Age-Biased Technological and Organizational Change: Firm-Level Evidence and Management Implications

Michael Beckmann[*]

Abstract

This paper examines the question, whether the growing use of new technologies and decentralized forms of work organization affects the age structure of workforces within firms. The initial idea behind this relationship is that technological and organizational change may not only be skill-biased, but also age-biased. Based on human capital theoretical explanations that mainly focus on skill obsolescence in association with the need to acquire new skills, the hypothesis of an age-biased technological and organizational change (ABTOC) is derived and tested econometrically using German firm-level data. The empirical results show that the adoption of technological and organizational innovations decreases the firms' demand for older workers and increases the demand for younger workers. Hence, ABTOC is found to be at the expense of older workers. Since ABTOC does not fit to the current development in terms of age-specific labor supply, this paper also suggests human resource management practices that encourage firms to combine the use of new technologies and organizational forms with an ageing workforce.

JEL Classification: J23; L23; M12; M5; O33

Keywords: Ageing workforces, new technologies, decentralized work organization, skill obsolescence, skill adaptation, productivity-wage-differentials

---

[*] Prof. Dr. Michael Beckmann, University of Munich, Munich School of Management, Ludwigstraße 28 RG, D-80539 Munich, Tel.: +49-89-2180-5616, Email: beckmann@bwl.uni-muenchen.de.

I. Introduction

Since a couple of years many firms in industrialized countries have been restructuring their production processes adopting technological and organizational innovations. Nowadays, it is well known that the use of new production and information technologies and decentralized (holistic) forms of work organization including, for example, self-managed teams, just-in-time production, multi-tasking, and the delegation of decision rights, largely contributes to changing the employment patterns of heterogeneous workers. Particularly, the consequences on the firms' demand for workers with different skill levels have widely been examined and many empirical studies provided evidence consistent to what is known today as skill-biased technological change (SBTC) and skill-biased organizational change (SBOC), respectively. Moreover, some studies examined if technological (and organizational) change is also gender-biased and found evidence consistent with the hypothesis of a gender-biased technological change (GBTC) favoring female workers relative to male workers (e.g. Weinberg 2000, Beckmann, Schauenberg and Timmermann 2004).

Similarly, the idea of this paper is that technological and organizational changes may also shift the age-specific labor demand of firms. Thereby, it is a prior unclear, whether technological and organizational change is biased against younger or older workers. If these innovations increased the demand for experience knowledge, older workers would benefit from their adoption relative to younger workers. Intuitively, however, it appears to be more likely that technological and organizational change shifts the age-structure of the workforces at the expense of older workers. First, according to the well-known results of SBTC and SBOC, both types of restructuring firms require workers adapting to new and multiple skills, for example, flexibility, responsibility, and cooperativeness to perform a variety of tasks. Second, according to human capital considerations, technological and organizational change is also supposed to involve and even accelerate skill obsolescence. Typically, the need of skill adaptation and skill obsolescence emerge contemporaneously in innovative corporate restructuring processes. As older workers are usually unprivileged relative to younger workers regarding the acquisition of necessary skills by formal training programs, their relative employment prospects may degrade with the intra-firm diffusion of technological and organizational innovations. If this were the case, technological and organizational change could be regarded as age-biased against older workers. New technologies and work practices would then be associated with a relative decline in the demand for older workers. During the course of the paper, this viewpoint is called the hypothesis of an age-biased technological and organizational change (ABTOC).

It is important to note, however, that an empirical confirmation of the ABTOC hypothesis would call for a fundamental different firm behavior in terms of suitable adjustment strategies compared to SBTC or GBTC, respectively. This conclusion directly follows from the current labor supply developments. While the demand effects of SBTC and GBTC and the developments on the labor supply side look the same way, this would not be true in the ABTOC case. Firms can cope with SBTC quite easily because both the relative demand and supply of skilled workers increase simultaneously. Analogously, firms can benefit from an increasing relative supply of female workers, when technological change favors the employment patterns of female workers. However, if the ABTOC hypothesis was true, relative labor demand would clearly not correspond to the relative labor supply trend. While ABTOC is associated with an increase in the relative demand of younger workers, due to demographic reasons the long-term relative labor supply of younger workers is, in fact, declining. In Germany, for example, labor supply projections demonstrate that between 2005 and 2020 the labor supply rate of individuals aged 50 years and above will increase from 23 percent to 35 percent, while the corresponding rate for individuals not exceeding the age of 30 years will decline from 22 percent to 19 percent (Köchling 2000).[1] Therefore, firms would be forced to reconcile their age-specific labor demand with a diametrically different labor supply. If the adoption of technological and organizational innovations hampered the employment of older workers, this information would be bad news for the firms, because firms will increasingly depend on ageing workforces in the future. As a result, firms would be desperate to develop human resource management practices that allow both the implementation of innovations and profitable employment of older workers.

These considerations demonstrate that the objective of the present paper is twofold. First, the ABTOC hypothesis is tested econometrically analyzing the impact of technological and organizational innovations on the age structure of workforces with the aid of establishment data from West German firms. Second, the paper suggests human resource management strategies that encourage firms to combine new technologies and

[1] Since 2000 the rate of labor suppliers aged 50 years and above has been exceeding the corresponding rate of the labor suppliers below 30 years.

organizational forms with an ageing workforce. In this context, an age-specific job design, continuous training for older workers, team work in mixed age-groups, and the dropping of seniority wages will exemplarily be discussed.

A number of labor market statistics indicate a general and ongoing long-term trend towards a decline in the employment patterns of older workers in a wide majority of industrialized countries. For example, statistics on the labor force participation and early retirement decisions of senior workers show that between 1960 and 1995 the average retirement age decreased in all OECD countries substantially. The declining employment rates for older workers, which are typical for most OECD countries, are in accordance with this trend. Notably, the correspondent rates for Germany are far below OECD average. More precisely, in 1998 the employment rate of the 55 to 64 years old workers in Germany was 38.8 percent, while OECD average was 47.9 percent (Klös 2000).[2]

Consistent with the relatively low employment rate of older workers in Germany is a relatively high and increasing unemployment rate. Since 1975 the share of the 55 to 64 years old unemployed relative to all unemployed individuals registered in West Germany has been increasing from 10.2 percent to 23.1 percent in 2000.[3] At the same time, a directly opposed development regarding the unemployment of younger workers could be observed. While in 1975 28.6 percent of all unemployed in West Germany were younger than 25 years, this percentage decreased steadily to a level of 10.8 percent until the year 2000 (Institute for Employment Research 2002; 2003).[4] Wage differentials represent another indicator of labor demand. Card and Lemieux (2001) report that in the United States, the United Kingdom and Canada the college-high school wage gap for younger men has ascended in the past 30 years, while the gap for older men has been

[2] The difference is at least partially caused by the very common use of early retirement programs in Germany. These programs enable firms to lay off older workers ahead of time, while a considerable part of their dismissal costs is borne by the German social security system (unemployment and pension insurance). Since the mid 1980s German employers and employees have frequently been agreeing upon such early retirement rules.

[3] Nowadays, approximately 40 percent of all establishments in Germany do not employ workers aged 50 years and above anymore (Strotmann and Hess 2003). This percentage refers to a survey among firms located in the German federal state Baden-Wuerttemberg. However, according to information of the Institute for Employment Research the reported share of about 40 percent is representative for the entire Germany.

[4] The directions of these patterns do not change substantially, when the age-specific population shares are applied as the determination base instead of total unemployment.

stable or declining. As a consequence, the wage differential between older and younger workers has also been declining.

All these labor market outcomes reflect a declining relative demand for older workers.[5] Hence, it seems quite natural to test whether technological and organizational change contributes to shifting the age structure within firms at the expense of older workers. The very fact, namely, that dismissing older workers has legally been facilitated by early retirement rules cannot be reason enough to explain the decline in the demand for older workers. Rather, this development must mainly be driven by economic reasons. The sole existence of a non-binding law is unlikely to explain the impairing employment patterns of older workers sufficiently. Due to data availability the study focuses on firms located in the former West Germany.

The remainder of the paper is organized as follows: Section II derives the ABTOC hypothesis using standard human capital theory and delayed payments contract theory. Section III summarizes the results of prior empirical studies that aimed at explaining the observed labor market trends for older workers. The ABTOC hypothesis is econometrically examined and confirmed in section IV using establishment data for the former West Germany. Section V therefore discusses human resource management practices that encourage firms to cope with an ageing workforce in a work environment influenced by technological and organizational innovations. Finally, section VI concludes.

II. The Hypothesis of an Age-Biased Technological and Organizational Change

The labor market statistics mentioned in the introduction indicate a clear trend towards a declining relative demand for older workers. Rationally, a firm will only loose its interest to employ an older worker, if his marginal productivity fall below his wage payments. Therefore, from the viewpoint of human capital theory a decline in the demand for older workers is far away from being self-explanatory. According to Becker (1962) standard human capital theory never postulates wage profiles that exceed the productivity of trained workers. In the case of general human capital formation a worker’s post-training wage raises lock-step with his marginal productivity, while specifically trained

[5] This observation is quite bizarre as due to the demographic trends to become apparent there is a lively political debate in Germany to rise the legal retirement age from 65 to 67 years. Obviously, the interests of German firms and social politicians in times of an ageing population are directly opposed.

workers earn wages below their marginal productivity. Why should a rational employer thus have an incentive to reduce his relative demand for older employees? Moreover, as older workers usually have accumulated more specific human capital than younger workers, employers should be less likely to lay off older workers.

Even if the assumption of a competitive labor market, which is crucial for Becker's model, is relaxed and labor market imperfections are explicitly taken into account, the question mentioned above must at first remain unanswered. Acemoglu and Pischke (1999a; 1999b) show that with labor market frictions firms will only have an incentive to invest in general skills, when post-training productivity exceeds post-training wages and wages rise less steeply than productivity. In other words, firms will only invest in general training, if they are able to earn rents, which increase with the skill level of their educated workers. Hence, even under the conditions of imperfect labor markets workers will not be paid above their marginal productivity. So far, therefore, the empirical observation of a declining relative demand for older workers remains a puzzle.

A declining relative demand for older workers can only be explained rationally, when the employment of older workers is too expensive for a firm relative to the employment of younger workers. This condition holds, if the productivity-wage differential for older workers is smaller than for younger workers. Especially, if the wages of older workers exceed their marginal productivity, the firm has a strong incentive to lay these workers off and replace them by younger workers, who are expected to provide a more profitable productivity-wage relation. The fact that wages for skilled workers exceed their marginal productivity is a realistic scenario in at least two cases.

In the first case, a firm pays seniority wages to prevent workers from shirking and ensure permanent working effort. This idea has been introduced by Lazear (1979; 1981). Central to this approach is that wage profiles are steeper than productivity profiles. As a result, young workers receive at first wage payments below their marginal productivity. This approach is equivalent to paying a bond to the employer, when tenure is low. The employer will return the bond to the older or more experienced worker by paying wages above marginal productivity. However, delayed payment contracts are typically susceptible to double moral hazard, which means that the employer himself has a strong incentive to behave opportunistically and lay older workers with high tenure off in order to retain the bond.

The second case is more crucial to the analysis of this paper. Here, productivity falls below wage payments, when human capital depreciations play an important role in occupations and firms are reluctant to put new human capital investments into practice. When a worker's tenure increases, the expected period of amortization declines, because the remaining duration of employment declines on average. Therefore, firms are likely to refrain from investing in the skills of older workers.[6] When the depreciations of human capital exceed the current human capital investments, productivity declines (Mincer 1974). Provided that productivity declines more sharply than wages, at a particular time the productivity profile falls below the wage profile. From that time a firm would suffer net-costs, if it continued to employ older workers.

It is well-known that technological and organizational changes require skilled workforces and employees, who are disposed to acquire new skills and adapt to new working environments permanently. Meanwhile, there is a large body of literature that documents a SBTC or a SBOC, respectively.[7] New technologies and working practices increasingly require employees with multiple skills who are able to deal with multiple tasks. The use of production and information technologies is more and more associated with intellectually demanding tasks, while pure operating tasks take a back seat. Similarly, organizational innovations like self-managed team work, job rotation, and just-in-time production call for the execution of coordination, cooperation, and delegation tasks. Hence, computerization and workplace decentralization tend to alter jobs and the necessary job skills, substituting for automated routine tasks and complementing non-routine tasks (Friedberg 2003). Usually, educated workers are more productive on non-routine tasks than unskilled workers. Thus, technological and organizational innovations favor the employment of educated workers relative to unskilled workers.

Moreover, it is also well-known that new technologies affect the obsolescence of skills, and thus, the rate at which human capital depreciates (Bartel and Sicherman 1993, Blechinger and Pfeiffer 1996, Ahituv and Zeira 2001, Rodriguez and Zavodny 2003).

[6] Descriptive evidence supporting this argument can be found in Klös (2000). The author shows that only 5 percent of the individuals aged 50 to 55 years and only 1 percent of those who are older than 55 years participate in occupational continuous training programs.

[7] See, for example, the seminal papers of Lindbeck and Snower (1996; 2000), Caroli and Van Reenen (2001), Bresnahan, Brynjolfsson and Hitt (2002), and the surveys of Aghion, Caroli and Garcia-Penalosa (1999), Chennels and Van Reenen (1999), Snower (1999), Acemoglu (2002), Card and DiNardo (2002), or Beckmann (2004).

Intuitively, high rates of technological change will cause human capital to depreciate at a faster pace. The same can reasonably be assumed for innovative organizational working practices. As a consequence, in addition to the skill dimension, workers' ages become increasingly important in the discussion of the employment effects of technological and organizational change. Specifically, the use of technological and organizational innovations within firms can be expected to accelerate the process of skill obsolescence and human capital depreciation. Therefore, even specific human capital that has traditionally protected older, more experienced workers from being dismissed may have become less valuable for employers (Rodriguez and Zavodny 2003). As a result, unless older workers are not retrained to acquire the necessary skills technological and organizational change is likely to encourage firms to reduce their relative demand for older workers.

Since technological and organizational innovations make some existing human capital obsolete, while contemporaneously creating demand for new types of skills, the employment of younger workers appears to be more attractive for innovative firms for at least two reasons. First, due to their recent education younger workers are more likely to provide the necessary state-of-the-art skills in the first place than older workers. Second, even if retraining workers can outweigh the skill shortcomings driven by technical and organizational change, firms will be more likely to offer continuous training to younger than older workers. The reason for this expected firm behavior is that retraining younger workers is supposed to be more profitable than investing in the skills of older workers, because, on average, firms have more time to recoup the training costs and are thus more likely to earn rents. Analogously, older workers themselves are often reluctant to invest in skill adaptation, because the remaining time horizon is supposed to be too short to capture the returns to their investment. Hence, the theoretical analysis suggests the hypothesis that technological and organizational change is not only skill-biased, but also age-biased at the expense of older workers.

III. Related Empirical Work

While examining the determination of age-specific employment patterns, the majority of recent work has focused on the supply side of the labor market. As a result, many studies analyze the retirement decisions of older workers using individual-level data. However, as technological and organizational innovations definitely affect business strategies and production processes, they should also have an impact on the age-specific labor demand of firms, which therefore deserves some more research attention than before.

The first stream of empirical literature investigates, whether older workers can be supposed to be more protected than younger workers, when firms cut existing jobs. For example, the empirical results of Boisjoly, Duncan and Smeeding (1998) indicate that older workers are generally less likely to be displaced than younger workers. The probability of involuntary job loss is significantly lower among male workers aged 35 and older than among men aged 25-34 with the same education attainment. Similarly, using German firm-level data Beckmann (2001; 2004) also found that downsizing decisions of the firms primarily go at the expense of younger workers. In contrast to a net-reduction in staff, however, churning is associated with a declining share of older workers and an increasing share of younger workers. The conclusion is therefore twofold. First, when firms aim at initiating net-reductions in jobs older workers are protected by seniority rules or specific human capital. Second, the result for staff replacements is in line with human capital depreciations or the delayed payments contract model of Lazear (1979; 1981).

A second research stream on the careers of senior workers argues on the basis of individual-level data but does not explicitly emphasize technological or organizational effects. For example, Chan and Stevens (2001) used individual-level data from the Health and Retirement Study and examined the senior workers' reemployment opportunities following an involuntary job loss. Their main result is that the future reemployment options of displaced workers significantly decline with the workers' age. Older workers are much less likely to be reemployed quickly than younger workers. Analyzing data from the Displaced Workers Surveys, Rodriguez and Zavodny (2003) found an increasing risk of involuntarily jobs losses for middle-aged and older workers relative to younger workers. Antolin and Scarpetta (1998) investigated the determinants of retirement decisions in Germany using micro data from the German Socio-Economic Panel. They found evidence consistent with the usually claimed explanations for early retirement. First of all, socio-demographic factors have a strong impact on the retirement decisions of older workers. Another result is that a worker's bad health increases the probability of an early drop out of the labor force. Finally, financial incentives provided by the pension system, for example by generous early retirement plans, also turned out to be powerful in shaping the age profile of retirement. Using data from the Health and Retirement Study, Adams (2002) examined, whether older workers who report that their employers generally favor younger workers in promotion decisions are objectively be harmed. The author found a lower wage growth and a greater propensity of early retirement for older workers who subjectively felt to be discriminated due to their age. Hence, firms were indeed identified to panelize older workers by denying them promotion opportunities.

A third research stream examines the employment patterns of differently aged and tenured workers analyzing the courses of productivity and wage profiles (e.g. Mendes de Oliviera, Cohn and Kiker 1989, Kotlikoff and Gokhale 1992, Haltiwanger, Lane and Spletzer 1999, Andersson, Holmlund and Lindh 2002, Crepon, Deniau and Perez-Duarte 2002). All these studies found evidence for inverted U-shaped wage and productivity profiles, where productivity rises and declines much steeper than wages. Moreover, individuals aged between 30 and 40 years realize the highest level of productivity. Employees above the age of 50 are found to have lower productivity and higher wage levels than prime-age workers. Hence, wages of older workers continue to rise in spite of a declining productivity. Typical for both profiles is a coinciding discrepancy between productivity and wages, where prime-age workers are underpaid and older workers are overpaid relative to their productivity.[8] In this situation firms will lose from employing older workers and profit from replacing them by younger workers. Therefore, the results suggest that the unfavorable productivity-wage differentials for older workers encourage firms to exclude them from the workforce, since they cost more than they produce.

A fourth stream of literature closely relates the declining employment patterns for older workers resulting from unfavorable productivity-wage differentials to the rapid growth of technological (and organizational) innovations. One study which is based on individual-level data comes from Bartel and Sicherman (1993). The authors used data from the National Longitudinal Surveys of older men and found that the retirement decisions of older workers are affected by technological change in two ways. First, given a net positive correlation between technical change and on-the-job training, workers in technology-intense industries retire later than workers occupied in less technology-intense sec-

[8] This result is consistent with the existence of delayed payment contracts and skill obsolescence.

tors. Second, an unexpected technology shock causes older workers to retire sooner, because the necessary retraining is considered to be an unattractive investment. On the basis of repeated cross sections from the Current Population Survey and longitudinal data from the Health and Retirement Study, Friedberg (2003) found that impending retirement rather than age alone explains why older workers use computers less than prime-age workers. In turn, however, changes in skill requirements also affect retirement plans as computer users retire later than non-users. The explanation for this result is that computer users either have the required skills or find it worthwhile to adopt them. Ahituv and Zeira (2001) merged data from the Health and Retirement Study with data on sector-specific productivity growth to test their claim that technological innovations induce early retirement of older workers. Their empirical results can indeed confirm their theoretical model, where human capital is technology-specific, so that technical change erodes some existing human capital. More precisely, the authors found that technical change contributes to reducing the aggregate labor force participation of older workers. Similarly, the results of Peracchi and Welch (1994) suggest that technological advances primarily pressurize older unskilled workers pushing them out of the labor force.

Boockmann and Zwick (2004) base their study on a sub-sample of the 2002-wave of the German IAB Establishment Panel to examine the employment determinants of older workers in general. One of their results is that firms using state-of-the-art technology employ fewer older workers than less technology-intense firms. Similar to the present study, Aubert, Caroli and Roger (2005) also investigated the relationship between new technologies, workplace organization and the age structure of the workers using a sample of French manufacturing firms. The authors provided evidence that innovative firms are characterized by relatively low wage bill shares of older workers, while the opposite holds for younger workers. Furthermore, the age-bias is found to be prevalent within occupational groups suggesting that even skilled workers are not completely protected against the labor market consequences of ageing. A final result comes from an analysis of employment inflows and outflows, where the authors showed that technological innovations enhance hiring opportunities for younger workers, while decreasing them for older workers. In contrast, organizational adjustments increase the exit probability for older workers, while younger workers are less likely to quit or being laid off in firms with an innovative work organization. All these results are consistent with the skill obsolescence interpretation mentioned above.

IV. Econometric Analysis

IV.1 Data, Variables and Descriptive Statistics

The data set used in this study is the Establishment Panel of the German Institute for Employment Research (IAB). This data set constitutes a firm-level survey, which is conducted every year since 1993. At first, the survey was restricted to West German firms. Since 1996 also East German firms have been taking part in the survey. The IAB Establishment Panel contains information about the firms' business policies and developments, innovations, workforce structures, recruitment and separation decisions, wages, working times, apprenticeship and further training programs, industrial relations, etc. Starting with a sample size of about 4,000 establishments, the IAB Establishment Panel currently provides information of more than 15,000 firms of all firm sizes and industries, which makes it being the most extensive firm-level data set in Germany.

The investigation in this paper uses data of the panel waves 1993 and 1995 and is therefore restricted to West German firms. So far, the panel wave of 1995 is the only wave containing detailed information about age-specific employment shares. Furthermore, in 1995 employers have for the first time been asked, whether or not they make use of certain work organization practices. Finally, the panel wave of 1993 is additionally used to address the problem of endogenous explanatory variables. The 1993 wave provides the lagged variables, which are incorporated into the econometric model in order to avoid a possible simultaneity bias.

The data set contains information about the age structure of the employees within firms. Specifically, firms have been asked for their number of workers not exceeding an age of 30 years and their number of workers, who are at least 50 years old. This information can be used to generate the dependent variables for the econometric analysis. The variable *YOUNG* represents the share of workers not exceeding the age of 30 years, while *OLD* measures the share of workers aged 50 years and above.[9] Table 1 displays the average age-specific employment shares in relation to firm size classes.

[9] A detailed description of all variables used in this study can be found in the appendix in Table A1 and Table A2.

[Insert Table 1 about here]

The results show that the employment shares range between about 23 and 32 percent for younger workers and between 17 and 25 percent for older workers. Apart from the firms which employ less than five employees, the share of younger workers tends to decline with firm size, while the opposite holds for the share of older workers. Finally, likewise excepting the smallest firms, the younger workers-older workers ratio within firms is always greater than unity.

Technological change can be measured by two variables. The first variable is $TSTATUS$, which captures the current technological status of a firm's production and information technologies. $TSTATUS$ is a variable measured at an ordinal scale ranging between 1 and 5. The value 1 means "the current technological equipment is obsolescent", while 5 is equivalent to "the technological equipment is state-of-the-art". The declarations are thereby based on subjective evaluations of the employers. Similarly, $TINVEST$ is also an ordinally scaled variable ranging between 0 and 2. Here, 0 represents firms, which have in the previous year neither invested in new production technologies, nor in information technologies. The value 1 captures firms, which have either invested in new production technologies, or in new information technologies, while 2 finally means that firms have invested in both new production and information technologies. Table 2 lists the descriptive statistics of both variables indicating technological progress.

[Insert Table 2 about here]

The strategy of estimating the coefficients of both explanatory variables representing technological innovations separately would probably induce a collinearity problem, because the variables are highly correlated. Collinearity usually comes along with excessive standard errors for the estimated coefficients and may therefore lead to spurious insignificances or misleading interpretations, respectively. For this reason, both technology variables are combined to one single explanatory variable applying the method of Bresnahan, Brynjolfsson and Hitt (2002). At first, the authors standardize each explanatory variable separately, i.e., they calculate $STD(x) = (x - \bar{x})/\sigma_x$, where $\bar{x}$ is the mean and σ_x is the standard deviation of a variable x. The combined variable can then be calculated by adding up the standardized single variables and standardizing the outcome once again. The resulting variable has a zero mean and a unity variance regardless of the scale level of the original variables. In the present case, the technology variable $TECH$ can be calculated as follows:

$$TECH = STD(STD(TSTATUS) + STD(TINVEST)). \qquad (1)$$

The construction of an explanatory variable measuring organizational innovation is analogous to the previous case. Organizational change is usually related to the decentralization of hierarchical structures within firms, which directly involves a more decentralized workplace organization. In the IAB Establishment Panel, these organizational innovations are captured by several dummy variables, which are summarized in Table 3.

[Insert Table 3 about here]

For example, firms that have recently cut hierarchy levels are captured by the dummy variable $HLEVEL$. The variable $DELEGA$ measures, whether or not firms have delegated decision rights and responsibility to lower-ranked hierarchical levels. $TEAM$ indicates firms, which have introduced team work concepts. The dummy variable $DIVISION$ receives the value 1, if firms have rationalized in the past by combining the tasks of at least two departments or divisions, respectively. Firms, which have changed their organization of production by adopting just-in-time production, are covered by the explanatory variable JIT. Finally, $PCENTER$ measures firms, which have established profit or cost center divisions.

Milgrom and Roberts (1990; 1995) as well as Holmstrom and Milgrom (1994) have introduced the concept of the firm as a system of factor complementarities. This view suggests that organizational change should account for interdependencies between single practices and avoid hasty isolated adjustments. For this reason and in order to prevent the collinearity problems mentioned above, a standardized system variable is generated and added to the model instead of introducing all the single organizational variables separately. Thus, the process of variable generation is similar to the specification of the technology variable $TECH$. In the first step, therefore, the sum of the dummy variables is calculated. The result is a variable OC valued in the interval between 0 and

6, where 0 (6) means that the firm has adopted none (all) of the organizational practices. Hence, larger values of OC indicate a higher amount of organizational innovativeness within firms. In the second step, OC is standardized to receive the variable $ORGA$, which will finally be used for model estimation:

$$ORGA = STD(OC). \tag{2}$$

In addition to the variables $TECH$ and $ORGA$, which are supposed to provide information about the ABTOC hypothesis, the regression model contains a number of other (control) variables. These additional explanatory variables will be introduced in the course of the following subsection, in which the econometric model and the estimation approach are illustrated.

IV.2 Econometric Strategy

In microeconomic theory firm behavior can adequately be characterized by the use of production or cost functions. When econometric modeling is embedded in a classical labor demand framework, factor demand equations are usually derived from cost functions. The estimated labor demand functions in this paper are derived from a transcendental logarithmic cost function (translog), which has been introduced by Christensen, Jorgenson and Lau (1973). The major advantage of the translog function compared to the alternative Cobb-Douglas or CES function is that the elasticities of substitution between the input factors are not restricted to unity or a constant value, respectively. Furthermore, the use of a translog cost function allows the derivation of factor demand equations, which are linear in the parameters. In the sequel, a short-term variable translog cost function is assumed, where variable costs arise by the use of heterogeneous labor inputs, i.e. in the present case, workers belonging to different age-groups. The term W_i describes the variable wage costs for age-group i. The quasi-fixed input factor capital is expressed by two components – the usual capital stock K and organizational capital R.[10] More precisely, in the present context R represents both technological and organizational innovations.

The specification of a variable translog cost function allows to derive the following variable wage cost shares for every age-group i:

[10] The separation in usual and organizational or technology intense capital is according to Chennels and Van Reenen (1999) and Bond and Van Reenen (2003).

$$S_i = \beta_{i0} + \beta_{ii} \ln W_i + \sum_{j,i \neq j} \beta_{ij} \ln W_j + \beta_{iY} \ln Y + \beta_{iK} \ln K + \beta_{iR} \ln R . \qquad (3)$$

Here, Y is the firm's output and the β_i describe the coefficients to be estimated. The input factor labor of the age-group i and organizational capital are complementary (substitutive), if $\beta_{iR} > 0$ ($\beta_{iR} < 0$). Organizational capital (technological and organizational innovations) is age-biased against older workers, if $\beta_{iR} > \beta_{jR}$, where $i = YOUNG$ and $j = OLD$.

Unfortunately, equation (3) cannot be estimated directly, because firm-level data sets do usually not contain detailed information about age-specific wages W_i but only aggregate information about the firm's total wage bill W. This instance also applies to the IAB Establishment Panel. In econometric applications the usual strategy to address the problem of unobservable wage terms is to proxy the W_i by variables representing the structure of the workforce, firm size, sector affiliation, and regional affiliation. These proxies are supposed to capture the unobservable wage effects. Furthermore, neither the age-specific wage cost shares S_i can directly be observed on the basis of firm-level data. The problem of unobserved wage cost shares is usually solved by replacing S_i with the corresponding employment share L_i.[11] In the present case, L_i represents the employment share of the age-group i. In this manner, a wage cost share equation can be transformed to a labor demand equation.

Applied econometricians usually proxy the output variable Y by total sales or value added, respectively. However, instead of solely using an output measure, it could also be helpful to calculate an output-input ratio Y/W to examine the effect of the productivity-wage differential on the age structure of the firm. According to the theoretical results introduced in section 2 large productivity-wage differentials should be associated with low employment shares of older workers relative to other age-groups. Contrary, small or even negative productivity-wage differentials can be explained by skill obsolescence which is supposed to become a crucial factor, when the employment share of older workers is relatively high.

[11] See, for example, Chennels and Van Reenen (1999), Falk and Seim (1999), or Hujer, Caliendo and Radic (2002).

Finally, another problem may occur, when the estimation approach fails to account for an endogenous technological and organizational change. In the first instance, equation (3) considers technological and organizational innovations expressed by $\ln R$ to be exogenous. However, this view neglects that firms usually take up an active part in adopting technological and organizational innovations. The model specification and estimation approach should explicitly account for this problem of endogeneity.

Taking all these issues into account, the following system of augmented labor demand equations can be derived from the cost share equations (3):

$$\begin{aligned} L_{it} &= \beta_{i0} + \beta_{iY} \ln(Y/W)_{t-1} + \beta_{iK} \ln K_{t-1} + \beta_{iT} TECH_{t-1} + \beta_{iO} ORGA_{t-1} \\ &\quad + \sum_{j=1}^{n} \delta_{ij} X_{jt-1} + u_{it} \ , \qquad (4) \\ i &= YOUNG, MIDDLE-AGED, OLD \ . \end{aligned}$$

The term for organizational capital in (3), $\ln R$, is replaced in equation (4) by the technology and work organization variables $TECH$ and $ORGA$. The expression Y in the explanatory output-input variable Y/W refers to the firms' total sales instead of value added.[12] Since firm-level data sets usually lack for information about capital stocks, K measures the firms' total investment in the considered period. Due to relative high capital depreciations per period the recent investments provide an adequate proxy variable for the unobservable capital stock. The expression u_i describes the error term of the regression equation i and has the usual characteristics, i.e., $u_i \sim N(0; \sigma_u^2)$.

Finally, the unobservable age-specific wages W_i from equation (3) are proxied by variables for the structure of the workforce (share of skilled workers, share of part-time workers, share of apprentices, share of participants in further training programs), firm size, sector affiliation, and regional affiliation. All these control variables are summa-

[12] Strictly speaking, value added (sales – intermediates) would be the theoretically correct measure for Y in equation (4), because intermediate products and services represent another input factor in the production or cost function. Nevertheless, the model specification includes total sales instead of value added for two reasons. First, the use of value added would have been associated with a substantial reduction of the number of observations, because many employers reported their sales volume, but were not able to give details upon their intermediates. Second, the item non-responses are unlikely to be randomly distributed. As a result, the estimates of the coefficients would be biased, if value added was part of Y/W. In the present case, the results of a probit estimation show that the probability of item non-responses regarding the firms' intermediates is highly correlated with firm size. Consequently, the explanatory variable Y/W is generated using the firms' total sales to avoid a potential selection bias, which would be associated with a variable that includes intermediates.

rized in the vector X_j. Additional control variables reflect staff reduction, the firms' use of incentive contracts (delayed payment contracts, pension plans), the commitment to collective wage agreements, the existence of a works council, the firm's proneness to seasonal fluctuations, the firm's legal form, and its economic independence. Possible endogeneity problems should be prevented by instrumenting the original variables with lagged explanatory variables. All these variables have a time lag of one or more years indicated by the time index $t-1$.[13] This approach limits the problem of endogeneity, because the use of lagged variables resolves the simultaneity of the firm's decision processes with respect to the adoption of innovations and the adjustment of the structure of the workforce.

The present model specification in equation (4) considers three dependent variables, which are all regressed on the same set of explanatory variables. Since (4) has been derived from a translog cost function, the homogeneity condition imposes two restrictions. First, the sum of the intercepts of all three system equations must equalize unity. Second, the sum of the three coefficients of each explanatory variable must be equal to zero. Moreover, as the sum of the employment shares necessarily equalizes unity, one of the equations becomes redundant. Due to the parameter restrictions the coefficients for this equation directly follow from the estimates of the remaining equations. In the present case, the equations for the share of younger workers ($i = YOUNG$) and older workers ($i = OLD$) as the dependent variables will be estimated, while the equation for middle-aged workers ($i = MIDDLE-AGED$) will be omitted.

Under these conditions, equation (4) reduces to a bivariate regression model. In principle, both equations can be estimated separately using OLS. However, the jointly estimation of the equations has the advantage that it allows the calculation of the inter-equation covariances for the residuals and the coefficients, while providing the same parameter estimates and standard errors like OLS. The inter-equation covariances can be used to calculate the correlation between the residuals u_i [14] and perform significance tests for the coefficients in different equations. Especially the opportunity to perform

[13] The strategy to account for endogeneity by using lagged explanatory variables can also be found in Caroli and Van Reenen (2001) and Bresnahan, Brynjolfsson and Hitt (2002).

[14] Since the present model specification considers two dependent variables regarding the firms' structure of the workforce, a substantial correlation between the residuals of both equations appears to be quite natural.

significance tests for the coefficients in both equations is very useful in the present context. Hence, multivariate regression analysis is preferred to a simple multiple regression model. As a result, according to Wooldridge (2002) the adequate estimation approach is SOLS (system OLS) instead of the usual OLS equation by equation.

IV.3 Empirical Results

Table 4 summarizes the estimates for the equations of the employment share of younger workers ($YOUNG$) and the employment share of older workers (OLD) resulting from bivariate regression analysis.[15] Panels A-D display the estimates for the technological and organizational variables resulting from several model specifications that differ in the set of other explanatory and control variables.[16] Moreover, as an alternative to the SOLS estimation of the preferred Panel D, Panel E displays the results of an OLS regression applying heteroskedasdicity-consistent standard errors according to White (1980) instead of conventional standard errors. The purpose of these different specifications and estimation strategies is to check the robustness of the estimated coefficients.

[Insert Table 4 about here]

The estimation results strongly support the ABTOC hypothesis. Both technological and organizational innovations are associated with larger shares of younger workers and lower shares of older workers. Remarkably, in both equations the successive addition of further control variables involves declining coefficients for the technology variable $TECH$ in absolute terms (excepting the transition from Panel C to Panel D in the OLD equation). However, the coefficients stay significant at the 5 percent level. In contrast, controlling for more observable firm heterogeneity always increases the coefficients for the organizational variable $ORGA$ in absolute terms. In the end, in Panel D the coefficient in the $YOUNG$ equation is significant at the 10 percent level, while simultane-

[15] Firms from the agricultural sector and forestry are excluded from the analysis. The same holds for firms, which employ less than ten employees. The purpose of this restriction is to avoid a selection bias due to the fact that a significant number of firms do not employ any worker in one of the considered age-groups.

[16] Except from the dummy variables representing firm size, sector affiliation, and regional affiliation, the coefficients for the remaining explanatory variables are listed in Table A3 in the appendix. An interpretation of each of the coefficients is beyond the scope of the paper. However, the coefficients for the variable $DOWNSIZE$ deserve some attention as they confirm the importance of seniority rules within the German dismissal legislation. When firms downsize, the younger workers are primarily concerned (ceteris paribus), while older workers are legally protected by seniority rules imposing a number of lay-off barriers to the firms.

ously the significance of the coefficient in the *OLD* equation improves from the 5 percent to the 1 percent level. Hence, explicitly accounting for firm characteristics by estimating augmented system equations does not diminish the significant effect of technological and organizational innovations on the age structure of the firm but, on the contrary, rather contributes to stabilizing or reinforcing the effect.

Moreover, the results of the inter-equation F_β test on equality of corresponding coefficients additionally confirm the age bias of new technologies and organizational practices against older workers. The test statistics are relatively unambiguous rejecting the null hypothesis of equal coefficients in almost all cases. Most importantly, the F_β-statistics for the complete model in Panel D are highly significant for both technological and organizational innovations.

Additionally, the results of the alternative estimation strategy, i.e., the robust OLS procedure for each single equation displayed in Panel E, are very similar to the SOLS estimates deviating by construction only in the standard errors of the coefficients. Apart from the robust coefficient estimate for the variable *TECH* in the *YOUNG* equation, where significance reduces from the 5 to the 10 percent level, the significance levels obtained by SOLS remain unaffected. Hence, the achieved results that strongly confirm the ABTOC hypothesis also stand up to alternative estimation strategies and can therefore be regarded as being robust.

Finally, an interesting result comes from the explanatory variable $\ln(Y/W)$, which measures the productivity-wage bill relation within firms. Specifically, the estimates in Table A3 in the appendix indicate a significant negative correlation between $\ln(Y/W)$ and the share of older workers. In addition, the corresponding F_β test yields a prob value which is significant at the 10 percent level ($p = 0.087$). These outcomes are consistent with the skill obsolescence interpretation. Provided that there is no adequate retraining for older workers, intra-firm productivity-wage differentials decline due to skill obsolescence and sometimes even turn negative. On the contrary, when firms are characterized by relatively large productivity-wage differentials they are also less likely to employ a large share of older workers.

Since both the effect for $\ln(Y/W)$ and the effects for $TECH$ and $ORGA$ are consistent with skill obsolescence, the depreciation effect can be disentangled to some extent. First, the coefficients for the innovation variables $TECH$ and $ORGA$ can be supposed to capture (at least a part of) that kind of skill obsolescence, which results from a decrease in the market value of skills. In this case, human capital depreciation is externally driven by competition, which encourages firms to keep innovative. Thus, as the adoption of innovations contemporaneously involve both the obsolescence and the development of skills to adapt to changing working environments, the market value perspective reflects the Schumpeterian view of creative destruction. Second, the coefficient for $\ln(Y/W)$ can be considered to measure the residual internal depreciation of skills. Here, skill obsolescence can be caused by declining physical capabilities, for example due to ageing, injuries, and illness, or by disregarding the use of skills.[17]

The empirical results as a whole lead to the conclusion that technological and organizational change is at least partially age-specific. More precisely, the adoption of technological and organizational innovations within firms is biased against older workers. Thereby, the age bias does not only exist in relative terms, i.e., $\beta_{iR} > \beta_{jR}$, where $i = YOUNG$ und $j = OLD$, but also in absolute terms, because the coefficients in both equations have different signs. Both technological and organizational innovations have been found to be complementary to a younger workforce ($\beta_{iR} > 0$), while they substitute for older workers ($\beta_{jR} < 0$). The results are therefore in line with the findings of Aubert, Caroli and Roger (2005), who proceed similarly using data for French manufacturing firms.

It is important to recognize, that the confirmation of the ABTOC hypothesis directly calls for a fundamental change in the behavior of many firms. More specifically, in the context of recent and lasting demographic trends the empirical results of this paper strongly suggest firms to adjust several areas of human resource management substantially, for example, staff recruitment and separation, training and wage policies, and work organization. In fact, the relative labor demand of innovative firms is diametrically opposed to the long-term relative labor supply trend, which is becoming more and

[17] See also Aubert, Caroli and Roger (2005). The distinction between internal and external depreciation of human capital can be attributed to Rosen (1975).

more apparent in most industrialized countries. Hence, as firms will increasingly have to cope with ageing workforces, they are forced to develop management practices that allow both the implementation of innovations and profitable employment of older workers. Some of these policies are discussed more detailed in the next section.

V. Managing an Ageing Workforce in Innovative Working Environments

So far, a wide majority of firms appear to ignore demographic change and the resulting consequences with respect to ageing workforces and an ageing labor supply. According to results of the IAB Establishment Panel only three to four percent of the German firms currently believe that superannuation is going to become a future problem of personnel management. However, these firms obviously disregard the fact that it is very short-sighted to reflect upon human resource strategies that primarily focus on younger, reportedly more capable and innovative workers first at the time when these workers become scarcer on the labor market. For example, demographic projections for Germany imply that in order to cope with ageing workforces firms are required to preventively adjust human resource management and adopt a long-term staff development in the first decade of the century. Therefore, firms are asked to realize these adjustments until 2010 to keep innovative and competitive in the long run, while ignoring demographic labor supply trends and idling can be very expensive (Buck, Kistner and Mendius 2002).

Management practices that appear suitable to make the employment of older workers more attractive when firms decide to adopt new technologies or decentralize their work organization must allow improving the relation of productivity and wages. Hence, adjustment strategies must either contribute to increasing the productivity of older workers handling technological and organizational innovations or cutting the wages of older workers. In this context, firms are asked to take the following adjustment policies into account: age-specific job design, continuous training for older workers, team work in mixed age-groups, and the dropping of seniority wages.

V.1 Age-Specific Job Design

A well-known result of the tayloristic vs. holistic work organization debate is that enduring monotonous efforts are likely to lower workers’ productivity and should therefore be diminished, for example, by systematic job rotation. Especially, low skilled, physically demanding tasks are associated with monotonous efforts. In addition, physical abilities of workers naturally decline with age, which also impairs productivity. Hence, in order to combine innovations and ageing workforces older workers should be relieved of physically demanding tasks. Instead, these tasks can preferably be undertaken by younger workers. In return, older workers can increasingly engage in mentoring and coaching tasks and train younger workers informally. Thereby, older workers transfer not only explicit knowledge and experiences to younger workers but even implicit knowledge. In this way, younger workers benefit from the experiences and the specific knowledge of senior workers. Hence, such an age-adequate job design explicitly considers age-specific comparative advantages and thus contributes to realizing complementary effects.

However, it is important to note that knowledge transfer from older to younger workers is not a matter of course. On the contrary, older workers are likely to refrain from sharing their knowledge and experiences with younger workers voluntarily, because knowledge transfer contributes to impairing their intra-firm competitiveness relative to younger workers. Therefore, the adoption of mentoring and coaching programs should be accompanied by other management practices that provide incentives for older workers to reveal private information. For example, relative job security should be one feature of human resource management. If jobs were insecure, older workers would refuse to transfer their experience knowledge to younger workers voluntarily, because knowledge sharing increases the risk for older workers to become redundant. In contrast, if human resource management is characterized by stable employment relationships, older workers are more likely to share their knowledge with younger workers. The adoption of group incentives represents a second example for a human resource management supporting knowledge transfer. If workers were compensated on the basis of a team output, older team members would extrinsically be encouraged to reveal their experiences and knowledge to younger members of the team.[18]

V.2 Continuous Training for Older Workers

[18] A more detailed discussion of suitable incentives to accompany mentoring programs is beyond the scope of the paper. Other suitable instruments are worker empowerment, performance evaluation including knowledge sharing as a decision criterion, cooperative leadership, or a corporate culture signaling open book management and tolerating mistakes.

This adjustment strategy directly aims at enhancing the productivity and thus improving the productivity-wage-gap of older workers. It is well-known that firms are usually less likely to invest in the skills of senior workers. Moreover, even senior workers are often reluctant to learn new tasks in innovative working environments. As a consequence, the previously accumulated skills become obsolete and the productivity of senior workers declines. However, older workers are neither lacking the ability nor the motivation to learn necessarily. Very often a relative low learning motivation of older workers is the result of the simple fact that they are not used to learn anymore. Thus, older workers may simply be frightened to acquire new skills. For both employers and employees, therefore, the period of amortizing human capital investments is of crucial importance. In this context, firms and older workers may benefit from current political efforts to lift up mandatory retirement ages, and thus, extend lifetime working times. Investing in the skills of older workers would become more beneficial for both parties, if the amortization period was extended.

Although the calling to intensify continuous training for senior workers appears to be necessary, it is clearly not sufficient. Moreover, firms are asked to develop elaborate concepts of life-long learning for all age-groups. Nowadays, apprenticeship certificates and even university degrees are only the basis for additional investments in human capital throughout the whole occupation. Usually, the skills accumulated for the first job are not sufficient anymore to allow a worker practicing his job unmodified until retirement. In addition to formal continuous training programs the productivity of older workers may also be increased applying informal training. Such informal training may take place, for example, in a team work environment.

V.3 Team Work in Mixed Age-Groups

Team work is an essential feature of holistic work organizations, which combines cooperative working with informal training and learning. The adoption of team work in mixed age-groups would be productive, if the team output reached at least the same level of a homogenous team consisting of younger workers. The rationale for team work in mixed age-groups is that these teams combine the comparative advantages of older and younger workers. Meanwhile, it is commonly accepted and confirmed by empirical studies that older workers have comparative advantages in areas as experience knowledge and established consumer relationships, firm-specific human capital, working motivation, perception of quality, leadership abilities, loyalty and reliability, while younger workers are usually more creative and flexible. Furthermore, younger workers are often supposed to have an advantage regarding physical skills, recent intellectual skills, and learning motivation relative to older workers (Boockmann and Zwick 2004). A composition of heterogeneous teams consisting of both younger and older workers is likely to utilize the age-specific capabilities of the workers complementarily. In principle, both age-groups can benefit mutually by such a team formation. Older workers acquire new skills and keep innovative cooperating with younger workers, while younger workers benefit from the experiences and the firm-specific knowledge of senior workers. It would thus be profitable for the firm to support the knowledge transfer between age-groups. Therefore, the adoption of team work in mixed age-groups should be accompanied by management practices mentioned in subsection V.1.

An inherent risk of team work in mixed age-groups is the exaggeration of specialization, for example, within production teams, project teams, or R&D teams. Excessive specialization would probably be associated with an age-specific polarization, and thus, stagnation of skills, which in turn may impair the flexibility of staff assignment. Job rotation and job enrichment provide possible solutions to this problem.

V.4 Cutting Seniority Wages

According to Table A2 in the appendix about 50 percent of the firms in the sample report on paying seniority wages to their workers voluntarily. The primary objective of seniority wages is to encourage employees to work hard until retirement. However, this delayed wage payment policy implies that the wages of older workers exceed their productivity contributions. As a result, firms paying seniority wages would suffer financial losses on employing older workers. Furthermore, as new technologies and decentralized work organizations tend to decline the productivity of older workers, the discrepancy between wages and productivity continues to accelerate. In order to make the employment of older workers in an innovative working environment more profitable for the firms, cutting seniority wages, and thus, flattening wage profiles would be helpful (Lazear 1988, Skirbekk 2003). Flatter wage profiles imply that wages and individual productivity converge. Negative productivity-wage-differentials diminish and may even turn positive. However, a serious drawback of cutting seniority wages is that firms abandon a powerful incentive mechanism. In this case, firms would be asked to substitute seniority wages for an alternative incentive instrument.

In this context, the use of fixed-term contracts represents an alternative mechanism to avoid paying seniority wages and employ older workers more profitable. If older workers were employed on the basis of a fixed-term contract, firms could attach wages directly to individual productivity or below instead of paying delayed wage bonds. Hence, firms may benefit from establishing contingent work for older workers, because this management practice allows improving the gap between productivity and wages. Furthermore, contingent contracts reduce dismissal costs for older workers, who would otherwise be protected by a number of dismissal rules (at least in Germany). Nevertheless, provided that fixed-term contracts improve their employment options, senior workers will also benefit from this instrument.

VI. Conclusion

The present paper adds to the research stream on innovations and labor markets by studying the effects of technological and organizational change on the intra-firm age structure of workforces. Theoretical considerations predict that the adoption of technological and organizational innovations involves an age-specific labor demand favoring younger workers and hurting older workers. The analysis thereby emphasizes that technological and organizational changes are likely to accelerate skill obsolescence. Since firms are supposed to provide less retraining opportunities for older workers than younger workers, human capital depreciations will sometime exceed the current human capital investments. At this time, the declining net-investments in new skills will finally turn negative and the productivity of older workers will decrease. From the time when individual productivity falls below the corresponding wage level a firm loses on employing older workers.

Using data from West German firms of the time period 1993-1995 the econometric analysis provides evidence for an age-biased technological and organizational change and thus confirms the ABTOC hypothesis. Specifically, the adoption of both technological and organizational innovations within firms significantly contributes to shifting the age structure of the workforce stacked against older workers. New technologies and organizational work practices complement to younger workers and substitute for senior workers. The estimation results are robust to several specifications and different estimation strategies.

In times of ageing societies the results of this paper are very challenging for both the firms and labor market politicians. When technology and reorganization hurt older workers, in the long run the social systems of industrialized countries will be under considerable strain. Moreover, due to the demographic developments in many industrialized countries firms must prepare for a declining labor supply of younger workers and ageing labor forces. As a consequence, both the firms and labor market politicians are forced to develop strategies to cope with ageing workforces or improve the employment prospects of older workers, respectively. In this context, section V has discussed some adequate management practices from the viewpoint of the firms: age-specific job design, continuous training for older workers, team work in mixed age-groups, and cutting seniority wages. Actually, most of these adjustment strategies can be adopted in the short run, for example, team work in mixed age-groups in order to encourage the knowledge and experience transfer between younger and older workers. The adoption of other policies may sometimes be more time-consuming. One example for such a middle-term strategy is the reorganization of job design to lower monotonous work load.

Politics should support these management practices by adjusting business environment. For example, if politicians lifted up mandatory retirement ages, firms would benefit from investing in the skills of older workers, because extended lifetime working times would on average be associated with enlarged time intervals of amortization. Second and perhaps even more important, politicians are desperate to reduce the incentives for early retirement. In recent years, several early retirement programs largely contribute to continuously declining the labor force participation rate of older workers in Germany. To make a long story short, early retirement rules allow firms to dismiss older employees in large part at the expense of the social security system. Hence, these rules have been creating a strong incentive for downsizing firms to lay older workers off. In order to stop this process, therefore, early retirement rules have to be withdrawn in the short run.

This paper should not end without pointing to some aspects that could not directly be addressed in the empirical study. First, due to data limitations the skills of workers in different age-groups could not explicitly be considered. Although the IAB Establishment Panel provides data for the skill structure of the firms' workforces, the skill dimension can not be combined with the age dimension to gain information on the workers' age and skills simultaneously. Hence, it may be argued that the empirical results suffer from not explicitly accounting for heterogeneous worker skills across age-groups.[19] However, this objection can be countered with the results of Aubert, Caroli and Roger (2005) and Beckmann, Schauenberg and Timmermann (2004). Neither of the papers found evidence for a limited age or gender bias, focusing not only on the age (gender) dimension but additionally on the skill dimension. In fact, age (gender) bias and skill bias are coexisting, where skill bias is shown to exist within age (gender) groups. Furthermore, the estimates for the control variable *QUAL* (share of skilled workers within firms) in Table A3 in the appendix do also not give reason to suspect the measured age bias to be superposed by an unconsidered skill bias. On the contrary, there is no significant correlation between the share of skilled and older workers, while the correlation between skilled and younger workers is even slightly negative. Thus, the objection that younger workforces may, on average, be more skilled than older workforces, so technological and organizational change could rather supposed to be skill-biased than age-biased, is obviously unfounded. For these reasons, the focus on the age dimension in this paper is unlikely to impair the conclusions achieved with respect to the robustness of the age bias. A more precise analysis that examines the impact of technological and organizational innovations on the firms' demand for differently aged workers with heterogeneous skills, however, requires the application of linked employer-employee data, which are currently under construction in Germany. Such investigations must therefore be left to future studies.

The second aspect that could not directly be considered in this study is unobserved firm heterogeneity. Not accounting for unobserved firm heterogeneity can indeed bias the estimation results of cross sectional analyses. Unfortunately, the only panel wave that reveals information on the share of younger and older workers is the wave of 1995. As a consequence, estimation strategies that explicitly account for unobserved firm characteristics, e.g. the first-difference estimator or the fixed effects estimator, cannot be applied. However, Black and Lynch (2001) propose an alternative strategy to address the

[19] One might conclude that the ABTOC results could be biased in a way that technical and organizational change would rather be skill-biased than age-biased if skill differences were additionally considered.

problem of unobserved firm effects. Specifically, the authors enrich their basic model specification by adding a large number of control variables. The objective of this strategy is to capture as much unobserved heterogeneity as possible by observed firm characteristics. The present empirical examination follows this approach so that unobserved firm characteristics are unlikely to affect the obtained results substantially. Again, an empirical analysis that explicitly accounts for unobserved heterogeneity must also be left to future studies, when linked employer-employee data can be used.

Table 1
Age-specific employment shares in relation to firm size (number of employees)

Variable	0-4	5-19	20-99	100-199	200-1,999	≥ 2,000	All firms
YOUNG	23.30	31.73	28.98	24.70	25.83	24.46	27.37
OLD	25.02	16.80	16.82	20.16	19.66	20.20	19.00

Note: The calculations are restricted to firms that do not provide item non-responses for the regression analysis. The age-specific employment shares are displayed in percent.

Source: IAB Establishment Panel 1995 (3rd wave West Germany), own calculations.

Table 2
Descriptive statistics of the variables indicating technological innovations

Variable	Intervall	Mean	Standard deviation
TSTATUS	1-5	3.86	0.78
TINVEST	0-2	1.29	0.77

Note: The calculations are restricted to firms that do not provide item non-responses for the regression analysis.

Source: IAB Establishment Panel 1995 (3rd wave West Germany), own calculations.

Table 3
Descriptive statistics of the variables indicating organizational innovations

Variable	Intervall	Mean	Standard deviation
HLEVEL	0-1	0.27	0.44
DELEGA	0-1	0.43	0.49
TEAM	0-1	0.28	0.45
DIVISION	0-1	0.32	0.46
JIT	0-1	0.12	0.33
PCENTER	0-1	0.24	0.43
OC	0-6	1.69	1.67

Note: The calculations are restricted to firms that do not provide item non-responses for the regression analysis.

Source: IAB Establishment Panel 1995 (3rd wave West Germany), own calculations.

Table 4
Technological and organizational innovations as determinants of an age-specific labor demand

Dependent variable	$YOUNG_t$		OLD_t		F_β test
Panel A: basic model					
$TECH_{t-1}$	2.238***	(0.418)	-1.566***	(0.299)	0.000***
$ORGA_{t-1}$	0.076	(0.345)	-0.506**	(0.247)	0.235
Panel B: Panel A + workforce characteristics + net employment reduction					
$TECH_{t-1}$	1.054**	(0.438)	-0.802**	(0.348)	0.003***
$ORGA_{t-1}$	0.344	(0.361)	-0.616**	(0.287)	0.069*
Panel C: Panel B + incentive contracts + industrial relations					
$TECH_{t-1}$	0.922**	(0.448)	-0.707**	(0.353)	0.012**
$ORGA_{t-1}$	0.615*	(0.367)	-0.760***	(0.290)	0.010***
Panel D: complete model					
$TECH_{t-1}$	0.905**	(0.455)	-0.797**	(0.354)	0.009***
$ORGA_{t-1}$	0.654*	(0.373)	-0.824***	(0.290)	0.006***
Panel E: robust OLS estimation of Panel D					
$TECH_{t-1}$	0.905*	(0.469)	-0.797**	(0.351)	
$ORGA_{t-1}$	0.654*	(0.373)	-0.824***	(0.264)	
F test	11.33***		7.49***		
R^2	0.203		0.144		
ρ	-0.314				
Breusch-Pagan test	161.37***				
N	1,634		1,634		

Note: */**/*** indicates significance at the 10/5/1 percent level. The coefficients in Panel A-D are estimated by SOLS. The values in parentheses represent the estimated standard errors for the coefficients. The F_β test is an F test on the equality of corresponding coefficients in both equations. The displayed values represent the prob values of the F_β-statistics. The complete specification of Panel D additionally contains the model variables $\ln(Y/W)$ and $\ln K$ as well as control variables for the share of skilled workers, part-time workers, apprentices, and participants in further training programs, the amount of staff reduction, the firms' use of incentive contracts (delayed payment contracts, pension plans), the commitment to collective wage bargaining, the existence of a works council, the firm's proneness to seasonal fluctuations, the firm's legal form, and the economic independence of a firm. Finally, three firm size dummies, nine sector dummies, and eleven dummies for the firm's regional affiliation are added. In addition to $TECH$ and $ORGA$ the basic model of Panel A includes $\ln(Y/W)$, $\ln K$, the firm size and sector dummies. The F test and R^2 indicate the estimation quality of both equations. The parameter ρ describes the correlation coefficient between the residuals of the two equations. The Breusch-Pagan test examines the hypothesis that the calculated residuals are statistically independent. N indicates sample size. All the latter statistics refer to Panel D.

Source: IAB Establishment Panel (waves 1993 and 1995), own calculations.

Appendix

The following table contains the variables used in the regression analysis (except from firm size, sector, and regional dummies). Unless otherwise declared the reporting date is June 30th 1995.

Table A1
Description of the variables

Variable	Definition
YOUNG	Share of workers (as a percentage of total workforce) not exceeding the age of 30 years
OLD	Share of workers (as a percentage of total workforce) aged at least 50 years
TSTATUS	Ordinal variable ranged between 1 (firm uses obsolete technologies) and 5 (firm uses state-of-the-art technologies)
TINVEST	Variable ranging between 0 and 2; 0 = firms have neither invested in production technologies nor in information technologies in 1994; 1 = firms have either invested in production technologies or in information technologies; 2 = firms have invested in both production and information technologies
HLEVEL	Dummy variable indicating whether or not firms have cut hierarchical levels before 1995
DELEGA	Dummy variable indicating whether or not firms have delegated decision rights and responsibility to lower-ranked hierarchical levels before 1995
TEAM	Dummy variable indicating whether or not firms have adopted team work concepts before 1995
DIVISION	Dummy variable indicating whether or not firms have rationalized by combining the tasks of at least two departments or divisions before 1995
JIT	Dummy variable indicating whether or not firms have changed their organization of production by adopting just-in-time production before 1995
PCENTER	Dummy variable indicating whether or not firms have established profit or cost center divisions before 1995
OC	Count variable ranging between 0 (firm has not adopted any of the organizational practices before 1995) and 6 (firm has adopted all considered organizational practices before 1995)
$\ln Y$	Log of a firm's total sales in 1994 in German Marks
$\ln K$	Log of a firm's total investment in 1994
QUAL	Share of skilled workers (as a percentage of total workforce) at June 30th 1993, i.e., graduated workers who have completed vocational education or higher educational degrees
PTIME	Share of part-time workers (as a percentage of total workforce) at June 30th 1993

Table A1
Description of the variables (continued)

Variable	Definition
APPREN	Share of apprentices (as a percentage of total workforce) at June 30th 1993
FURTHER	Share of participants in further training programs (as a percentage of total workforce) at June 30th 1993
DOWNSIZE	Censored variable; 0 = firms with a constant or increasing employment between June 30th 1992 and June 30th 1994; positive values = amount of net staff reduction between June 30th 1992 and June 30th 1994 in percent.
SENWAGE	Dummy variable indicating whether or not firms paid seniority wages according to a delayed payment contract in 1993
PENSION	Ordinal variable between 1 and 3 indicating to what amount firms offered pension plans in 1993; 1 = pension plans were not offered; 2 = pension plans were offered to a part of the workforce; 3 = pension plans were offered to all workers
UNION	Dummy variable indicating whether or not firms commit to collective wage bargaining at the industry or firm level
WORKC	Dummy variable indicating whether or not a firm has a works council
DSHOCK	Dummy variable indicating whether or not a firm was prone to seasonal fluctuations in 1993
AUTARK	Dummy variable indicating whether or not a firm was autarkic in 1993.
PARTNER	Dummy variable indicating whether or not a firm was managed under the legal form of a one-man business or a business partnership in 1993

Source: IAB Establishment Panel (waves 1993 and 1995).

Table A2
Descriptive statistics of the variables not explicitly mentioned in the text

Variable	Intervall	Mean	Standard deviation
$\ln(Y/W)$	-2.26-6.83	1.62	1.05
$\ln K$	0-21.19	12.19	5.46
QUAL	0-100 %	62.33 %	26.09
PTIME	0-98.87 %	11.68 %	15.13
APPREN	0-94.54 %	4.72 %	6.07
FURTHER	0-95.83 %	10.36 %	14.34
DOWNSIZE	0-97.25 %	7.91 %	12.40
SENWAGE	0-1	0.51	0.50
PENSION	1-3	2.21	0.83
UNION	0-1	0.88	0.31
WORKC	0-1	0.72	0.44
DSHOCK	0-1	0.50	0.50
AUTARK	0-1	0.51	0.49
PARTNER	0-1	0.17	0.38

Note: The calculations are restricted to firms that do not provide item non-responses for the regression analysis. Firms without any investments in 1994 have been corrected by setting total investment to 1 DM, so that these firms need not to be excluded from the analysis by taking logs. Due to simplification time indices are not displayed.

Source: IAB Establishment Panel (waves 1993 and 1995), own calculations.

Table A3
Parameter estimates of the variables not listed in Table 4 (Panel D)

Dependent variable	*YOUNG*		*OLD*	
Explanatory variables				
$\ln(Y/W)$	0.375	(0.435)	-0.701**	(0.338)
$\ln K$	-0.112	(0.090)	0.179**	(0.070)
QUAL	-0.025*	(0.014)	0.005	(0.011)
PTIME	-0.003	(0.026)	0.052***	(0.020)
APPREN	0.889***	(0.061)	-0.304***	(0.047)
FURTHER	-0.024	(0.025)	-0.027	(0.019)
DOWNSIZE	-0.120***	(0.029)	0.042*	(0.023)
SENWAGE	0.768	(0.700)	-0.656	(0.554)
PENSION	-1.064***	(0.412)	0.236	(0.320)
UNION	-1.055	(1.252)	2.561***	(0.973)
WORKC	-2.935***	(1.061)	3.204***	(0.824)
DSHOCK	-0.348	(0.726)	0.039	(0.564)
AUTARK	-0.599	(0.738)	0.305	(0.574)
PARTNER	-0.182	(0.949)	0.754	(0.737)
CONST	29.337***	(3.906)	15.817***	(3.035)

Note: */**/*** indicates significance at the 10/5/1 percent level. The coefficients are estimated by SOLS. The values in parentheses represent the estimated standard errors for the coefficients. Additionally, the model contains three firm size dummies, nine sector dummies, and eleven dummies for the firm's regional affiliation. Due to simplification time indices are not displayed.

Source: IAB Establishment Panel (waves 1993 and 1995), own calculations.

References

Acemoglu, K. Daron. "Technical Change, Inequality, and the Labor Market." *Journal of Economic Literature* 40 (2002): 7-72.

Acemoglu, Daron, and Pischke, Jörn-Steffen. "Beyond Becker: Training in Imperfect Labour Markets." *Economic Journal* 109 (1999a): F112-F142.

Acemoglu, Daron, and Pischke, Jörn-Steffen. "The Structure of Wages and Investment in General Training." *Journal of Political Economy* 107 (1999b): 539-572.

Adams, Scott J. "Passed Over for Promotion Because of Age: An Empirical Analysis of the Consequences." *Journal of Labor Research* 23 (2002): 447- 461.

Aghion, Philippe; Caroli, Eve; and Garcia-Penalosa, Cecilia. "Inequality and Economic Growth: The Perspective of New Growth Theories." *Journal of Economic Literature* 37 (1999): 1615-1660.

Ahituv, Avner, and Zeira, Joseph. "Technical Progress and Early Retirement." Mimeo. Cambridge, MA: Kennedy School of Government, Harvard University, 2001.

Andersson, Fredrik; Holmlund, Bertil; and Lindh, Thomas. "Labor Productivity, Age and Education in Swedish Mining and Manufacturing 1985-96." Mimeo. Uppsala: Department of Economics, Uppsala University, 2002.

Antolin, Pablo, and Scarpetta, Stefano. "Microeconometric Analysis of the Retirement Decision: Germany." OECD Economics Department Working Paper no. 204. Paris: Organisation for Economic Co-operation and Development, 1998.

Aubert, Patrick; Caroli, Eve; and Roger, Muriel. "New Technologies, Workplace Organization and the Age Structure of the Workforce: Firm-Level Evidence." Working Paper no. 2005-18. Paris-Jourdan Sciences Economiques, 2005.

Bartel, Ann P., and Sicherman, Nachum. "Technological Change and Retirement Decisions of Older Workers." *Journal of Labor Economics* 11 (1993): 162-183.

Becker, Gary S. "Investment in Human Capital: A Theoretical Analysis." *Journal of Political Economy* 70 (Supplement) (1962): 9-49.

Beckmann, Michael. "Die Auswirkungen des betrieblichen Personalabbaus auf die Altersstruktur der Belegschaften in westdeutschen Unternehmen." In *Entlohnung, Arbeitsorganisation und personalpolitische Regulierung*, edited by Uschi Backes-Gellner, Matthias Kräkel, Dieter Sadowski and Johannes Mure, pp. 217-242. München und Mering: Rainer Hampp Verlag, 2001.

Beckmann, Michael. *Betriebliche Personalpolitik im technologischen und organisatorischen Innovationsprozess*. München und Mering: Rainer Hampp Verlag, 2004.

Beckmann, Michael; Schauenberg, Bernd; and Timmermann, Andrea. "Betriebliche Innovationen und geschlechtsspezifische Arbeitsnachfrage." Mimeo. Department of Economics, University of Freiburg, 2004.

Black, Sandra E., and Lynch, Lisa M. "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity." *Review of Economics and Statistics* 83 (2001): 434-445.

Blechinger, Doris, and Pfeiffer, Friedhelm. "Technological Change and Skill Obsolescence: The Case of German Apprenticeship Training." ZEW Discussion Paper No. 96-15. Mannheim: Zentrum für Europäische Wirtschaftsforschung, 1996.

Boisjoly, Johanne; Duncan, Greg J.; and Smeeding, Timothy. "The Shifting Incidence of Involuntary Job Losses from 1968 to 1992." *Industrial Relations* 37 (1998): 207-231.

Bond, Stephen, and Van Reenen, John. "Microeconometric Models of Investment and Employment". Mimeo. London: Institute for Fiscal Studies, 2003.

Boockmann, Bernhard, and Zwick, Thomas. "Betriebliche Determinanten der Beschäftigung älterer Arbeitnehmer." *Zeitschrift für ArbeitsmarktForschung* (*Journal for Labour Market Research*) 37 (2004): 53-63.

Bresnahan, Timothy F.; Brynjolfsson, Erik; and Hitt, Lorin M. "Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm-Level Evidence". *Quarterly Journal of Economics* 117 (2002): 339-376.

Buck, Hartmut; Kistner, Ernst; and Mendius, Hans Gerhard. "Demographischer Wandel in der Arbeitswelt: Chancen für eine innovative Arbeitsgestaltung". Stuttgart, 2002.

Card, David, and DiNardo, John E. "Skill-Biased Technological Change and Rising Wage Inequality: Some Problems and Puzzles". *Journal of Labor Economics* 20 (2002): 733-783.

Card, David, and Lemieux, Thomas. "Can Falling Supply Explain the Rising Return to College for Younger Men? A Cohort-Based Analysis." *Quarterly Journal of Economics* 116 (2001): 705-746.

Caroli, Eve, and Van Reenen, John. "Skill Biased Organizational Change? Evidence from a Panel of British and French Establishments." *Quarterly Journal of Economics* 116 (2001): 1449-1492.

Chan, Sevin, and Stevens, Ann Huff. "Job Loss and Employment Patterns of Older Workers." *Journal of Labor Economics* 19 (2001): 484-521.

Chennells Lucy, and Van Reenen, John. "Has Technology Hurt Less Skilled Workers? An Econometric Survey of the Effects of Technical Change on the Structure of Pay and Jobs." IFS Working Paper no. W99/27. London: Institute for Fiscal Studies, 1999.

Christensen, Laurits R.; Jorgenson, Dale W.; and Lau, Lawrence J. "Transcendental Logarithmic Production Frontiers" *Review of Economics and Statistics* 55 (1973): 28-45.

Crepon, Bruno; Deniau, Nicolas; and Perez-Duarte, Sebastien. "Wages, Productivity, and Worker Characteristics: A French Perspective". Mimeo. Paris: INSEE, 2002.

Falk, Martin, and Seim, Katja. "Workers' Skill Level and Information Technology: E-vidence from German Service Firms". In *Panelanalysen zu Lohnstruktur, Qualifikation und Beschäftigungsdynamik*. Beiträge zur Arbeitsmarkt- und Berufsforschung, BeitrAB 229, edited by Lutz Bellmann and Viktor Steiner, pp. 79-116. Nuremberg, 1999.

Friedberg, Leora "The Impact of Technological Change on Older Workers: Evidence from Data on Computer Use". *Industrial and Labor Relations Review* 56 (2003): 511-529.

Haltiwanger, John C.; Lane, Julia I.; and Spletzer, James R. "Productivity Differences Across Employers: The Role of Employer Size, Age and Human Capital." *American Economic Review*, Papers and Proceedings 89 (1999): 94-98.

Holmstrom, Bengt, and Milgrom, Paul R. “The Firm as an Incentive System”. *American Economic Review* 84 (1994): 972-991.

Hujer, Reinhard; Caliendo, Marco; and Radic, Dubravko. “Skill Biased Technological and Organizational Change: Estimating a Mixed Simultaneous Equation Model Using the IAB Establishment Panel.” IZA Discussion Paper no. 566. Bonn: Institut Zukunft der Arbeit, 2002.

Institute for Employment Research. “Zahlen-Fibel, Übersicht 3.1.2: Arbeitslosenquoten nach Altersgruppen: Bundesgebiet West.” http://doku.iab.de/zfibel/03_01_02.pdf (Status: August 24th 2004), 2002.

Institute for Employment Research. “Zahlen-Fibel, Übersicht 3.6.2: Arbeitslosigkeit im Bundesgebiet (West) 1961-2002.” http://doku.iab.de/zfibel/03_06_02.pdf (Status: August 24th 2004), 2003.

Klös, Hans-Peter. “Ältere Arbeitnehmer: Entwicklungstrends und beschäftigungspolitischer Reformbedarf.” *iw-trends* 27 (2000): 71-88.

Köchling, Annegret. “Leitfaden zur Früherkennung altersstruktureller Probleme im Betrieb.” http://www.demotrans.de/documents/PR508.pdf (Status: August 5th 2005), 2000.

Kotlikoff, Lawrence, and Gokhale, Jagadeesh. “Estimating a Firm’s Age-Productivity Profile Using the Present Value of a Worker’s Earnings.” *Quarterly Journal of Economics* 107 (1992): 1215-1242.

Lazear, Edward P. “Why is there Mandatory Retirement?.” *Journal of Political Economy* 87 (1979): 1761-1784.

Lazear, Edward P. “Agency, Earnings Profiles, Productivity, and Hours Restrictions.” *American Economic Review* 71 (1981): 606-620.

Lazear, Edward P. “Adjusting to an Aging Labor Force.” NBER Working Paper no. 2802. Cambridge, MA: National Bureau of Economic Research, 1988.

Lindbeck, Assar, and Snower, Dennis J. “Reorganization of Firms and Labor-Market Inequality.” *American Economic Review*, Papers and Proceedings 86 (1996): 315-321.

Lindbeck, Assar, and Snower, Dennis J. “Multitask Learning and the Reorganization of Work: From Tayloristic to Holistic Organization.” *Journal of Labor Economics* 18 (2000): 353-376.

Mendes de Oliviera, M.; Cohn, Elchanan; and Kiker B.F. “Tenure, Earnings and Productivity.” *Oxford Bulletin of Economics and Statistics* 51 (1989): 1-14.

Milgrom, Paul R., and Roberts, John. “The Economics of Modern Manufacturing: Technology, Strategy, and Organization”. *American Economic Review* 80 (1990): 511-528.

Milgrom, Paul R., and Roberts, John. “Continuous Adjustment and Fundamental Change in Business Strategy and Organization.” In: *Trends in Business Organization: Do Participation and Cooperation Increase Competitiveness?*, edited by Horst Siebert, pp. 231-258. Tübingen: Mohr-Siebeck, 1995.

Mincer, Jacob. *Schooling, Experience, and Earnings*. New York: University Press for NBER, 1974.

Peracchi, Franco, and Welch, Finis. “Trends in Labor Force Transitions of Older Men and Women.” *Journal of Labor Economics* 12 (1994): 210-242.

Rodriguez, Daniel, and Zavodny, Madeline. “Changes in the Age and Education Profile of Displaced Workers.” *Industrial and Labor Relations Review* 56 (2003): 498- 510.

Rosen, Sherwin. “Measuring the Obsolescence of Knowledge.” In: *Education, Income and Human Behavior,* edited by F. Thomas Juster, pp. 199-232. New York: Carnegie Foundation and Columbia University Press, 1975.

Skirbekk, Vegard. “Age and Individual Productivity: A Literature Survey.” MPIDR Working Paper WP 2003-028. Rostock: Max Planck Institute for Demographic Research, 2003.

Snower, Dennis J. “Causes of Changing Earnings Inequality.” IZA Discussion Paper no. 29. Bonn: Institut Zukunft der Arbeit,1999.

Strotmann, Harald, and Hess, Wolfgang. “Eigenschaften und Beschäftigungschancen älterer Arbeitnehmer sowie betriebliche Maßnahmen für ältere Arbeitnehmer in Baden-Württemberg.” IAW-Kurzbericht 7/2003. Institut für Angewandte Wirtschaftsforschung. Tübingen, 2003.

Weinberg, Bruce A. “Computer Use and the Demand for Female Workers.” *Industrial and Labor Relations Review* 53 (2000): 290-308.

White, Halbert. “A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity.” *Econometrica* 48 (1980): 817-838.

Wooldridge, Jeffrey M. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA and London: MIT Press, 2002.