elasticity of substitution and the time trend produce implausible coefficients. However, estimations in first-differ-

12 This may be another reason why the Dutch studies faced problems in estimating the elasticity of substitution.

13 Results are available from the author upon request.

TABLE 2 – OVERVIEW OF ESTIMATES OF ELASTICITY OF SUBSTITUTION AND RELATIVE DEMAND SHIFTS

Study	Country	Data	σ	g
Welch (1970)[a]	US	CS s	1.4	
Johnson (1970)	US	CS s	1.3	
Dougherty (1972)	US	CS s	8.2	
Psacharopoulos et al.[b] (1972)	var.	CS c	1000	
Psacharopoulos et al.[c] (1972)	var.	CS c	2.1 – 2.5	
Tinbergen (1974)	var.	CS c	.6 – 1.2	
Layard and Fallon (1986)	var.	CS c	.6 – 3.5	
Hebbink (1991)	NL	TS	0 – 1.2	−.06 – −.13
Katz and Murphy (1992)	US	TS	1.41	.033
Bound and Johnson (1992)	US	P m	1.7	
Schmitt (1995)	UK	TS m	3.4	
Kim and Topel (1995)	S. Korea	TS m	3.7 – 4.2	.033 – .002
Edin and Holmlund (1995)	Sweden	TS m	2.9	.008 – .011
Draper and Manders (1996)	NL	P s	1.53 – 3.01	.03
Heckman et al. (1998)	US	SM m	1.44	.036
Murphy et al. (1998)	Canada	TS m	1.37	
Krussel et al. (2000)	US	SM m	1.67	
Stegeman and Waaijers (2000)	NL	P m	8	

Note: CS stands for cross section, TS for time series, P for panel, SM for structural model, s denotes state-level data, c denotes country-level data, m denotes micro-level data. [a] Only agricultural sectors. [b] Only developed countries. [c] Only undeveloped countries.

ences when the trend or the elasticity of substitution is fixed give very similar coefficients as the levels specification, which is a reassuring finding.

Although this analysis has some shortcomings caused by the strong multicollinearity between relative supply of skilled workers and the growth rate in relative demand for skilled workers, we can at least conclude that our estimations, while fixing one of the parameters at plausible values, produce values of the other coefficients that are considered to be amongst the most reasonable values found in the literature. Therefore, the rest of the analysis is based on three specifications for the macroeconomic production function consistent with the data:

1. $\sigma = 1.4$ and $g = .02$.
2. $\sigma = 2.0$ and $g = .01$.
3. $\sigma = 1.0$ and $g = .03$.

The first is our ‘best guess’ scenario with an elasticity of substitution suggested by most authors and a time trend which is somewhat lower than found in most US studies. Eden and Holmstrum (1995) find a trend of 1% per year for Sweden, a country whose labor market conditions are probably more similar to the Netherlands than the US. The other two scenarios are based on a low trend in relative demand shifts and a high elasticity of substitution, and *vice versa*.

The goodness of fit as measured by the R^2_{adj} from the estimation equations are quite high in our scenarios, ranging from .95 to .97. We plotted in Figure 2 the actual development in wage inequality and the development in wage inequality as predicted by our scenarios, in order to get an idea to what extent our model approaches reality. The model of relative supply and demand predicts quite well after 1980. Before 1980, however, the fit is not too good. We have checked whether this result could be traced to the fact that we used the relative supply of labor years rather than relative labor supply in persons. This was not the case. Also projections based on relative supply measured in persons showed the same pattern before 1980. Furthermore, one can argue that especially low-skilled workers were hit by unemployment during the years of the oil crises. This would imply that relative supplies of skilled workers would have gone up in these years and predicted wage inequality should have decreased even further. Consequently, allowing for employment effects would have increased the observed gap between predicted and actual wage differentials. We further checked whether omitting the years 1969-1974 gave different estimates. This did not turn out to be the case.

One may also question the appropriateness of using a linear time trend to measure relative demand shifts. In Figure 3 we plotted the time series of implied demand shifts for the period 1969-1996, based on an assumed elasticity of substitution equal to 1.4. Given the fact that relative supply of skilled workers increases almost linearly through time, it is not surprising that the trend in relative demand shifts is also approximately linear. We checked whether there are non-

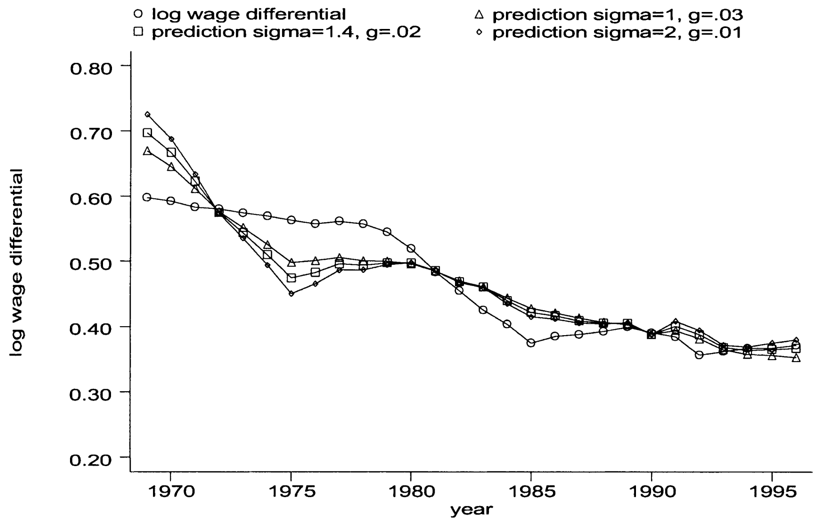

Figure 2 – Ex-post prediction of wage differentials in The Netherlands 1969-1996

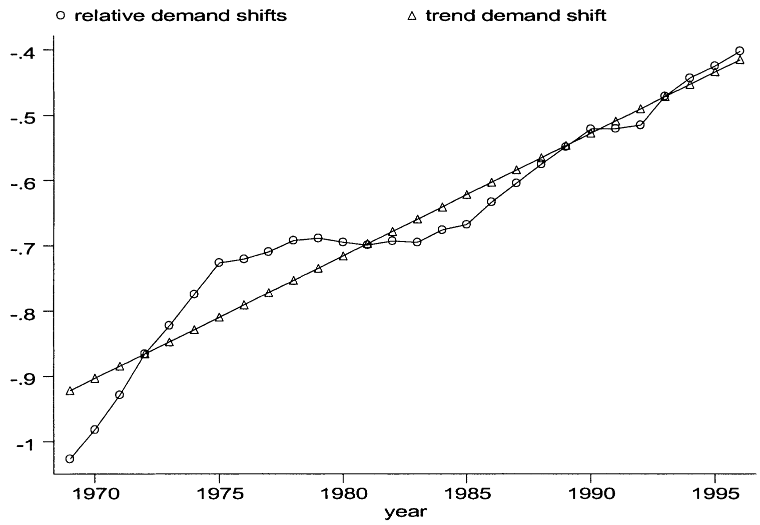

Figure 3 – Implied relative demand shifts in the Netherlands 1969-1996 (σ = 1.4).

linearities in the time trend by regressing the differences between implied demand shifts (based on an elasticity of substitution equal to 1.4) and predicted demand shifts (based on a linear trend) on the time trend. Estimates are not significant at conventional levels, so that we cannot reject the hypothesis that the time trend is linear.

6 WAGE DIFFERENTIALS IN THE NETHERLANDS 2000-2020

Projections on the development of supplies of workers with different levels of education are given in CBS/CPB (1997). In this study we use an update of these data made available by CPB.[14] Data are only available on the number of employable people in the labor force. We make predictions about the future development in wage inequality based on our three specifications of the production structure.

We have to make two assumptions in our predictions. First, we assume that the developments in the relative supply of labor years are comparable to the development in the number of employable workers in the work force. However, participation rates will probably increase faster for low-skilled than for high-skilled workers because low-skilled workers are lagging behind with respect to hours worked and participation rates. Therefore, we may overestimate the growth in effective relative skilled labor supply in labor years.

14 Data are available from the author upon request.

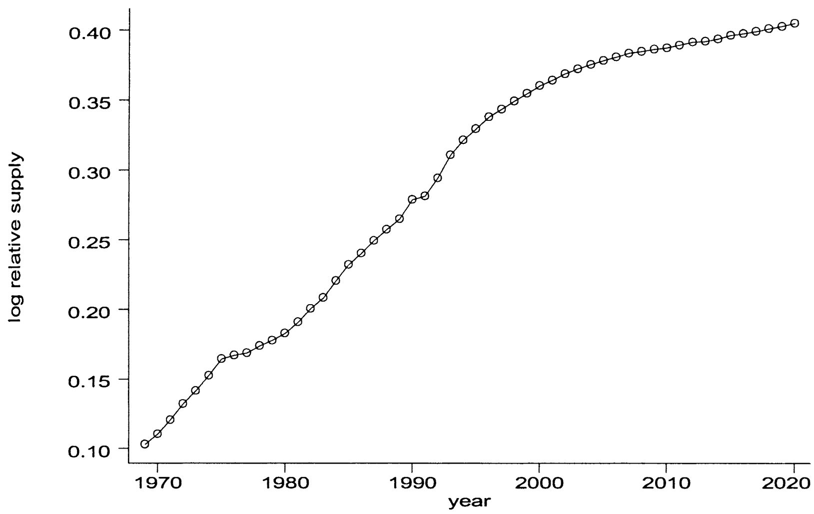

Figure 4 – Time series log relative supply of skilled workers

Second, we assume that the growth in the relative supply of skilled workers is exogenous.[15] This implies that relative supply of skilled labor is not affected by relative wages. Only an advanced general equilibrium model, where the supply side of the labor market is based on individually optimizing behavior with regard to investments in human capital, can tackle the consequences of changes in relative wages on incentives for skill formation. This is beyond the scope of this paper, but see for example Heckman et al. (1998a, 1998b) for an application. We discuss this assumption later in more detail.

Figure 4 shows the development of the relative supply of skilled workers in the period 1969-2020.[16] Relative supply of skilled workers increases to about 39% in 2000 and stabilizes around 44% in 2020. In other words, the average growth rate of the relative supply of skilled workers falls from 4.1% per year in the period 1969-2020 to a modest 0.6% per year in 2000-2020. Consequently, there will be a strong decline in the growth rate of relative supply of skilled labor.

In Figure 5 we plotted the predicted wage differentials between skilled and unskilled workers for the various parameter values regarding the trends and elasticities of substitution. We harmlessly normalized the initial (log) wage differential in 2000 at zero, since we do not have a value of wage inequality in 2000.

15 This assumption was also made in the construction of the time series.

16 We made a correction for the break in the time series by adjusting the initial level of the second time series to the level of the first. The first time series has been extrapolated with the average growth rate in relative supply of skilled workers (0.6% per year) in 1997-2000. In later calculations we use CBS/CPB projections.

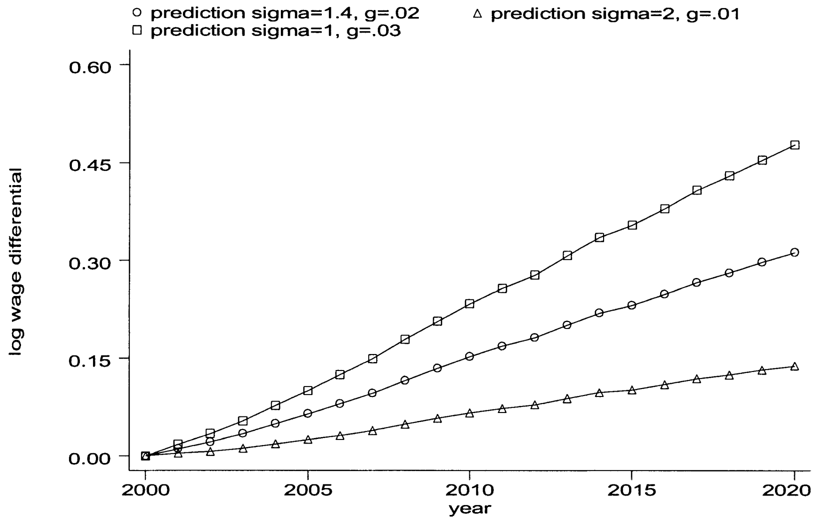

Figure 5 – Ex-ante predictions wage differentials in the Netherlands 2000-2020

This is also convenient since any log differences at later dates can be interpreted as percentage changes relative to 2000. The figure shows that the increase in relative supply of skilled workers will not be sufficient to reduce future wage inequality. Wage inequality will increase by 14% in the scenario with the lowest presumed trend in relative demand for skilled workers. Relative wages increase by 31% in the base line scenario. And, wage differentials increase by 48% in the scenario with the highest growth in relative demand for skilled workers. It is easily established that the bulk of the increase in wage inequality can be attributed to skill-biased labor demand shifts and only a minor part can be attributed to substitution of skilled for unskilled workers. Table 3 breaks down the increase in wage inequality in increases in relative demand and in substitution effects.

To check for robustness, we also made projections on developments in wage inequality for a 'worst case' and a 'best case' scenario. In the 'worst case scenario,' the elasticity of substitution and the time trend in demand have been set relatively high, but not at such extreme levels that are found in the literature, i.e., $\sigma = 2$ and $g = .03$. The elasticity of substitution may increase due to, for ex-

TABLE 3 – DECOMPOSITION WAGE INEQUALITY 2000-2020

	Trend	Substitution	Total
$g = .02,\ \sigma = 1.4$	.40	−.09	.31
$g = .01,\ \sigma = 2.0$	.20	−.06	.14
$g = .03,\ \sigma = 1.0$	.60	−.12	.48

ample, increased international trade, whereas a higher rate of growth in relative demand for skilled workers may reflect an acceleration in the rate of skill-biased technical change. In the 'best case scenario,' both parameters have been set at the lowest values that seem reasonable, i.e., $\sigma = 1$ and $g = .01$.

Ideally, we would like to provide confidence intervals for our predictions, but the true standard error of our estimations is unknown since we fixed one of the parameters in the estimations. Nevertheless, we can get some idea on the prediction intervals for the individually estimated parameters. If the estimated coefficient for σ is about 1.4 and the partial standard error for the estimates of $1/\sigma = 1/1.4$ equals at most .036 (see Table 1), the 99% confidence interval for σ would be $\sigma \in [1.2; 1.7]$. Similarly, for the time trend, for a value of $g = .02$ and a standard error of at most .0023 (see Table 1) we would obtain a 99% confidence interval for $g \in [.01; .03]$. Therefore, our worst and best case scenarios probably cover the upper and lower bounds of parameters quite reasonably.

Figure 6 presents both cases. At best, wage inequality will diminish in the short run, but will increase in the long run. In the worst case, wage inequality will increase tremendously leading to an increase of the wage differential between skilled and unskilled workers of about 55% in 2020.

To summarize, it is very likely that wage inequality between skilled and unskilled workers will increase in years to come. The reason is that the growth rate in relative supply will slow down to a rate of only 0.6% per year. This will not be sufficient to meet the increase in relative demand resulting in a growth in wage inequality of at least 1% per year under the most plausible circumstances.

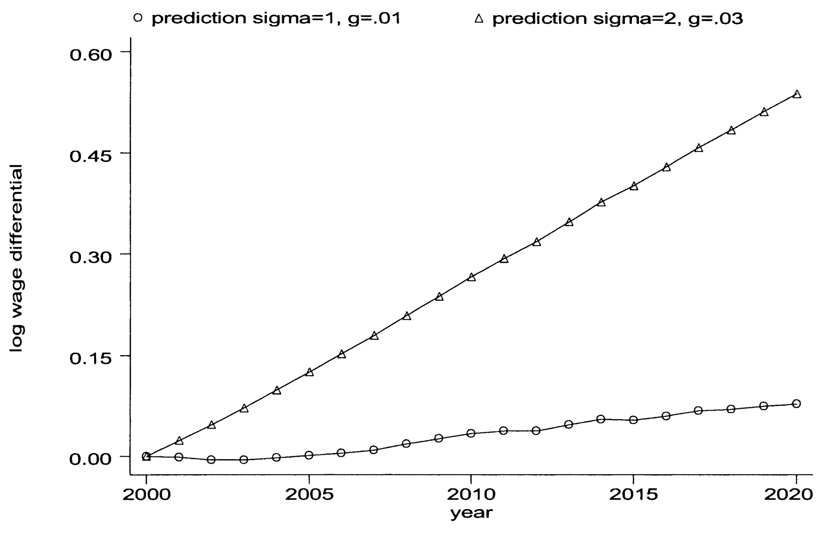

Figure 6 – Ex-ante predictions of wage differentials in the Netherlands 2000-2020 for 'extreme' scenarios

Therefore, one may conclude that the race between schooling and technology is lost by schooling.

7 EDUCATION POLICY TO REDUCE INEQUALITY

Tinbergen (1975) and Teulings (2000) argue that there is a role for the government in reducing wage inequality by means of education subsidies. The argument is based on the idea that increasing the incentives to enroll in higher education stimulates the relative supply of skilled workers and reduces wage inequality as a consequence. If equity is valued in society, then there is a possibility for the government to use education policies in reducing wage inequality.

In this section we show to what extent the government can indeed contribute to a reduction in wage inequality by means of education subsidies. Firstly, we compute the increase in the stock of skilled workers needed to keep wage inequality constant. Secondly, we derive the necessary yearly increase in the flow of skilled workers to the labor market. Thirdly, we calculate the required reduction in tuition costs in order to boost the supply of skilled workers.

A natural point of reference is to take the current amount of wage inequality as a measure for the desired amount of income inequality. According to Becker's (1983) efficient redistribution hypothesis, policies would have changed if they did not meet current political demands for redistribution. Suppose that the government considers education policy to keep wage inequality constant, how much should the relative demand for skilled workers increase to keep wage inequality at its current level?

The answer can easily be obtained by totally differentiating the estimated equation for wage inequality:

$$d \log \pi = g dt - \frac{1}{\sigma} d \log \left(\frac{H}{L} \right) . \tag{8}$$

If wage inequality does not increase we have $d \log \pi = 0$. Now we can solve equation (8) for $d \log (H/L)$:

$$d \log \left(\frac{H}{L} \right) = \frac{d (H/L)}{H/L} = \sigma g dt . \tag{9}$$

In other words, the percentage increase in the relative supply of skilled workers is linear in the elasticity of substitution, the growth in relative demand for skilled workers, and the length of the time period under consideration.

We can compute the increase in relative supplies of skilled workers in order to keep wage inequality constant in the next 20 years for the various scenarios, see Table 4. The current relative supply of skilled workers will increase from .39

TABLE 4 – CALCULATIONS OF INCREASE IN RELATIVE SUPPLY OF SKILLED WORKERS

	Required $H=L$	Prediction $H=L$	Difference (%-points)	Difference (%)	Required growth (%)
$g = .02,\ \sigma = 1.4$	.61	.44	17	39	2.2
$g = .01,\ \sigma = 2.0$	.55	.44	11	25	1.7
$g = .03,\ \sigma = 1.0$	.62	.44	18	41	2.3

Note: the time period is 20 years ($dt = 20$) and the ratio of skilled to unskilled workers in 2000 is $H/L = .39$.

to .44 in 2020. If we confront the predicted relative supply of skilled workers with the relative supply of skilled workers necessary to keep wage inequality constant, the relative supply of skilled workers has to increase with 11%-points in the most favorable case, and with 18%-points in the most unfavorable case.

Consequently, the relative number of skilled workers has to increase at least 25% and at most with 41% relative to the situation in 2020. The average growth rate of relative supply of skilled workers must increase from .6% per year to 2.2%, 1.7%, or 2.3% per year, respectively. Therefore, the growth rate of relative supply of skilled workers needs to double at least, and quadruple at most, in the period 2000-2020 in order to keep wage inequality constant. Recall that these growth rates are always lower than the growth in relative supply of skilled workers that occurred in recent decades (4.1% per year).

A qualification is in order here because these numbers do of course depend critically on the accuracy of the predictions by CBS/CPB (1997). Since standard errors of the predictions are not available, we cannot assess the extent to which these numbers are sensitive to uncertainties involved in the future development of the relative supply of skilled workers.[17]

Education policy allows the government to increase the number of skilled workers in the labor force. However, education policies only affect the stock of skilled workers indirectly. The reason is that stimulating skill formation only affects the inflow of younger age cohorts that become higher educated as a result of the policy.

We do not only have projections for 2000-2020 on the relative number of skilled and unskilled workers in the labor force, but also on the in- and outflows of workers in the labor force. This allows us to compute the percentage increase in the inflow of higher educated workers to the labor market that is necessary to increase the stock of skilled workers so as to keep wage inequality at current levels.

17 The projections by CBS/CPB (1997) do consider three scenarios but the scenarios only differ very little from each other as regards the development of relative supply of skilled workers over time.

To that end we propose a highly stylized labor market model of flows. Let H_t and L_t denote the number of high and low-skilled workers at time t. In every year there is an inflow of higher and lower educated workers, IH_t and IL_t. There is an outflow of older workers (OH_t and OL_t) from the labor force as a consequence of retirement, mortality, etc. The stocks of higher and lower educated workers at time $t + 1$ are

$$H_t + 1 = H_t + IH_t - OH_t$$
$$L_{t+1} = L_t + IL_t - OL_t\,. \tag{10}$$

The relative supply of skilled workers at time t is now given through backward iterating the last equation to time $t = 0$:

$$\frac{H_t}{L_t} = \frac{H_0 + \sum_{v=0}^{v=t} (IH_v - OH_v)}{L_0 + \sum_{v=0}^{v=t} (IL_v - OL_v)}\,, \tag{11}$$

where L_o and H_o denote the given number of unskilled and skilled workers at time $t = 0$ (2000).

Suppose that we increase the inflow of skilled workers in the period 2000-2020 with a constant fraction δ of all workers that flow into the labor market, i.e., $\delta(IL_t + IH_t)$. The increased inflow of skilled workers originates from a decrease in the inflow to the labor market of unskilled workers. Therefore, the inflow of unskilled workers falls with fraction δ of the total inflow of workers. The question is: how high must δ be to increase the inflow of skilled workers so as to get the stock of relative supply of skilled workers at .61 instead of .44 in 2020 (for the base line scenario)? δ follows from solving:

$$\frac{H_t}{L_t} = \frac{H_0 + \sum_{v=0}^{v=t} (1+\delta)\ IH_v + \delta IL_v - OH_v}{L_0 + \sum_{v=0}^{v=t} (1-\delta)\ IL_v - \delta IH_v - OL_v}\,, \tag{12}$$

where $t = 20$ (2020) and $\dfrac{H_t}{L_t} = \dfrac{H_{2020}}{L_{2020}}$.

Table 5 shows the results. Since δ is the increase in the inflow of higher educated workers to the labor market, δ is approximately equal to the %-point increase in the fraction of each birth cohort that enters the labor market directly from college and university. Some quantitatively less important factors may play a role such as an inflow to the labor market from unemployment, migration, etc.

TABLE 5 – CALCULATIONS OF INCREASE IN THE YEARLY INFLOW RATE OF SKILLED WORKERS TO THE LABOR MARKET

	H/L_{2020} (%)	δ (%)
$g = .02,\ \sigma = 1.4$	61	15
$g = .01,\ \sigma = 2.0$	55	10
$g = .03,\ \sigma = 1.0$	62	15

From Table 5 it follows that the fraction of skilled workers in each birth cohort has to increase by 10-15%-points every year in order to keep wage inequality constant. The fraction of each birth cohort that graduated in higher education was 34.6% in 1998 (Ministry of Education (2000, p. 25)). This implies that, if the outflow percentage was 35%, it has to go up to 45-50%. In other words, about 45%-50% of each birth cohort should enter the labor market in 1998 as a worker with higher education. In the future, this will have to be an even larger number because the fraction of each birth cohort that graduates increases.

The effectiveness of education policy in reducing wage inequality critically hinges on the price elasticity of enrollment. The more responsive enrollment is to reductions in educational costs, the more potent is education policy in stimulating the relative supply of skilled workers. However, empirical estimates of the price elasticity of enrollment seem to suggest that the price responsiveness of enrollment in higher education is quite low. In Table 6 we summarize the findings on estimated enrollment elasticities that are found for Dutch and US studies.[18]

Dutch findings imply an almost completely inelastic demand for higher education. Kodde (1985) finds that doubling tuition costs results in a decline of enrollment of only 1%-point. Oosterbeek and Webbink (1995) show that this effect is approximately zero. Kane's findings for the US suggest a relatively low price elasticity of enrollment. Doubling tuition rates reduces enrollment 3-6%-points. However, Leslie and Brinkman (1987) find a very high price elasticity of enrollment: doubling tuition rates will reduce enrollment rates by a substantial 21-27%-points. This has also been found in Hilmer (1998). However, both studies do not control for the selectivity of enrollment in higher education. Non-observed individual characteristics may blur the estimates.

Three studies explicitly take into account the selectivity: Heckman et al. (1998), Dynarski (1999), and Cameron and Heckman (1999). All studies find roughly similar estimates of a decrease between 3 and 8 percentage points in higher education when tuition costs increase by USD 1000. The implied quasi elasticity of enrollment is 2-7% accordingly. The difference between the elasticities of Dynarski and the others is that she evaluates the elasticity of enrollment at

18 The enrollment elasticity is defined as the change in the enrollment rate in %-points divided by the percentage change in prices, i.e., $e = -dq/(dp/p)$.

TABLE 6 – ENROLLMENT RESPONSES TO INCREASES IN TUITION COSTS AND CORRESPONDING QUASI ELASTICITIES

Study	Data	Type[a]	Control	Selection	Sign.?[b]	$-dq$	dp/p	e
Kodde (1985)	NL	CS	Yes	No	–	.0045	.5	.01
Oosterbeek et al. (1995)	NL	CS	Yes	No	No	0	–	0
Kane (1994)	US	CS + TS	Yes	No	Yes	.05	.83	.06
Kane (1995)	US	CS + TS	Yes	No	Yes	.035	1.33	.03
Leslie et al. (1987)	var.	M	–	No	–	.006 – .008	.029	.21 – .27
Hilmer (1998)	US	M	Yes	No	Yes	.01	.028	.36
Dynarksi (1999)	US	CS	Yes	Yes	Yes	.036	.10	.35 (.03)[c]
Heckman et al. (1998a)	US	SM, P	Yes	Yes	Yes	.08	.80[d]	.07
Card et al. (2000)	US	CS + TS	Yes	No	Yes	–	–	.01 – .04
Cameron et al. (2001)	US	P	Yes	Yes	Yes	.3 – .06	.80[d]	.02 – .05
Canton et al. (2002)	NL	TS	No	No	No	–	–	−.10 – .29[e]

Notes: ‘Control’ indicates whether estimations are done when controlling for background characteristics, IQ, and other individual characteristics. ‘Selection’ indicates whether corrections are made for the selectivity of individuals enrolling in college (non-observed heterogeneity). [a] CS = Cross-section; TS = Time series; P = Panel; M = Meta analysis; SM = Structural model. [b] Indicates significance at the 5% level of the estimated coefficient for tuition. [c] Price change relative to all costs of college *including tuition, room and board*. In parentheses we show elasticity evaluated at average tuition rates used by Cameron and Heckman (2001). [d] Price changes taken relative to an approximated weighted mean of 2 and 4 years tuition costs for Blacks, Hispanics, and Whites in Cameron and Heckman (2001) (USD 1250). [e] Quasi-elasticity equals the directly estimated elasticity under the assumption that enrollment of eligible students in university education is 100%. About 95% of all eligible students with pre-university education enroll, see Ministry of Education (2000).

TABLE 7 – REDUCTIONS IN TUITION RATES

	dq (%)	$dp = p$ (%) $e = .01$	$dp = p$ (%) $e = .03$	$dp = p$ (%) $e = .06$	$dp = p$ (%) $e = .10$
$t = .02,\ \sigma = 1.4$	15	1500	500	250	150
$t = .01,\ \sigma = 2.0$	10	1000	333	167	100
$t = .03,\ \sigma = 1.0$	15	1500	500	250	150

all costs, including board and room. The recent study by Card and Lemieux (2000), without correcting for selectivity in enrollment, also finds that the elasticity is around 1-4% in the US. Canton and De Jong (2002) find widely varying estimates of the elasticity of enrollment between −10% and 29% on Dutch data. None of the Dutch estimates are statistically significant, however.

Based on all these considerations it seems reasonable to assume that the enrollment elasticity in the Netherlands is somewhere between 0 and .1. We compute the required reduction in tuition costs to induce the appropriate increase in supply of skilled workers for our three scenarios with enrollment elasticities of .01, .03, .06 and .10, respectively. Table 7 shows the results.[19]

Enormous decreases in tuition costs are needed at very low enrollment elasticities: 1000% or more, i.e., ten times lower tuition rates. Still, very substantial decreases in tuition costs are needed in the middle cases ($e = .03$, $e = .06$), in the order of 200% or more. Substantial reductions in tuition costs are needed even at high enrollment elasticities: figures are always above 100% or more. Tuition costs should therefore be abolished even in most favorable cases to generate the increase in supply of skilled workers to keep wage inequality at its current level. In less favorable cases, students have to be paid to enroll in higher education. Our tentative calculations suggest that, even if our enrollment elasticities are only roughly plausible, that very substantial reductions in tuition costs are necessary to increase the stock of skilled workers so as to reduce wage inequality.

8 FACTORS THAT AFFECT THE EFFECTIVENESS OF EDUCATION POLICIES

So far, in the analysis a number of assumptions have been made that deserve further examination. Relaxing the assumptions may strengthen or weaken the conclusions reached so far. The effectiveness of education policies in reducing wage inequality can be affected in a number of ways.

Firstly, under free trade, wage rates of workers with the same skills will converge to levels that are determined on global, rather than local markets. Relative

19 We make the assumption that the percentage change in the outflow from higher education equals the percentage change in the inflow of higher educated to the labor market. This assumption is correct if drop-out rates remain constant.

wages will then depend on the global relative supplies of skilled workers and global relative demands for skilled workers, see Topel (1999) and Katz and Autor (1999). Boosting the relative supply of skilled workers in a small open economy, such as the Netherlands, will have a negligible effect on relative wages. However, empirical work shows that perfect factor price equalization is hard to establish. This implies that education policies may be used in reducing inequality.

Secondly, some endogenous growth theories link the supply of skilled workers to the rate of skill-biased technological change. An increase in the stock of skilled workers spurs R&D activities that result in new technologies that are more complementary to skilled workers. Consequently, stimulating skill formation with education subsidies will not only increase relative supply of skilled workers, but also the relative demand for skilled workers. The tendency for relative wages to fall is countered and this effect may be so strong that relative wages may even increase in the long run. Inequality may increase rather than decrease (Acemoglu (1998), Kiley (1999), and Nahuis and Smulders (2002)). We did not pay attention to this interaction between schooling and skill-biased technological change. If, however, this mechanism is indeed relevant, then increasing the number of skilled workers has only a limited or no effect on wage inequality. Moreover, if this interaction is empirically important, we also expect a slowing down of the rate of skill-biased technological change if the growth rate of relative supply of skilled workers falls.

Thirdly, decreases in relative wages that are caused by increases in relative supplies will reduce the incentives to invest in higher education. If agents are rational and forward-looking, they will anticipate that education policies will reduce the skill premium and they will reduce their investments in human capital accordingly. Then, education subsidies loose their effectiveness in reducing wage inequality. We assumed, however, that relative supplies of skilled workers were exogenous. Heckman et al. (1998b) show that the general equilibrium effects on relative wages may be so strong that the positive incentives generated by education subsidies evaporate almost completely. Similarly, anticipated general equilibrium effects that increase the skill-premium will increase incentives to acquire higher education. If these effects are indeed relevant, then there will be less wage inequality than we predicted because we assumed that relative supplies of skilled workers were exogenous.

Fourthly, subsidies on higher education are unequally distributed. The 50% richest households receive about 80% of education subsidies, see SCP (1994). Furthermore, only the most talented parts of each birth cohort receive education subsidies because they learn most. We did not take the unequal incidence effects into account in our calculations. On the one hand, education subsidies compress wage differentials and thereby reduce inequality, but, on the other hand, inequality increases because the subsidies are regressive. Dur and Teulings (2001) show that both effects roughly cancel out, so that there is no net reduction in income inequality.

Fifthly, it is reasonable to presume that the distribution of academic potential in the population is bounded. Not everyone has sufficient ability to pursue higher education. This implies that it becomes increasingly more difficult, and costly, to increase the stock of skilled workers, because the potential number of higher educated persons is limited by the underlying distribution of talent in the population. Stiglitz (1975, p. 288) remarks: 'The efficiency losses in attempting to train a moron to become an engineer are obvious.'

Sixthly, trends and developments in labor markets may further undermine the potency of education subsidies to reduce inequality. One may think of increased competitive pressures on goods and labor markets, possibly facilitated through institutional reforms, further international economic integration of industrialized countries, and the increase in mobility of factors of production, all resulting in pressures towards more income inequality. It is conceivable that the capital intensity of the Dutch economy increases. Older workers leave the labor market whereas the stock of capital remains fixed in the short run. Wage inequality increases due to capital-skill complementarity. Also the ICT revolution is associated with increases in wage inequality. Since European countries have seen their productivity growth figures lagging behind those of the US, an acceleration in skill-biased technical change may occur. Further, increased pressure of migration typically increases the supply of low-skilled workers and may therefore increase wage inequality. Labor mobility may also increase in the future. If skilled labor becomes more mobile than unskilled labor, which is arguably the case, then wage inequality increases if skilled labor becomes more scarce. Nevertheless, labor mobility is not very high at the current moment, see also Nahuis et al. (2002). On the other hand, increases in future participation rates and hours worked of the skilled workers, especially women, may counter some increases in wage inequality because effective supply of skilled labor is increased. Also, the upcoming ageing of the population may increase the demand of services that are typically intensive in unskilled labor, thereby off-setting the trend in skill-biased labor demand.

All the trends towards internationalization, increased mobility of factors of production, higher capital intensity, skill-biased technological changes, and inflow of low-skilled migrants will become more pronounced in the future. Both elasticities of substitution and trends in the relative demands for skilled workers move towards the 'worst case' scenario discussed earlier. The required increase in the stock of skilled workers to keep wage inequality constant will then increase even further. Only increased labor force attachment of the unskilled, sectoral shifts towards low-skilled production such as services, e.g. due to ageing, or a lower rate of skill-biased technological progress may counter these trends.

9 CONCLUSION

This paper analyzes wage inequality between skilled and unskilled workers. Although wage differentials have decreased in the last decades in the Netherlands, it has increased in recent years. Apparently, growth in relative demand for skilled workers is overtaking the growth in relative supply of skilled workers. Skill-biased technological change is the major candidate in explaining these widening wage differentials.

We try to predict the evolution of wage inequality between skilled and unskilled workers in 2000-2020. To that end we attempt to substantiate our simulations with estimates of the elasticity of substitution between skilled and unskilled workers and the size of relative demand shifts for skilled workers. Our empirical assessment confirms findings from the literature.

Our predictions suggest that wage differentials will increase in the coming decades. Wages of skilled workers will increase by about 10% relative to unskilled workers in the most favorable case. If, however, developments are severely unfavorable to unskilled workers, wage differentials may increase to 55%. In our base-line scenario, based on our best estimates of the trend in relative demand and elasticity of substitution, wage differentials increase by about 30%. We show that the increase in inequality is due to the strong slowdown of the growth rate in skilled labor supply and the assumed continuation of relative demand shifts favoring skilled labor. The projected growth rate of relative supply of skilled workers falls from 4.1% per year in 1969-1996 to only 0.6% per year in 2000-2020. If assumed relative demand shifts cause a steady increase in wage differentials of at least 1% per year, it is not surprising that wage inequality will increase in years to come.

We show that education policy, i.e., reduction in tuition rates, is probably a very ineffective instrument to counter increasing wage inequality. The reason is threefold. Firstly, very substantial increases in the inflow of skilled workers to the labor market are needed to keep relative wages constant. The inflow of skilled workers to the labor market needs to increase from 35% of each birth cohort (the current inflow rate) to about 45% to 50% of each birth cohort. Secondly, the price elasticity of enrollment is likely to be low. Consequently, very large subsidies are needed to boost the supply of skilled workers. Thirdly, there are potentially important factors that undermine the effectiveness of education subsidies in reducing wage inequality. These factors are: i) Education subsidies loose their potency to affect the income distribution under free trade; ii) By stimulating the supply of skilled labor, education subsidies may accelerate the rate of skill-biased technological change; iii) Trends in the overall economy seem to hint at the direction of the ‘worst case’ scenario: internationalization and increased trade with low-wage countries, more capital-intensive production, and the upcoming of ICT-related technological changes; iv) Education subsidies have an highly unequal incidence, which may off-set the gain in equality from changes in relative wages.

The challenge for the future is to design policies that are potentially more effective in boosting the supply of skills or to reduce income inequality more directly. Heckman (2003) convincingly argues that emphasis in education policy should be placed on the early stages of the life-cycle and on non-cognitive skills. Furthermore, more direct instruments like progressive income taxes are potentially better suited in reducing income inequality than indirect instruments such as education subsidies. Indeed, Saez (2003) has shown that under relatively mild conditions the government should refrain from distorting relative wages for redistributional purposes and should carry out all redistributions of income through the tax system.

APPENDIX

A tilde denotes a log-linear deviation from an initial equilibrium. Linearizing the first order condition for wages yields:

$$\tilde{\pi} = \tilde{S} + \tilde{F}_G - \tilde{F}_L + \tilde{G}_H .$$

We use the various properties of linear homogenous functions to determine each of the parts of the equation above, see also Heijdra and van der Ploeg (2002, Chapter 4). First of all, the first derivatives are homogeneous of degree zero:

$$GF_{GG} = -LF_{LG}, \; LF_{LL} = -GF_{LG},$$

$$SHG_{HH} = -KG_{KG}, \; KG_{KK} = -SHG_{KG} .$$

Secondly, we use the definitions of the elasticities of substitution:

$$\sigma \equiv \frac{FL_{FG}}{F(.)\; F_{LG}}, \quad \rho \equiv \frac{G_H G_K}{G(.)\; G_{HK}} .$$

Thirdly, we define the shares of low-skilled labor and the composite function G in output, the shares of skilled labor and capital in the composite function G, and the income shares of skilled labor and capital in output, as follows:

$$\omega_L \equiv \frac{LF_L}{F(.)}, \quad \omega_G \equiv \frac{GF_G}{F(.)}, \quad \omega_L + \omega_G = 1 ,$$

$$\omega_{GH} \equiv \frac{SGH_H}{G(.)}, \quad \omega_{GK} \equiv \frac{KG_K}{G(.)}, \quad \omega_{GH} + \omega_{GK} = 1 ,$$

$$\omega_H \equiv \omega_G \omega_{GH}, \quad \omega_K \equiv \omega_G \omega_{GK}, \quad \omega_L + \omega_H + \omega_K = 1 .$$

Fourthly, we apply Euler's rule:

$$\tilde{G} = \omega_{GH}(\tilde{S} + \tilde{H}) + \omega_{GK}\tilde{K} \, .$$

Fifthly, we use the properties and definitions to derive:

$$\tilde{F}_G - \tilde{F}_L = \frac{1}{\sigma}(\tilde{L} - \tilde{G}) \, ,$$

$$\tilde{G}_H = \frac{\omega_{GK}}{\rho}(\tilde{K} - \tilde{S} - \tilde{H}) \, .$$

Finally, we substitute the last three results in the linearized equation for inequality and obtain the equation in the text.

REFERENCES

Acemoglu, D. (1998), 'Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality,' *Quarterly Journal of Economics*, 113, pp. 1055-1089.

Autor, D.H., L.F. Katz, and A.B. Krueger (1998), 'Computing Inequality: Have Computers Changed the Wage Structure?,' *Quarterly Journal of Economics*, 113, pp. 1169-1213.

Becker, G.S. (1983), 'A Theory of Competition among Pressure Groups for Political Influence,' *Quarterly Journal of Economics*, 98, pp. 371-400.

Beaudry, P. and D. Green (2000), 'The Changing Structure of Wages in the US and Germany: What Explains the Difference?,' *NBER Workingpaper* 7679.

Berman, E., J. Bound, and Z. Griliches (1994), 'Changes in the Demand for Skilled Labor Within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufactures,' *Quarterly Journal of Economics*, 109, pp. 367-397.

Blau, F.D. and L.M. Kahn (1996), 'International Differences in Male Wage Inequality: Institutions versus Market Forces,' *Journal of Political Economy*, 104, pp. 791-837.

Borjas, G.J. and V. Ramey (1995), 'Foreign Competition, Market Power and Wage Inequality,' *Quarterly Journal of Economics*, 110, pp. 1075-1110.

Borjas, G.J., R.B. Freeman, and L.F. Katz (1997), 'How Much Do Immigration and Trade Affect Labor Market Outcomes?,' *Brookings Papers on Economic Activity*, 1, pp. 1-90.

Bound, J. and G. Johnson (1992), 'Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations,' *American Economic Review*, 82, pp. 371-392.

Cameron, S.V. and J.J. Heckman (2001), 'The Dynamics of Educational Attainment for Blacks, Hispanics, and Whites,' *Journal of Political Economy*, 109(3), pp. 455-499.

Card, D. and T. Lemieux (2000), 'Dropout and Enrollment Trends in the Post-War Period: What Went Wrong in the 1970's?,' *NBER Working Paper,* 7658.

Caselli, F. (1999), 'Technological Revolutions,' *American Economic Review*, 89, pp. 78-102.

CBS (1999), *Arbeidsrekeningen 1969-1997*, Voorburg/Heerlen, CBS.

CBS/CPB (1997), *Bevolking en Arbeidsaanbod: Drie Scenario's tot 2020*, Den Haag, SDU Uitgevers and Centraal Planbureau.

CPB (2000), *Ageing in the Netherlands*, The Hague, CPB Netherlands Bureau for Economic Policy Analysis.

Davis, D.R. (1998), 'Does European Unemployment Prop Up American Wages? National Labor Markets and Global Trade,' *American Economic Review*, 88(3), pp. 478-494.

Davis, S.J. (1992), 'Cross-Country Patterns of Changes in Relative Wages,' in: O.J. Blanchard and S. Fischer (eds), *NBER Macroeconomic Annuals 1992*, pp. 239-400.

DiNardo, J., N. Fortin and T. Lemieux (1996), 'Labor Market Institutions and the Distribution of Wages,' *Econometrica*, 64, pp. 1001-1044.

Dougherty, C.R.S. (1972), 'Estimates of Labor Aggregation Functions,' *Journal of Political Economy*, 80(6), pp. 1101-1119.

Draper N. and T. Manders (1996), 'Structural Changes in the Demand for Labor,' *CPB Research Memorandum* No. 128, The Hague, CPB Netherlands Bureau for Economic Policy Analysis.

Dur, R. and C.N. Teulings (2001), 'Education and Efficient Redistribution,' *Tinbergen Institute Discussion Paper* 01-90/3.

Dynarski, S. (1999), 'Does Aid Matter? Measuring the Effect of Student Aid on College Attendance and Completion,' *NBER Working Paper*, 7422.

Edin, P.-A., and B. Holmlund (1995), 'The Swedish Wage Structure: The Rise and Fall of Wage Policy?,' in: R.B. Freeman and L.F. Katz (eds.), *Differences and Changes in Wage Structures*, Chicago, Chicago University Press, pp. 307-343.

Fase, M.M.G. (1969), *An Econometric Model of Age-Income Profiles: A Statistical Analysis of Dutch Income Data 1958-1967*, Rotterdam, Universitaire Pers.

Feenstra, R.C. and G.H. Hanson (1999), 'The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979-1990,' *Quarterly Journal of Economics*, 114, pp. 907-940.

Goldin, C. and L.F. Katz (1998), 'The Origins of Capital-Skill Complementarity,' *Quarterly Journal of Economics*, 113, pp. 693-732.

Hartog, J., H. Oosterbeek, and C. Teulings (1993), 'Age, Wages and Education in the Netherlands,' in: P. Johnson and K.F. Zimmerman (eds.), *Labour Markets in an Aging Europe*, Cambridge (UK), Cambridge University Press, pp. 182-211.

Hebbink, G.E. (1991), 'Employment by level of Education and Production Factor Substitutability,' *De Economist*, 139, pp. 319-400.

Heckman, J.J. (1999), 'Policies to Foster Human Capital,' *NBER Working Paper,* 7288.

Heckman, J.J., L. Lochner, and C. Taber (1998a), 'Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents,' *Review of Economic Dynamics*, 1, pp. 1-58.

Heckman, J.J., L. Lochner, and C. Taber (1998b), 'A Study of Tuition Policy,' *American Economic Review – AEA Papers and Proceedings*, 88(2), pp. 381-386.

Heckman, J.J. (2003), 'The Supply Side of the Race Between Demand and Supply: Policies to Foster Skill in the Modern Economy: Tinbergen Lecture 2002,' *De Economist*, 151, pp. 1-34.

Heijdra, B. and F. van der Ploeg (2002), *Foundations of Modern Macroeconomics*, Oxford, Oxford University Press.

Hilmer, M.J. (1998), 'Post-Secondary Fees and the Decision to Attend a University or a Community College,' *Journal of Public Economics*, 67, pp. 329–348.

Johnson, G. (1970), 'The Demand for Labor by Educational Category,' *Southern Economic Journal*, pp. 190-204.

Kane, T.J. (1994), 'College Entry by Blacks since 1970: The Role of College Costs, Family Background and the Returns to Education,' *Journal of Political Economy*, 102(5), pp. 878-911.

Kane, T.J. (1995), 'Rising Public Tuition and College Entry: How well do Public Subsidies Promote Access to College,' *NBER Working Paper*, 5164.

Katz, L.F. and D.H. Autor (1999), 'Changes in the Wage Structure and Wage Inequality,' in: O. Ashenfelter and D. Card (eds.), *Handbook of Labor Economics,* 3A, Elsevier Science BV, pp. 1463-1555.

Katz, L.F. and K.M. Murphy (1992), 'Changes in Relative Wages 1963-1987: Supply and Demand Factors ,' *Quarterly Journal of Economics*, 107, pp. 35-78.

Kiley, M. T. (1999), 'The Supply of Skilled Labour and Skill-Biased Technological Progress,' *Economic Journal*, 109, pp. 708-724.

Kim, D.I. and R.H. Topel (1995), Labor Markets and Economic Growth: Lessons from Korea's Industrialization, 1970-1990, in R.B. Freeman and L.F. Katz (eds.), *Differences and Changes in Wage Structures*, Chicago: Chicago University Press, pp. 227-264.

Kodde, D.A. (1985), 'On Estimating the Impact of Tuition on the Demand for Education from Cross-Sections,' *Economics Letters*, 18, pp. 293-296.

Krueger, A.B. (1993), 'How Computers Have Changed the Wage Structure: Evidence from Micro Data,' *Quarterly Journal of Economics*, 108, pp. 33-60.

Krugman, P. R. (1995), 'Technology, Trade and Factor Prices,' *NBER Working Paper,* 5355.

Krugman, P.R. (1998), 'Growing World Trade: Causes and Consequences,' *Brookings Papers on Economic Activity*, 1, pp. 327-377.

Krusell, P., L.E. Ohanian, J-V. Rios-Rull, and G. Violante (2000), 'Capital-Skill Complementarity: A Macro-Economic Analysis,' *Econometrica*, 68(5), pp. 1029-1053.

Layard, P.R.G. and P.R. Fallon (1975), 'Capital-Skill Complementarity, Income Distribution, and Output Accounting,' *Journal of Political Economy*, 83(2), pp. 279-302.

Lee, D.S. (1999), 'Wage Inequality in the U.S. during the 1980's: Rising Dispersion or Falling Minimum Wage?,' *Quarterly Journal of Economics*, 114, pp. 977-1023.

Leslie, L.L. and P.T. Brinkman (1987), 'Student Price Response in Higher Education: The Student Demand Studies,' *Journal of Higher Education*, 58(2), pp. 181-204.

Leuven, E. and H. Oosterbeek (2000), 'Rendement van Onderwijs Stijgt,' *Economisch Statistische Berichten*, 4262, pp. 523-524.

Leuven, E., H. Oosterbeek, and H. van Ophem (2000), 'Explaining International Differences in Male Wage Inequality by Differences in Demand and Supply of Skill,' mimeo, University of Amsterdam.

Ministry of Education (2000), *Onderwijs in Kerncijfers 2001*, The Hague, SdU.

Murphy, K.M. and F. Welch (1992), 'The Structure of Wages,' *Quarterly Journal of Economics*, 107, pp. 285-326.

Murphy, K.M., W.C. Riddell, and P.M. Romer (1998), 'Wages, Skills, and Technology in the United States and Canada,' in: E. Helpman (ed.), *General Purpose Technologies and Economic Growth*, Cambridge MA, MIT Press, pp. 283-309.

Nahuis, R. (2000), *Knowledge and Economic Growth*, Ph.D. Dissertation, Tilburg University.

Nahuis, R. and A. Parikh (2002), 'Factor Mobility and Regional Disparities: East, West, Home's Best?,' *CPB Discusson Paper*, 4, CPB Netherlands Bureau for Economic Policy Analysis.

Nahuis, R. and S. Smulders (2002), 'The Skill-Premium, Technological Change and Appropriability,' *Journal of Economic Growth*, 7, pp. 137-156.

Oosterbeek, H. and D. Webbink (1995), 'Enrolment in Higher Education in the Netherlands,' *De Economist*, 143(3), pp. 367-380.

Psacharopoulos, G., and V. Hinchliffe (1972), 'Further Evidence on the Elasticity of Substitution Among Different Types of Labor,' *Journal of Political Economy*, 80(4), pp. 786-791.

Saez, E. (2003), 'Direct or Indirect Instruments for Redistribution,' forthcoming in *Journal of Public Economics*.

Schmitt, J. (1995), 'The Changing Structure of Male Earnings in Britain, 1974-1989,' in: R.B. Freeman and L.F. Katz (eds.), *Differences and Changes in Wage Structures*, Chicago: Chicago University Press, pp. 177-204.

Smits, J., J. Odink, and J. Hartog (2001), 'New Results on Returns to Education in the Netherlands,' in: C. Harmon, I. Walker and N. Westergard-Nielsen (eds), *Education and Earnings in Europe: A Cross Country Analysis of Returns to Education.* Edward Elgar Publishing Ltd, pp. 179-197.

Stegeman, H. and R. Waaijers (2000), 'Beloningsverhoudingen in Nederland 1979-1998: Ontwikkelingen en Verklaringen voor de Veranderingen in de Be-loningsstructuur,' mimeo, CPB Netherlands Bureau for Economic Policy Analysis.

Stiglitz, J.E. (1975), 'The Theory of 'Screening', Education, and the Distribution of Income,' *American Economic Review*, 65(3), pp. 283-300.

Teulings, C.N. (2000), 'Onderwijs: Een Nuttige Maatschappelijke Investering?,' *Socialisme en Democratie*, 9, pp. 405-410.

Teulings, C.N. (2003), 'The Contribution of Minimum Wages to Increasing Wage Inequality,' *Economic Journal*, forthcoming.

Tinbergen, J. (1974), 'Substitution of Graduates by Other Labour,' *Kyklos*, 27(2), pp. 217- 226.

Tinbergen, J. (1975), *Income Distribution*, Amsterdam: North-Holland Publishing Company BV.

Topel, R. (1999), 'Labor Markets and Economic Growth,' in: O. Ashenfelter and D. Card (eds.) (1999), *Handbook of Labor Economics* 3C, Elsevier Science BV, pp. 2943-2984.

Welch, F. (1970), 'Education in Production,' *Journal of Political Economy*, 78, pp. 764-771.

Wolff, P. de, and R. Ruiter, (1968), "De Economie van het Onderwijs", *Preadvies van de Vereniging voor Staatshuis-Haudkunde,* 's-Gravenhage: Martinus Nijhoff, pp. 111-179.

Wood, A. (1994), *North-South Trade, Employment and Inequality: Changing Fortunes in a Skill-Driven World*, Oxford, Clarendon Press.