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Abstract

We consider the economic implications of a compressed wage structure which is exogenously determined by institutions. An important feature of our analysis is that human capital is endogenous and can be achieved either as formal education or as informal training within firms after entering the labour market. While institutional wage compression decreases the incentives of individuals to become educated, it increases the incentives of firms to invest in training. As a result, the net effects of wage compression on the aggregate human capital level and GDP are ambiguous. Moreover, with wage compression, a skill-biased technological change may cause wage inequality to decrease.

Keywords: Wage compression, training, education, inequality, institutions, skill-biased technological change.

JEL: I21, J31, J5, O33.

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1 Introduction

In recent years, there has been considerable focus on the increasing wages of educated workers relative to uneducated workers in the US, and more generally in the OECD, see, *e.g.*, Welch (1999) – though in most European countries, the tendency towards increased wage inequality has been less pronounced, see OECD (1996) and Gottschalk and Smeeding (1997). In the academic literature, it is by now generally agreed that the skill-biased technological change of recent decades is the underlying cause of this trend in wage inequality, see, *e.g.*, Berman, Bound, and Griliches (1994) and Berman, Bound, and Machin (1998).

In a recent comparison of OECD countries, Denmark is found to have the smallest wage ratio between highly educated and uneducated workers (OECD, 2002).[1] Furthermore, the average wage of educated workers has actually been decreasing relative to the average wage of uneducated workers over the last 20 years in Denmark as documented by Malchow-Møller and Skaksen (2003). In addition to this, Denmark has the lowest tertiary graduation rate in the OECD area with only 9.2% of a cohort obtaining a tertiary type A education, while the corresponding figures for the US, the UK and Germany are 33.2%, 37.5%, and 19.3%, respectively.[2] More importantly, the increase in the tertiary graduation rate has been more modest in Denmark than in the OECD on average (OECD, 2002). If the recent decades have actually been characterised by skill-biased technological change, it seems somewhat paradoxical that the country with the smallest share of individuals with a long further education and where this share has increased only modestly has experienced decreasing wage inequality and furthermore has the second highest GDP per capita in the EU (Eurostat, 2003).

Wallerstein (1999) has recently shown that differences in labour market institutions are capable of explaining differences in wage compression across OECD countries. More precisely, he finds that centralisation and concentration of wage setting as well as the coverage of union contracts all serve to increase wage equality, and when accounting for these factors, other variables

[1] In Denmark, the ratio of average wages of tertiary educated to uneducated is 1.75, while it is 2.78 in the US, 2.59 in the UK, and 2.17 in Germany.

[2] According to the International Standard Classification of Education (ISCED-97), tertiary educations are divided into types A and B, with type A educations being of a longer and more theoretical nature, *e.g.* university degrees. It should be mentioned that the share of a cohort receiving tertiary type B educations is higher in Denmark than in the other countries. However, the overall fraction of a cohort receiving a tertiary education (either type A or B) is still only 33.7% in Denmark, while the mean among the countries included in the sample is 37.1%, and for the US, the figure is 41.5%, see OECD (2002).

cease to matter.[3] With the Scandinavian countries dominating in all three respects, this can explain why inequality is lowest in Denmark, but does it also explain the observed patterns of *change* in inequality, *i.e.* the reactions to skill-biased technological change?

In this paper, we pursue the empirical finding of Wallerstein (1999) by exploring how an institutionally induced wage compression can account for the different outcomes with respect to education, inequality and GDP, reported above. An important feature of our model is that human capital is endogenous and can be acquired either as formal education before entering the labour market or as informal firm-sponsored training after entering the labour market. A more compressed wage structure will lower the incentives for individuals to acquire education, while raising the incentives of firms to invest in training of their employees. The effects on the aggregate human capital level and GDP are thus ambiguous in most cases.

Furthermore, a skill-biased technological change might both increase and decrease wage inequality, depending on the degree of wage compression in the economy. While the direct effect of a skill-biased technological change is to increase wage inequality, composition effects both within and between the groups of educated and uneducated workers might have the opposite effect through increased incentives to acquire both training and education. We shall argue that these results are consistent with the development in Denmark over the last decades, and that the importance of such composition effects is often masked in data on inequality.

1.1 Wage Compression, Training, and Education

Before presenting the formal set-up in Section 2, we first take a closer look at the existing literature on wage compression and training, explaining how our model relates to this literature.

Wage compression has previously been used to explain why firm-sponsored general training of workers might arise, see Acemoglu and Pischke (1999a) and Acemoglu and Pischke (1999c) among others. This is by now a well-established result and goes contrary to the Beckerian proposition that only the workers themselves have incentives to invest in general training. According to this literature, wage compression can arise as a consequence of: a) search costs; b) asymmetric information about training, abilities and/or effort; c) interaction between general and specific skills; and d) labour market institutions such as trade unions, see Acemoglu and Pischke (1999a) for an

[3] Wallerstein (1999) offers a range of economic, political, and ideological explanations for his results.

overview. As Wallerstein (1999) shows, the latter cause of wage compression finds most support in the data, and therefore forms the basis of the present analysis.

Acemoglu and Pischke (1999b) analyse the implications for general training of wage compression caused by a specific type of labour market institution: A minimum wage. In their model, a minimum wage provides incentives for the firms to invest in training of individuals with productivities (abilities) below the minimum wage, since the firm in this case is the residual claimant of any increases in productivity. On the other hand, a minimum wage prevents some workers from investing in training since training must be financed through wage cuts, which are no longer feasible. In sum, however, the introduction of a minimum wage might increase overall training.

In this paper, we take the analysis one step further by considering the implications of wage compression for training as well as education, and by analysing the reactions to skill-biased technological change. Furthermore, we consider a different type of institutional wage compression than in Acemoglu and Pischke (1999b). This is motivated by the results of Wallerstein (1999) which indicate that labour market institutions affect wage compression more generally than through a minimum wage. Also Calmfors et. al. (2001) document that even within Europe, labour market institutions differ along several dimensions. In some countries, minimum wages are legally binding and in other countries, trade unions are powerful in wage bargaining with different degrees of centralisation. In this paper, we therefore assume that labour market institutions impose wage compression not only at the bottom end, but also at the upper end of the wage scale.

In our model, both education and training are treated as endogenous choices. We assume a recursive structure where education is decided by and paid by the individual prior to entering the labour market, while training takes place after entering the labour market and is financed by the employer. The assumption of a non-Beckerian world where training can only be financed by the firm is consistent with our assumption of a wage structure determined by institutions, as well as a lot of empirical work demonstrating that often firms do pay for general training, see Acemoglu and Pischke (1999a).

Since focus is on general training, we view training and education as perfect substitutes in our model, though in practice, at least some elements of training will typically be complementary to education. Furthermore, training is assumed to be general but informal in the sense that a person who receives training but no education is formally uneducated.

In general, considerable indivisibilities are associated with both education and training since both activities typically involve fixed costs – either monetary or in terms of time invested. More specifically, different levels of education and different types of training come at different (fixed) costs. As a result, important composition effects are likely to arise. To analyse the importance of these effects while keeping the exposition clear, we assume the existence of a single educational level and a single training level. Moreover, the human capital level achieved through training is assumed to be lower than the human capital level achieved through education.

In Section 2, we set up a simple theoretical model with endogenous education and training. This model is solved recursively in Section 3. In Section 4, we derive some comparative statics, and in Section 5, we discuss to which extent the model is able to explain the recent development in Denmark. Section 6 concludes the paper.

2 The Model

In this Section, we set up a simple model to analyse the economic implications of different wage structures. In order to be able to undertake comparative analyses, we simply assume an exogenously determined wage structure, which is implicitly determined by labour market institutions. An obvious possibility is that the wage structure is the outcome of a bargaining process involving trade unions and employer organisations, but there may be other institutions which affect the wage structure, such as politically imposed minimum wages or monopsony power at the labour market, see, *e.g.*, Acemoglu and Pischke (1999c).

2.1 Production and Utility

To simplify, physical capital is not included in the model. Production depends solely on labour input. In other words, a firm simply realises the productivity of a worker.[4] The productivity of individual i is assumed to depend on a weighted average of the input of raw labour and human capital. More specifically, we assume that:

$$q_i = \gamma_i \left((1 - \alpha) + \alpha h_i \right) \tag{1}$$

where q_i is productivity of individual i, γ_i is personal ability, and h_i is the human capital level which can take three possible values:

[4] The model could easily be extended to include capital input. Thus, the production function can be seen as a reduced form of a constant returns to scale technology.

$$h_i = \begin{cases} u, & if \quad unskilled \\ \tau, & if \quad trained \\ e, & if \quad educated \end{cases} \tag{2}$$

Note that there is a complementarity in production between raw labour and ability as well as between human capital and ability. The parameter α is a measure of the importance of human capital relative to "raw labour" in explaining the productivity of a worker. An increase in α can therefore be interpreted as a skill-biased technological change in production. To ensure that a skill-biased technological change increases the productivity of trained and educated individuals, we assume that $e > 1$ and $\tau > 1$. Moreover, for analytical tractability, we assume that $u = 0$. That is, a skill-biased technological change is assumed to decrease the productivity of the unskilled.[5]

Education is assumed to take place before the individual enters the labour market, whereas training can only take place in a firm. It is assumed that the human capital level of an educated individual is higher than the human capital level of a trained individual, $e > \tau$. Hence, it will never be optimal to train an educated individual. Similarly, the cost of education is assumed to exceed the cost of training, $c^e > c^\tau$.

The utility function of individual i is linear:

$$U_i = y_i - c_i^e \tag{3}$$

where y_i is the income of individual i, c_i^e is the cost of education, where c_i^e equals zero if the person remains uneducated, and $c_i^e = c^e$ if educated. The cost of education may comprise both a financial cost and an opportunity cost reflecting the time and effort spent in education. We abstract from any disutility of working.

Individuals only differ with respect to their ability level, γ_i, and it is assumed that γ_i is distributed across individuals according to a density function, $\varphi(\gamma)$, with positive support.

An important assumption in the following is that training must be financed by the firm. This is consistent with the assumption of a wage structure determined by institutions. If it was possible for the worker to pay the

[5] We would get the same qualitative results by just assuming $0 < u < 1$. The assumption of $u = 0$ is somewhat "extreme" in the sense that it implies that an increase in α gives rise to a rather large increase in the productivity difference between trained and unskilled as well as between educated and unskilled workers. *A priori*, this makes it more likely that a skill-biased technological change will raise wage inequality. We show that despite this "extreme" assumption, it is possible that a skill-biased technological change gives rise to a decrease in wage inequality when the wage structure is compressed.

firm for training, this would indirectly circumvent the institutionalised wage structure, see also Acemoglu and Pischke (1999c).

2.2 Wages

With respect to wages, we assume that the wage of an employed worker is a weighted average of a constant, θ, and the productivity, q_i, of the worker:

$$w_i = \theta(1-\beta) + \beta q_i, \quad 0 < \beta < 1 \tag{4}$$

In a competitive labour market, wages are determined solely by productivity, which is the special case of (4) where $\beta \to 1$. In the following, a more compressed wage structure is synonymous with a decrease in β.

In equilibrium, a worker will only be employed if her institutionalised wage, w_i, does not exceed her productivity level, q_i. This implicitly defines a minimum level of productivity, q^*, required to qualify for a job:

$$q^* = \theta(1-\beta) + \beta q^* \quad \Leftrightarrow \quad q^* = \theta \tag{5}$$

Since the wage is just equal to productivity at $q_i = q^*$, this is also the lowest observable wage in the economy. We can think of this as the minimum wage. The interpretation of the wage-setting equation in (4) is that an individual with just the required productivity, q^*, will be paid her marginal product – the minimum wage – whereas more able individuals will be paid less than their marginal productivity when $\beta < 1$.

2.3 Timing

The agents take decisions in four stages or periods. For simplicity, we assume that there is no discounting between stages.

At stage 1 (the young age), each individual decides whether to incur the cost of education, c^e, and become educated, or to enter the labour market without education.

At stage 2, each individual meets with a firm. The firm observes both the ability level and the educational attainment of the individual. Based on this information, the firm decides whether to offer employment to the individual. Individuals may choose to turn down an offer and continue to search for a job at another firm.

At stage 3, firms decide whether to train an employed worker thereby incurring the training cost, c^τ. When training has been completed, employed workers either stay with the firm or search for a job in another firm. In addition, we assume that there is a probability $1 - z$ that a worker moves to another firm for exogenous reasons.

Finally, at stage 4, production takes place and workers receive their wages upon completion of the production process.

As discussed in the previous Section, it is assumed that the wage structure is exogenously fixed. This also implies that at stage 2, firms cannot credibly commit to a certain training level in stage 3, since this would simply be a way of circumventing the exogenous wage structure. Similarly, firms cannot credibly offer sidepayments thereby attracting more profitable (possibly trained) workers at the end of stage 3. This implies that there are no expected wage gains associated with leaving a firm, neither at stage 2 nor at stage 3. Hence, we will simply assume that there are no voluntary quits at these stages.[6]

2.4 Parameter Restrictions

Throughout the following, we will impose the following two parameter restrictions with respect to the costs of training and education:

$$c^{\tau} > \frac{\theta z \alpha \tau}{1 - \alpha} \tag{6}$$

$$c^{e} > \left(1 + \frac{\alpha e}{1 - \alpha}\right)\theta \tag{7}$$

In the following, it becomes clear that these restrictions imply that the costs of training and education are sufficiently high to ensure that some individuals always remain untrained as well as uneducated .

3 Solving the Model

The model can be solved by backwards induction. At stage 4, an employed worker, i, receives the wage:

$$w_i = \theta(1 - \beta) + \beta q_i$$

irrespective of the firm she is employed in.

[6] This can be formally justified by introducing an arbitrarily small but positive search cost.

3.1 Stage 3

At stage 3, the firm decides whether or not to train an individual i who was hired at stage 2. Two situations can be distinguished. First, in the case where the hired individual is educated, it will never be worthwhile to train her since $\tau < e$. The expected profit to the firm from hiring an educated individual i is therefore given by:

$$E\pi_i^e = z\,(1-\beta)\,[\gamma_i\,(1-\alpha+\alpha e)-\theta] \tag{8}$$

Second, in the case where the hired person is uneducated, the firm chooses to train the person if the expected profit from training:

$$E\pi_i^\tau = z\,(1-\beta)\,[\gamma_i\,(1-\alpha+\alpha\tau)-\theta]-c^\tau \tag{9}$$

exceeds the expected profit from keeping the individual as uneducated:

$$E\pi_i^0 = z(1-\beta)\,[\gamma_i\,(1-\alpha)-\theta] \tag{10}$$

By comparing (9) and (10), it follows that:

Lemma 1 *At stage 3, an uneducated employee will be trained if and only if:*

$$\gamma_i \geq \gamma^\tau \equiv \frac{c^\tau}{z\,(1-\beta)\,\alpha\tau} \tag{11}$$

Due to the complementarity between human capital and individual ability in production, and the fact that the productivity-wage differential (the surplus to the firm) increases with productivity, firms will have incentives to train only the most able of the uneducated employees.

3.2 Stage 2

At stage 2, a firm must decide whether to hire an individual with ability γ_i, who might be either educated or uneducated. If the individual is educated, she will be hired if and only if:

$$E\pi_i^e \geq 0 \tag{12}$$

Using the expression in (8), this condition can be rewritten in terms of γ_i and stated formally as:

Lemma 2 *At stage 2, an educated individual will be hired if and only if:*

$$\gamma_i \geq \gamma^{eh} \equiv \frac{\theta}{1-\alpha+\alpha e} \tag{13}$$

On the other hand, if the individual is uneducated, she will be hired if and only if:

$$\max\{E\pi_i^0, E\pi_i^\tau\} \geq 0 \tag{14}$$

By use of the expressions in (9) and (10), and the parameter restriction in (6), this condition can also be rephrased in terms of γ_i:

Lemma 3 *At stage 2, an uneducated individual will be hired if and only if:*

$$\gamma_i \geq \gamma^h \equiv \frac{\theta}{1-\alpha} \tag{15}$$

where $\gamma^{eh} < \gamma^h < \gamma^\tau$*.*

Lemmas 2 and 3 state that only the most able individuals will qualify for employment. Furthermore, the restriction in (6) implies that the cost of training is sufficiently high to ensure that only a share of the employed workers will be trained, *i.e.* $\gamma^\tau > \gamma^h$.

3.3 Stage 1

At stage 1, each individual decides whether or not to pay for education. A distinction is made between three types of individuals. First, an individual with $\gamma_i < \gamma^h$ knows that she will never be hired at stage 2 should she remain uneducated. This follows directly from Lemma 3. On the other hand, her expected return from taking an education – provided that she is hired at stage 2 – is given by:

$$w_i - c^e = \theta(1-\beta) + \beta\gamma_i(1-\alpha+\alpha e) - c^e$$

However, the parameter restriction in (7) implies that c^e is sufficiently high to ensure that this return is always negative for $\gamma_i < \gamma^h$. Hence, no individual with $\gamma_i < \gamma^h$ will find education worthwhile.

Lemma 4 *An individual, i, with* $\gamma_i < \gamma^h$*, where* γ^h *is given by (15), will remain unskilled and unemployed in equilibrium.*

Second, an individual with $\gamma_i \in [\gamma^h, \gamma^\tau]$ will be hired but not trained at stage 2. Hence, this individual will choose education if and only if:

$$\theta(1-\beta) + \beta\gamma_i(1-\alpha+\alpha e) - c^e \geq \theta(1-\beta) + \beta\gamma_i(1-\alpha)$$

This condition can be rephrased formally in a Lemma:

Lemma 5 *An individual, i, with $\gamma_i \in [\gamma^h, \gamma^\tau]$, where γ^τ and γ^h are given by (11) and (15), will in equilibrium be: i) unskilled and employed if $\gamma_i < \widehat{\gamma}^{eh}$; and ii) educated and employed if $\gamma_i \geq \widehat{\gamma}^{eh}$, where:*

$$\widehat{\gamma}^{eh} = \frac{c^e}{\beta\alpha e} \tag{16}$$

Note that $\widehat{\gamma}^{eh}$ may exceed γ^τ at some parameter values, in which case, no individuals in this interval will choose education.

Third, if $\gamma_i \geq \gamma^\tau$, an uneducated individual will always be trained at stage 2. Hence, she prefers education if and only if:

$$\theta(1-\beta) + \beta\gamma_i(1-\alpha+\alpha e) - c^e \geq \theta(1-\beta) + \beta\gamma_i(1-\alpha+\alpha\tau)$$

Lemma 6 *An individual, i, with $\gamma_i \geq \gamma^\tau$, where γ^τ is given by (15), will in equilibrium be: i) trained and employed if $\gamma_i < \widehat{\gamma}^{e\tau}$; and ii) educated and employed if $\gamma_i \geq \widehat{\gamma}^{e\tau}$, where:*

$$\widehat{\gamma}^{e\tau} = \frac{c^e}{\beta\alpha(e-\tau)} \tag{17}$$

Again, $\widehat{\gamma}^{e\tau}$ might be smaller than γ^τ for some parameter values, in which case, all individuals with $\gamma_i > \gamma^\tau$ become educated.

3.4 Equilibrium Regimes

The degree of wage compression, β, affects the incentives for education and training and hence the sizes of the critical values, $\widehat{\gamma}^{eh}$ and $\widehat{\gamma}^{e\tau}$, relative to γ^τ. It is straightforward to show that depending on the value of β, three possible regimes can be identified. The equilibrium outcomes in the three different regimes are summarised in the following Proposition.

Proposition 7 *Let γ^τ, γ^h, $\widehat{\gamma}^{eh}$, and $\widehat{\gamma}^{e\tau}$ be defined by (11), (15), (16), and (17), respectively. Furthermore, let:*

$$\beta_1 = \frac{c^e z\tau}{c^\tau e + c^e z\tau} \in (0,1) \quad \textit{and} \quad \beta_2 = \frac{c^e z\tau}{c^\tau(e-\tau) + c^e z\tau} \in (0,1)$$

Then $\beta_1 < \beta_2$, and:

1. *If $\beta \geq \beta_2$ (the low-compression regime), then $\gamma^\tau \geq \widehat{\gamma}^{e\tau} > \widehat{\gamma}^{eh}$, and the equilibrium choices of education, training and employment are:*

    - *If $\gamma_i < \gamma^h$, worker i is unskilled and unemployed.*

- *If* $\gamma^h \leq \gamma_i < \widehat{\gamma}^{eh}$, *worker* i *is unskilled and employed.*
- *If* $\gamma_i \geq \widehat{\gamma}^{eh}$, *worker* i *is educated and employed.*

2. *If* $\beta_1 < \beta < \beta_2$ *(the medium-compression regime), then* $\widehat{\gamma}^{e\tau} > \gamma^\tau > \widehat{\gamma}^{eh}$ *and the equilibrium choices of education, training and employment are:*

   - *If* $\gamma_i < \gamma^h$, *worker* i *is unskilled and unemployed.*
   - *If* $\gamma^h \leq \gamma_i < \widehat{\gamma}^{eh}$, *worker* i *is unskilled and employed.*
   - *If* $\widehat{\gamma}^{eh} \leq \gamma_i < \gamma^\tau$, *worker* i *is educated and employed.*
   - *If* $\gamma^\tau \leq \gamma_i < \widehat{\gamma}^{e\tau}$, *worker* i *is trained and employed.*
   - *If* $\gamma_i \geq \widehat{\gamma}^{e\tau}$, *worker* i *is educated and employed.*

3. *If* $\beta \leq \beta_1$ *(the high-compression regime), then* $\widehat{\gamma}^{e\tau} > \widehat{\gamma}^{eh} \geq \gamma^\tau$ *and the equilibrium choices of education, training and employment are:*

   - *If* $\gamma_i < \gamma^h$, *worker* i *is unskilled and unemployed.*
   - *If* $\gamma^h \leq \gamma_i < \gamma^\tau$, *worker* i *is unskilled and employed.*
   - *If* $\gamma^\tau \leq \gamma_i < \widehat{\gamma}^{e\tau}$, *worker* i *is trained and employed.*
   - *If* $\gamma_i \geq \widehat{\gamma}^{e\tau}$, *worker* i *is educated and employed.*

Proof. By condition (7), $\hat{\gamma}^{eh} > \gamma^h$. Hence, $\gamma^h < \hat{\gamma}^{eh} < \hat{\gamma}^{e\tau}$, and from condition (6), we know that $\gamma^h < \gamma^\tau$. This defines three possible regimes: 1) $\gamma^h < \hat{\gamma}^{eh} < \hat{\gamma}^{e\tau} \leq \gamma^\tau$; 2) $\gamma^h < \hat{\gamma}^{eh} < \gamma^\tau < \hat{\gamma}^{e\tau}$; and 3) $\gamma^h < \gamma^\tau \leq \hat{\gamma}^{eh} < \hat{\gamma}^{e\tau}$, which can equivalently be expressed as: 1) $\beta \geq \beta_2$; 2) $\beta_1 < \beta < \beta_2$; and 3) $\beta \leq \beta_1$, where: $\beta_1 \equiv c^e z\tau / (c^\tau e + c^e z\tau) \in (0,1)$ and $\beta_2 \equiv c^e z\tau / (c^\tau (e-\tau) + c^e z\tau) \in (0,1)$ with $\beta_1 < \beta_2$. Equilibrium choices of education, training and employment for the three regimes then follow directly from Lemmas 4-6. ■

Individuals with a sufficiently low ability level always end up unemployed. Moreover, we observe that if the ability level of an individual is sufficiently high, she always chooses to become educated – independently of the regime.

For high values of β, the economy is in the low-compression regime, where training by the firm is never optimal, simply because workers are paid close to their productivity. In the other two regimes, however, firms invest in training of individuals who have an intermediate ability level. Furthermore, in the medium-compression regime, *i.e.* $\beta_1 < \beta < \beta_2$, there will be individuals with a relatively low ability level who choose to become educated. These persons are not sufficiently able to qualify for training, and in order to obtain human capital, they must invest in education.

4 Comparative Statics

In this Section, we derive comparative statics with respect to changes in the degree of wage compression, β, and with respect to the skill bias, α, in the production function. A low value of β – a high degree of wage compression – corresponds to a Scandinavian type of country according to the findings of Wallerstein (1999), whereas a high value of β is interpreted as an Anglo-Saxon country.

4.1 A Change in Wage Compression

The aim of this subsection is to analyse how a change in β (the degree of wage compression) affects: i) the number of individuals who are employed, trained and educated; and ii) total utility.

In all three regimes, the number of employed persons is given by:

$$H = \int_{\gamma^h}^{\infty} \varphi(x)\, dx \tag{18}$$

where we recall that $\varphi(x)$ is the density function over individuals with respect to ability. As stated in Proposition 7, only individuals with an ability level above γ^h become employed. In the high- and medium-compression regimes, the number of trained persons is given by:

$$T = \int_{\gamma^\tau}^{\hat{\gamma}^{e\tau}} \varphi(x)\, dx \tag{19}$$

whereas in the low-compression regime: $T = 0$. The expression for the number of educated persons depends on the regime:

$$E^{low} = \int_{\hat{\gamma}^{eh}}^{\infty} \varphi(x)\, dx \tag{20}$$

$$E^{med} = \int_{\hat{\gamma}^{e\tau}}^{\infty} \varphi(x)\, dx + \int_{\hat{\gamma}^{eh}}^{\gamma^\tau} \varphi(x)\, dx \tag{21}$$

$$E^{high} = \int_{\hat{\gamma}^{e\tau}}^{\infty} \varphi(x)\, dx \tag{22}$$

where E^{low} is the number of educated in the low-compression regime, etc. Note that in the medium-compression regime, there are two intervals of educated individuals, *cf.* Proposition 7.

The effects on the number of employed, trained and educated individuals of a change in wage compression are stated in the following Proposition:

Proposition 8 *An increase in wage compression (a decrease in β) implies that:*

1. *The number of employed persons remains unchanged.*

2. *In the high- and medium-compression regimes, $\beta < \beta_2$, the number of trained persons increases. In the low compression regime, $\beta > \beta_2$, the number of trained persons remains zero.*

3. *The number of educated persons decreases.*

Proof. Differentiation of the expressions in (18)-(22) using the definitions of γ^h, γ^τ, $\hat{\gamma}^{eh}$, and $\hat{\gamma}^{e\tau}$. ■

An increase in wage compression lowers the return to education for each individual. As a result, we observe a decrease in the number of persons who become educated. On the other hand, firms have a higher return on training, and more persons will therefore receive training.

By construction, the minimum wage is not affected by changes in β, leaving the number of employed persons unchanged. Perhaps more realistically, an increase in wage compression would be associated with a higher minimum wage and increased unemployment, thereby further raising the share of trained workers among the uneducated with employment.

Since the utility function is linear, total utility (or GDP), Y, can be found as total production less total costs on education and training. By using the fact that only individuals with an ability level below γ^h become unemployed, and that final productivity and the incurred costs of education and training of person i can all be expressed as functions of the ability level, γ_i, total utility, Y, can be written in short form as:

$$Y = \int_{\gamma^h}^{\infty} \left(q\left(x\right) - c^e\left(x\right) - c^\tau\left(x\right)\right)\varphi\left(x\right)dx \tag{23}$$

Each regime contains different intervals of educated, trained and unskilled workers. In the Appendix, we provide the exact expression for Y in each of the three regimes. The effect on total utility, Y, of an increase in wage compression will therefore also depend on the regime, *i.e.* the value of β, as summarised in the following proposition.

Proposition 9 *An increase in wage compression (a decrease in β) implies that:*

1. *If $\beta > \beta_2$ (the low-compression regime), total utility, Y, unambiguously decreases, i.e. $\frac{dY}{d\beta} > 0$.*

2. *If $\beta < \beta_2$ (the medium- and high-compression regimes), the effect on total utility is ambiguous.*

Proof. Follows directly from differentiation of the expressions for Y in Appendix A.1 with respect to β, taking into account that γ^{τ}, $\hat{\gamma}^{eh}$, and $\hat{\gamma}^{e\tau}$ all depend on β. ■

Since $\beta < 1$, individuals do not receive the full return from investing in education. Similarly, since $\beta > 0$, firms do not receive the full return from investing in training. Hence, the equilibrium level of human capital will in general be inoptimally low. As a consequence, since wage compression tends to increase incentives for the firms to finance training, whereas it decreases the incentives for individuals to invest in education, the effect on total utility of an increase in wage compression is in general ambiguous. However, in the low-compression regime where there is no training, an increase in wage compression gives rise to an unambiguous decrease in the level of human capital and therefore to a decrease in total utility.

It is thus possible that total utility may increase as a consequence of higher wage compression. Figure 1 contains a numerical example based on a standard lognormal distribution of individual abilities.[7] In this example, the relative costs of education and training are the same, $\frac{c^e}{e} = \frac{c^{\tau}}{\tau} = \frac{2}{3}$, implying that the results are not driven by training being more "cost efficient" than education.

For $\beta < 0.47$, the economy is in the high-compression regime, where Y is decreasing in β, *i.e.* $dY/d\beta < 0$. An increase in β (less compression) will increase the group of educated while decreasing the group of trained, *cf.* Proposition 8. At first glance, this should increase overall utility since the effect of education on productivity is higher than the effect of training on productivity; something which is reinforced by the fact that educated individuals belong to the high end of the ability scale. On the other hand, we have important composition effects: The decrease in the number of trained is larger than the increase in the number of educated, since the interval of trained workers is reduced from both ends. First, the most able of the trained become educated ($\hat{\gamma}^{e\tau}$ drops), and the least able of the trained become unskilled (γ^{τ} increases). The importance of the latter effect is stronger if: i) the density of the distribution at γ^{τ} is high; and/or if ii) the effect of the change in β on γ^{τ} is large, which will be the case if, *e.g.*, the probability of an exogenous quit, $1 - z$, is high.

[7] Parameter values used are: $c_{\tau} = 1$, $c_e = 1.33$, $\tau = 1.5$, $e = 2$, $\theta = 0.1$, $\alpha = 0.6$, $z = 0.9$, and $\sigma^2 = 1$, where σ^2 is the shape parameter of the standard lognormal distribution.

As β increases above 0.47, the economy enters the medium-compression regime. Here, an increase in β is still detrimental to training, but the positive effects are now more important, since two intervals of educated individuals are affected positively, *cf.* Proposition 7. Thus, the composition effects favouring education are more important in this regime. In the low-compression regime, $\beta > 0.78$, the effect is still positive but less pronounced. The composition effect favouring education is now smaller since we again only have one interval of educated individuals. On the other hand, there will be no detrimental effect on trained individuals in this regime.

Figure 1: The effect on total utility of a change in wage compression, β.

4.2 Skill-Biased Technological Change

Next, we turn to the implications of skill-biased technological change, where the most interesting questions seem to be how a change in α affects training and education decisions as well as the relative wages of educated and uneducated individuals. In the productivity function, a skill-biased technological change, *i.e.* an increase in α, raises the importance of human capital relative to raw labour.

The following Proposition, summarises how a skill-biased technological change affects the number of individuals who are employed, trained and educated.

Proposition 10 *A skill-biased technological change (an increase in α) implies that:*

1. *The number of employed persons decreases in all three regimes.*
2. *In the low- and high-compression regimes, the number of educated persons increases.*
3. *The effect on the number of trained persons is ambiguous.*

Proof. Differentiation of the expressions in (18)-(22) with respect to α using the definitions of γ^h, γ^τ, $\hat{\gamma}^{eh}$, and $\hat{\gamma}^{e\tau}$. ■

First, since the productivity of unskilled persons decreases when α increases, a larger number of unskilled persons will not be sufficiently productive to qualify for the minimum wage, *i.e.* γ^h increases. Hence, more unskilled persons become unemployed in response to a skill-biased technological change.[8]

Second, education has a higher human capital content than training, and since the return to human capital increases with α, there is an unambiguous increase in the number of educated individuals in both the low-compression and the high-compression regimes. In the medium-compression regime, the effect is ambiguous because two types (intervals) of educated individuals are affected: i) high-ability educated; and ii) low-ability educated, *cf.* Proposition 7. While the former group will grow as α increases, the effect on the latter group is ambiguous. It will be reduced from above (γ^τ drops), since more will be trained, while it will be increased from below ($\hat{\gamma}^{eh}$ drops), since more of the low-ability individuals will find it optimal to acquire an education.

Third, the effect upon the number of trained individuals is also ambiguous. On the one hand, it will be optimal for the firms to train more of the uneducated workers, increasing the group of trained from below (γ^τ drops). On the other hand, more persons will choose to become educated, which tends to diminish the number of trained persons from above ($\hat{\gamma}^{e\tau}$ drops).

We now consider the effects on relative wages. The relative wage of two individuals, i and j, is given by:

$$w_{i,j}^{rel} = \frac{\theta(1-\beta) + \beta\left(1-\alpha+\alpha h_i\right)\gamma_i}{\theta(1-\beta) + \beta\left(1-\alpha+\alpha h_j\right)\gamma_j} \tag{24}$$

[8] By construction, the size of the effect on γ^h is independent of β, but increases with θ.

where h_i and h_j are the human capital levels of the individuals.

Proposition 11 *A skill-biased technological change (an increase in α) implies that:*

1. *The wage of a given educated (or trained) individual, i, relative to the wage of a given unskilled employed individual, j, increases.*

2. *The wage of a given educated individual, i, relative to the wage of a given trained individual, j, increases, if $\gamma_i > \gamma_j$.*

Proof. Differentiation of the expression in (24), using that if person i is educated or trained ($h_i = e$ or τ) and person j is unskilled ($h_j = 0$), then $\gamma_i > \gamma_j$ independently of the regime, and $e > \tau > 1$. ■

An unskilled individual, j, will always have lower ability than an educated or trained individual, i, $\gamma_j < \gamma_i$. Since ability and human capital are complements, a skill-biased technological change will always raise the relative wage, $w_{i,j}^{rel}$.

A similar intuition underlies the second part of the Proposition. Note, however, that in the medium-compression regime, a trained worker j might have ability, γ_j, which exceeds that of an educated worker, i. In this case, their relative wage may drop.

An often used measure of wage inequality is the average wage of educated relative to the average wage of uneducated workers, e.g. OECD (2002).

Proposition 12 *A skill-biased technological change (an increase in α) has an ambiguous effect on the average wage of educated persons relative to the average wage of uneducated persons.*

Proposition 12 says that even though the wage of a given educated individual relative to the wage of a trained or an unskilled rises (Proposition 11), the ratio of average wages may decrease. Composition effects are the underlying cause. First, the average ability of the educated persons tend to decrease because more persons choose to become educated. This effect tends to limit the increase in the average wage of educated persons, and can even reverse it under plausible parameter values. Second, the effect on the average ability of uneducated persons is ambiguous. The most able persons, who used to be trained, now choose to become educated, which tends to decrease the average ability of uneducated individuals. However, the least able unskilled individuals become unemployed, which tends to increase the average ability of uneducated persons. Third, among the group of uneducated individuals, there will typically be a larger fraction which receives training in the medium- and high-compression regimes, and this effect tends to increase the average wage of uneducated individuals. In sum, the effect on the relative wage of a skill-biased technological change is ambiguous.

Intuitively, a more compressed wage structure should increase the likelihood of a negative effect on the relative average wage between educated and uneducated of an increase in α. First, the increase in the return to human capital is lower when the wage structure is compressed. Second, the group of trained persons is larger with a more compressed wage structure. This intuition is supported partly by Figure 2, which contains a numerical example based on the same parameter values as in Figure 1, showing how the effect on the relative wage depends on the degree of wage compression.

The relative wage decreases at small values of β in the high-compression regime, and again in the medium-compression regime, where the group of educated individuals consists of two sub-groups: High-ability individuals and low-ability individuals, and where the positive wage effects on the latter group of an increase in α are limited due to their lower personal abilities.

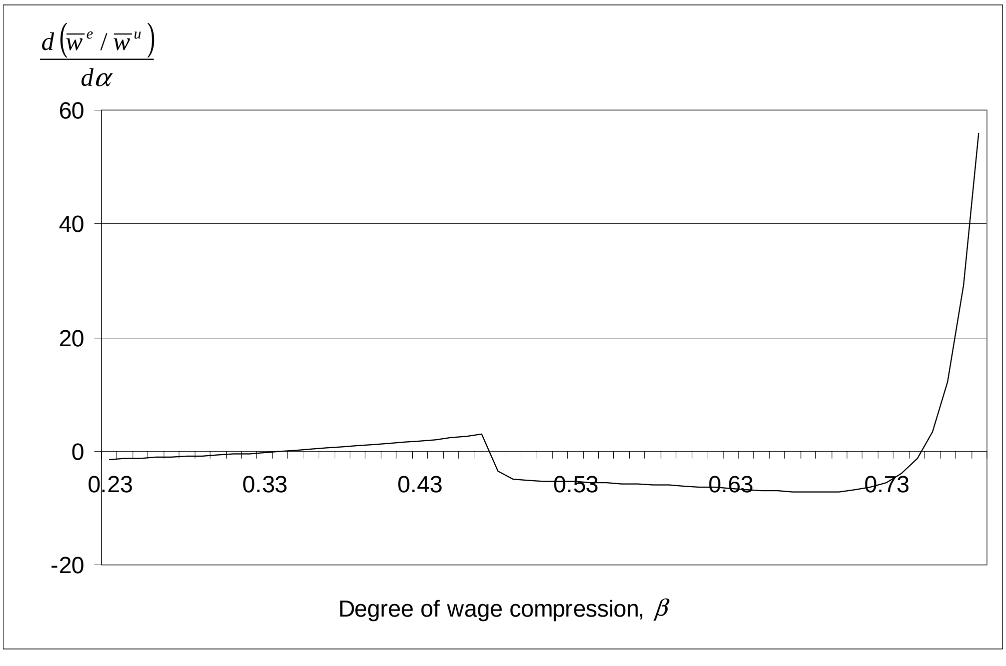

Figure 2: The effect of a skill-biased technological change on the average wage of educated relative to the average wage of uneducated, as a function of the degree of wage compression, β.

In a more general model with many different levels of education and training, similar effects would be observed. A skill-biased technological change will in general affect the incentives to acquire human capital – both through education and training, where the latter becomes increasingly important with a compressed wage structure. As a result, the compositions of the groups of educated and uneducated will change: More will be trained (educated) or receive a higher level of training (education) in response to a skill-biased technological change This can have significant effects on not only average wages, but also the different percentiles in the wage distribution. If a skill-biased technological change implies that the workers with only a little or no training become better trained, it is for example perfectly possible that the 5th percentile in the wage distribution increases relative to the 95th percentile.

5 The Danish Labour Market

As argued in the Introduction, the development at the Danish labour market is particularly interesting as it appears to be very different from the development at, for instance, the US labour market. In this Section, we discuss to which extend the above theoretical model is able to explain the Danish experience.

First, Denmark has the second largest GDP per capita in the EU and, at the same time, has the smallest wage difference between educated and uneducated workers. This is fully consistent with the above model as we found that utility (or GDP per capita) may be high both when the degree of wage compression is high and when it is low.

In the rest of this Section, we focus on the implications of a skill-biased technological change. In the literature, it is well established that the recent decades have been characterised by skill-biased technological changes, and that this is one of the main explanations behind the increasing wage inequality observed in the US, see, *e.g.*, Berman, Bound, and Griliches (1994) and Berman, Bound, and Machin (1998). In Table 1Statistics Denmark (2000), we summarise the development in average wages at the Danish labour market in the period 1980 to 1998. We choose to focus on persons with a long further education (*i.e.* the most highly educated persons) and persons without any education except lower-secondary school. It is seen that the average wage of educated workers has actually been decreasing relative to the average wage of uneducated workers.[9] Above, we found that if the degree of wage com-

[9] The development in average relative wages can be heavily influenced by changes in demographic compositions within groups, and for instance the age composition is important. Therefore, we report the development in the relative wage for a fixed demographic compo-

pression is high, it is likely that a skill-biased technological change gives rise to a decrease in the average wage of educated workers relative to the average wage of uneducated workers. One important reason for this is that a skill biased technological change implies that firms get an increased incentive to train uneducated persons, and that this composition effect implicitly raises the average wage. At the same time, similar composition effects with respect to education are typically eliminated in the data by using fixed weights with respect to the distribution on level and type of education.

Table 1: Wage Development at Danish Labour Market (yearly percentage change)

	1980-89	1989-98	1980-98
Relative wage change of educated*	-0.36	0.01	-0.17
Real wage changes:			
Uneducated:			
16-24 years	-0.76	0.30	-0.23
25-34 years	-0.27	-0.09	-0.18
35-44 years	0.17	0.01	0.09
45-54 years	0.24	0.32	0.28
55-64 years	0.50	0.56	0.53
Educated:			
25-34 years	-0.17	-0.35	-0.26
35-44 years	-0.61	0.14	-0.23
45-54 years	-1.01	-0.22	-0.61
55-64 years	-0.91	-0.05	-0.48

Source: Statistics Denmark (2000) and own calculations. Educated are defined as persons with a long further education. Uneducated are persons with only a lower secondary education.
* The wage rate of educated persons relative to the wage rate of uneducated persons using fixed demographic weights

Table 1 also indicates that training of uneducated workers has been increasingly important. In practice, training is an ongoing process implying that productivity, and in turn wages, will be increasing in experience. In Table 1, we see that there has been an increasing wage premium to experience

sition within each of the two groups, *i.e.* for a fixed age distribution, gender distribution and, for the group of educated, a fixed composition with respect to type of education, see Malchow-Møller and Skaksen (2003) for details.

among uneducated workers during the 1980s and 1990s as real wages of older workers have been increasing faster than real wages of younger workers. The same development is not observed among educated workers, indicating that there has not been the same tendency for increased training of this group.

Another prediction of the theoretical model of this paper is that skill-biased technological change implies that an increasing share of the unskilled will not be able to find employment. In Table 2, we report the development in non-employment rates for Danish men. We focus on men as the employment rates for women have been affected by an increasing tendency for women to participate at the labour market which is due to other factors than skill-biased technological change. We observe that there has been an overall tendency for non-employment rates for men to be decreasing, but we also see that this is much more pronounced for uneducated men than for educated men. Hence, this seems to confirm that it has become increasingly difficult for uneducated men to find employment.

Table 2: Non-Employment Rates of Danish Men, 16-64 years

	1980-89	1989-98	1980-98
Total	19.6	23.8	24.5
Educated	10.6	11.7	12.0
Uneducated	27.2	35.3	39.0

Source: Statistics Denmark (2000) and own calculations. Educated are defined as persons with a long further education. Uneducated are persons with only a lower secondary education.

Table 1 and 2 only provide indirect evidence of the importance of training in the Danish labour market. OECD (2000) gives some more direct evidence for this by considering the actual literacy skills of workers and not just their formal education. First, it is found that the skills of the formally uneducated workers is much higher in Denmark than in, for instance, the US. Second, Denmark has the lowest inequality in skills in the survey of 22 OECD countries. Third, Denmark is the country where most workers participate in job-related education (or training) after entering the labour market. Finally, it is found that in Denmark, firms more often pay for job-related education than in, *e.g.*, the US. All this seems to indicate that training (or job-related education) is more important in Denmark than in the US – especially training of uneducated workers.

6 Conclusion

In this paper, we have considered the economic implications of a compressed wage structure which is exogenously determined by institutions. An important feature of our analysis is that human capital is endogenous and can be achieved either as formal education before entering the labour market or as informal training within firms after entering the labour market. While institutional wage compression decreases the incentives of individuals to become educated, it increases the incentives of firms to invest in training. As a result, the net effects of wage compression on the aggregate human capital level and GDP are ambiguous.

Another result is that skill-biased technological change may have very different effects in an economy where wages are compressed compared to an economy where wages to a larger extent reflect the productivity of workers. We actually find that with wage compression, a skill-biased technological change may cause wage inequality to decrease. The possible decrease in wage inequality arises because a skill-biased technological change has a number of composition effects within and between the groups of educated and uneducated workers. In particular, more will receive training within the group of uneducated workers.

In the analysis, we assumed only one level of education and training. In reality, a large number of different levels of education and training exist. When observing statistics on relative average wages, it is often possible to control for most composition effects within the group of educated workers by using fixed weights with respect to the distribution of workers on educational level and type. On the other hand, since training of uneducated workers is often informal, and therefore remains unobserved in statistics on the qualifications of these, it is not possible to control for composition effects within this group. In countries where wages are compressed, and informal training within firms therefore play an important role, skill-biased technological change may give rise to significant but unobserved skill-upgrading within the group of workers who are formally uneducated. This will make it even less likely that skill-biased technological change increases the observed average wage of educated labour relative to uneducated labour.

We confronted the predictions of our model with the recent development in Denmark, which it seems to explain very well. In Denmark there is a high degree of wage compression, and the GDP per capita is relatively high. Moreover, the relative wages of educated workers have been decreasing while they have been increasing in most other countries. Finally, it has become increasingly difficult for especially uneducated workers to find a job in Denmark. These developments are all explained by our model.

A Appendix

This appendix contains the expressions for total utility and average wages of educated and uneducated workers in each of the three regimes.

A.1 Total Utility

In the low-compression regime, total utility, Y, is given by:

$$Y^{low} = \int_{\gamma^h}^{\widehat{\gamma}^{eh}} x\left(1-\alpha\right)\varphi(x)dx + \int_{\widehat{\gamma}^{eh}}^{\infty} x\left(1-\alpha+\alpha e\right)\varphi(x)dx - \int_{\widehat{\gamma}^{eh}}^{\infty} c^e\varphi(x)dx \tag{25}$$

whereas in the medium-compression regime, total utility becomes:

$$\begin{aligned} Y^{med} = & \int_{\gamma^h}^{\widehat{\gamma}^{eh}} x\left(1-\alpha\right)\varphi(x)dx + \int_{\widehat{\gamma}^{eh}}^{\gamma^{\tau}} \left[x\left(1-\alpha+\alpha e\right)-c^e\right]\varphi(x)dx \\ & + \int_{\gamma^{\tau}}^{\widehat{\gamma}^{e\tau}} \left[x\left(1-\alpha+\alpha\tau\right)-c^{\tau}\right]\varphi(x)dx + \int_{\widehat{\gamma}^{e\tau}}^{\infty} \left[x\left(1-\alpha+\alpha e\right)-c^e\right]\varphi(x)dx \end{aligned} \tag{26}$$

and in the high-compression regime:

$$\begin{aligned} Y^{high} = & \int_{\gamma^h}^{\gamma^{\tau}} x\left(1-\alpha\right)\varphi(x)dx + \int_{\gamma^{\tau}}^{\widehat{\gamma}^{e\tau}} \left[x\left(1-\alpha+\alpha\tau\right)-c^{\tau}\right]\varphi(x)dx \\ & + \int_{\widehat{\gamma}^{e\tau}}^{\infty} \left[x\left(1-\alpha+\alpha e\right)-c^e\right]\varphi(x)dx \end{aligned} \tag{27}$$

A.2 Average Wages

In the low-compression regime, the average wages of educated and uneducated workers, respectively, are:

$$\begin{aligned} \bar{w}^e_{low} &= \frac{1}{1-\Phi(\widehat{\gamma}^{eh})}\int_{\widehat{\gamma}^{eh}}^{\infty} \left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha e\right)x\right]\varphi(x)dx \\ \bar{w}^u_{low} &= \frac{1}{\Phi(\widehat{\gamma}^{eh})-\Phi\left(\gamma^h\right)}\int_{\gamma^h}^{\widehat{\gamma}^{eh}} \left[\theta\left(1-\beta\right)+\beta\left(1-\alpha\right)x\right]\varphi(x)dx \end{aligned}$$

where:

$$\Phi\left(\gamma^{*}\right)=\int_{0}^{\gamma^{*}}\varphi\left(x\right)dx$$

In the high-compression regime, the average wages are:

$$\begin{aligned}\bar{w}_{high}^{e} &= \frac{1}{1-\Phi\left(\hat{\gamma}^{e\tau}\right)}\int_{\hat{\gamma}^{e\tau}}^{\infty}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha e\right)x\right]\varphi(x)dx \\ \bar{w}_{high}^{u} &= \frac{1}{\Phi\left(\hat{\gamma}^{e\tau}\right)-\Phi\left(\gamma^{h}\right)}\left(\int_{\gamma^{h}}^{\gamma^{\tau}}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha\right)x\right]\varphi(x)dx\right. \\ &\quad \left.+\int_{\gamma^{\tau}}^{\hat{\gamma}^{e\tau}}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha\tau\right)x\right]\varphi(x)dx\right)\end{aligned}$$

and in the medium-compression regime, they are:

$$\begin{aligned}\bar{w}_{med}^{e} = &\frac{1}{1-\Phi(\widehat{\gamma}^{e\tau})+\Phi\left(\gamma^{\tau}\right)-\Phi(\widehat{\gamma}^{eh})}\cdot \\ &\left(\int_{\widehat{\gamma}^{e\tau}}^{\infty}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha e\right)x\right]\varphi(x)dx\right. \\ &\left.+\int_{\widehat{\gamma}^{eh}}^{\gamma^{\tau}}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha e\right)x\right]\varphi(x)dx\right)\end{aligned}$$

$$\begin{aligned}\bar{w}_{med}^{u} = &\frac{1}{\Phi\left(\widehat{\gamma}^{e\tau}\right)-\Phi(\gamma^{\tau})+\Phi(\widehat{\gamma}^{eh})-\Phi\left(\gamma^{h}\right)}\cdot \\ &\left(\int_{\gamma^{h}}^{\widehat{\gamma}^{eh}}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha\right)x\right]\varphi(x)dx\right. \\ &\left.+\int_{\gamma^{\tau}}^{\widehat{\gamma}^{e\tau}}\left[\theta\left(1-\beta\right)+\beta\left(1-\alpha+\alpha\tau\right)x\right]\varphi(x)dx\right)\end{aligned}$$

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