Cliometrica
DOI 10.1007/s11698-009-0048-x

ORIGINAL PAPER

Wily welfare capitalist: Werner von Siemens and the pension plan

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Received: 27 January 2009 / Accepted: 30 October 2009

Abstract The German firm of Siemens and Halske introduced many enterprising features of what later came to be known as welfare capitalism in the mid-nineteenth century. Profit sharing, annual bonuses, a pension fund, a reduction in work hours, and an annual party were all means to ensure a productive, trouble-free workforce. We investigate the reasons why Siemens and Halske introduced this internal welfare system. We focus on the by-far most expensive part of the welfare system: the pension fund introduced in 1872, more than a decade before the nationwide social security system was implemented in Germany. We find that the adoption of the internal welfare system increased labor productivity, and in addition discouraged workers from striking. We estimate that the company's gains due to strike prevention and higher productivity were at least as high as the cost of the pension fund. This suggests that (1) the introduction of a pension fund is not inconsistent with simple profit maximizing behavior on the firm's side and (2) increased labor unionization induced firms to introduce subjective components of workers' remuneration packages.

Keywords Welfare capitalism · Siemens · Productivity

JEL Classification J50 · L21 · N33 · N83

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Published online: 09 December 2009

1 Introduction

Siemens and Halske (known today as Siemens AG) was founded in Berlin in 1847 by scientist Werner von Siemens and engineer Johann Georg Halske. The firm soon after its founding introduced profit sharing, annual bonuses, an annual party, and from 1872 onwards a pension plan (combined with a fund for widows and orphans) for its workers. The company pension plan pre-dated the nationwide pension plan introduced in Germany by the chancellor, Bismarck, by more than a decade. We evaluate the impact of the introduction of the internal welfare system and attempt to distinguish among several potential alternative explanations. We examine the benefits associated with increased loyalty among workers, which reduced the probability of strikes, and we find sizable economic benefits. Although Siemens may have been concerned with the welfare of its workers for humanitarian reasons, there was also a direct economic benefit to the firm. We show that the adoption of the internal welfare system was accompanied by a significant increase in the labor productivity at Siemens toward the end of the nineteenth century. Moreover, focusing at the most expensive part of the welfare system, the pension fund, we argue that if the fund led to avoiding a labor strike of an average duration in a given year, the annual cost of the fund would have been more than recouped. Taken together, these two findings suggest that the adoption of the welfare paternalism by Siemens in the second half of nineteenth century could have been motivated by simple profit maximization.

Welfare capitalism, also known as welfare paternalism, began in Germany in the early-nineteenth century from roots in the miners' insurance funds of the eighteenth century. It has been defined by Moriguchi (2003, pp. 625) as: "employers' voluntary provision of non-wage benefits, greater employment security, and employee representation to their blue-collar workers." Welfare capitalism began in the large coal, steel, and machine-making firms of western Germany, particularly in the Ruhr valley (see McCreary 1968; Spencer 1984). The welfare plan of the Krupp Steelworks, which began in the 1830s, was only institutionalized in the 1850s and "served frequently as the model for similar company plans in Essen" (McCreary 1968, pp. 29). The Krupp plan began with health insurance, later extended to employees' dependents, the creation of a convalescent home, a disability and retirement program, a pension fund, and company housing. By the turn of the twentieth century, most of the large employers in the Ruhr, such as Krupp, Gutehoffnungshuette, and Bochumer Verein, practiced welfare capitalism by offering company housing, sickness and disability insurance, and pension funds. Schulz (2000, pp. 19–20) describes the improvements of workers' relationships with their employers in the second half of the nineteenth century and, in addition to the benefits described above, he also mentions a company grocery store, a company savings union, organization of sport tournaments, and company dining halls. He adds that the goal of these improvements was to provide employees with greater job security, but, more importantly, also to tie their rewards to the company's overall performance.[1]

[1] For example, when assigning company housing, employees with longer tenure were favored.

The origins of welfare capitalism in Germany, France, and Britain, and its spread in the early twentieth century to the US and later to Japan has been documented by Berkowitz and McQuaid (1978), Hannah (1986), and Moriguchi (2003). There are several reasons postulated for the spread of welfare paternalism from company to company. Berkowitz and McQuaid (1978, pp. 121) suggest that a successful program could: "lower the rising temperature of industrial debate." Jacoby (1993, pp. 532) suggests that, in the case of Eastman Kodak, "the company felt vulnerable to sabotage by disgruntled employees… Kodak managers repeatedly stressed the importance of securing the employees' "cooperation" by… receiving fair treatment, high wages, and good benefits." Spencer (1984, pp. 71–72) claims that Ruhr employers offered welfare programs "to attract workers to isolated areas and to hold them there… (and) as a means of blocking expanded government social legislation." McCreary (1968, pp. 39) argues that Krupp's motives for developing the plan were "a mixture of humanitarianism and self-interest."

It is difficult to discriminate between the many reasons given for the spread of welfare paternalism. Indeed, different businesses may have adopted paternalistic practices for different reasons. In the case of Siemens, the internal welfare system may have been introduced to reduce shirking and elicit extra effort from employees, by effectively raising wages. Alternatively, the pension fund itself may have acted as an implicit contract between the firm and employees. The firm would look after employees in their old age, as long as employees worked faithfully for the company. Third, the rise of socialism, and a greater leverage by employees over the firm, may have meant that employees were able to extract higher wages. What unites the current literature is the unquantifiable motivations given for the adoption of welfare paternalism by a workplace. We focus on a single, but fast-growing and innovative, company—Siemens and Halske. We use annual data on Siemens' labor force, capital stock, profits, and sales between 1861 and 1891 to estimate the firm's production function. We use these estimates to quantify the effect of the introduction of the old-age pension plan for employees and their dependants. We show that the introduction of the internal welfare system including the pension plan boosted Siemens' productivity and, perhaps more importantly, eliminated strike activity for the remainder of the nineteenth century. We estimate that the cost to run the pension fund for 1 year was approximately equal to the profits that would be lost if Siemen's workforce were to go on strike for 2 weeks—a strike of average duration in that time period in Germany. This suggests that the company owners may have believed that there was a serious threat of labor unrest in the company, and by creating the pension fund Siemens was willing to compensate workers to maintain a strike-free workplace. The economic benefits of welfare capitalism can help to explain the spread of this phenomenon throughout Germany and then to other developed countries.

We structure the article as follows. In Sect. 2, we describe the historical background and operations of Siemens. In Sect. 3, we review the literature on welfare paternalism and discuss possible explanations for the adoption of new institutional arrangements between owners and workers, in particular the pension fund. We discuss our econometric model and methods in Sect. 4. Section 5 describes the data and presents the results. We summarize and conclude in Sect. 6 and provide suggestions for future research. The appendix contains details of the estimation method.

2 Historical background

In 1837, Samuel Morse and Carl von Steinheil independently constructed an electromagnetic telegraph. Prussian army officer and amateur scientist Werner von Siemens, after success in developing a gold electroplating process, worked on technological improvements to telegraphy after 1846. In 1847, he developed improvements to the Wheatstone pointer telegraph. To market this invention Werner, together with Johann Georg Halske and Werner's cousin Johann Georg, founded Siemens and Halske Telegraph Construction Enterprise (hereafter known as Siemens) in Berlin in the same year. Werner designed a press to cover copper wire with gutta-percha, which was essential to insulate underground and undersea cables. In 1848, Siemens began the construction of the first electrical long-distance telegraph line in Europe, from Berlin to Frankfurt.[2]

Despite successful development and the promising growth of the domestic market, Werner decided in 1850 that his company needed to expand into foreign markets. In 1850, an agency was started in England under the control of Werner's younger brother, Wilhelm, who had earlier helped to sell Werner's electroplating process in England.[3] The arrangement was that the German firm would get 2/3 of the profits and Wilhelm would keep 1/3. In 1851, Siemens built the first electric fire alarm system for Berlin. In 1853, another of Werner's brothers, Carl, moved to St. Petersburg as Siemens' representative, and in the same year the company started construction of the Russian state telegraph network. A Russian branch of the firm was subsequently founded in 1855. The Russian branch expanded very quickly during the Crimean War (1853–1856) when they won a contract to install a telegraph line between Moscow and Sevastopol. Siemens also unsuccessfully ventured into the markets of Paris and Vienna in the 1840 and 1850s. Siemens' profits were shared among the Siemens brothers with a 40% share to Werner who resided in Berlin, 35% to Wilhelm in England, and 25% to Carl in Russia (see Feldenkirchen 1994, pp. 81).

Siemens continued to expand into building, installing, and maintaining telegraph cables during the 1860s and completed the first line from London to India in 1870. Several sub-Atlantic cables were laid in the 1870s in conjunction with the London firm and Siemens diversified its production into water meters, dynamos, and incandescent lamps. Werner continued to direct Siemens until 1890 when he handed over operational control to his sons, Arnold and Wilhelm, and his brother Carl. After Werner died in 1892, his sons and brother ran the company as a private concern until 1897 when Siemens was converted into a public company, Siemens and Halske Aktiengesellschaft.

Siemens, under the direction of Werner, was an early adopter of progressive policies toward staff that later came to be known as private welfare capitalism. Examining the personnel policies of Siemens, one of the early adopters of welfare

[2] Samuel Morse set up the first long-distance electric telegraph line in 1844, from Washington, D.C. to Baltimore.

[3] The formal subsidiary was set up in 1858 as Siemens, Halske and Co. The English company was reorganized as Siemens Brothers in 1865, with Wilhelm gaining more operational control. See Feldenkirchen (1994, pp. 72–76).

capitalism in Prussia, will illustrate the benefits to a firm that welfare capitalism could potentially provide, which suggests that the spread of welfare capitalism to other companies and countries was driven by considerations of profit maximization and reduction in worker turnover, as well as possible altruistic considerations.

In 1849, Siemens helped to start a health and death benefit fund for machine construction workers in Berlin. In 1855, the firm introduced a profit-sharing scheme in order to provide better incentives for the workers. Key officials, and some minor ones, received a share of the profits (*Tantiemisten*), and master craftsmen and officials were invited to Werner's house on Ascension Day every year for a garden party. In addition, individual workers received a reward at Christmas based on firm profits and individual performance (Feldenkirchen 1994, pp. 140–141). The intention of Werner was to achieve increased loyalty and productivity among his employees: "the money I made would burn my hands, if I did not give a share to my loyal and reliable helpers. Moreover, it would be very unwise to leave them empty-handed while having great expectations about the future of the business" (Kocka 1969, pp. 84). The annual bonuses were not part of the workers' contracts and depended on a subjective evaluation of the worker by his superiors. In 1855, this bonus was on average almost 15% of the annual wage. The bonus was given to the worker together with a personal letter every year shortly before Christmas. Werner's intention was to create the impression among the workers that this bonus was a gift from the company, rather than something they had a right to receive. Theory suggests that when effort is non-contractible (when it is observable to the employer, but not verifiable to a third party) a firm has an incentive to implement an implicit contract (see Shapiro and Sitglitz 1984; Baker et al. 1994). An employee is compensated via a bonus that depends on the subjective evaluation of the worker by the firm. The extra effort that the employee expends is compensated for by the bonus, and the extra output allows the firm to both pay the bonus and add to profits. Werner himself thought of this rewarding scheme very highly—as he wrote in a letter to his brother Carl on July 18, 1868:

> (since we pay the bonuses) quite a new spirit has entered our enterprise; we produce more, at lower cost and of better quality, and cannot cope with the amount of work…the benefits for the enterprise may far exceed the amount paid out as a bonus! (Feldenkirchen 1994, pp. 141)

Workers were paid a weekly wage, dependent on age and skill, with more productive workers compensated with the large annual bonus. The bonus was necessary since although worker productivity was observable by management, it was unverifiable to a third party (for example to a court of law). The importance of bonuses for workers declined after a transition to piece-rate compensation that began in 1858. Mass production techniques, developed in the US, were introduced by Siemens in the late 1860s that culminated in the opening of an "American shop". As productivity became more easily verifiable, with the introduction of mass production, the optimal contract focused more on a direct reward for extra output and reduced the importance of annual bonuses. The introduction of piecework was thought to place more strain on workers, therefore, to compensate, the working week was reduced to 54 h per week. The average firm had work hours of 6 a.m.–6 p.m.

six days per week, with a one to one and a half hour lunch break. The majority of German industrialists only matched Siemens' cut in hours in the 1890s. The final pre-WW1 paternalistic practice of Siemens was granting paid vacations in 1909 to long-serving and faithful workers (see Spencer 1984).

As the company grew, Werner realized that he and his brothers could not possibly oversee the whole business, and therefore he delegated control to other subordinates, a necessary step as the workforce increased rapidly. A senior official, William Meyer, received 5% of the overall profit and the main accountant, Haase, received 2.5% of the profits of the Berlin branch. The profit share of the two leading white-collar workers in the St. Petersburg and London branches was 2.5% of the profit of their respective branches. Kocka (1981, pp. 460) states that "financial, success-related incentives determined the income of the highest ranking officials." Contracts for managers were not standardized and usually consisted of a percentage of the local profits. For example, the Italian representative of Siemens, Carlo Moleschott, asked for financial assistance from head office, or instead a monthly salary, when in difficulty in 1890. In return, "Werner von Siemens plainly stated that Moleschott could get better results only with higher sales" (Feldenkirchen 1994, pp. 121).

The labor force of Siemens grew steadily and by 1872 reached almost 600 employees. The Franco-Prussian war of 1870–1871 caused many German companies, including Siemens, to lose a large share of their employees. Kocka (1969) states that Siemens lost approximately 20% of its employees due to the war. The company reacted by increasing wages, and some employees received salaries four times higher in 1871 than they had 5 years previously.

Another problem that Siemens had to face was an increasing tension between workers and employers. Trade unions and strikes had been legalized by the North German Federation in 1868, although an unsympathetic police force or judiciary could curtail trade union activity (see Moses 1982, pp. 44–45). Strikes increased from an annual rate of around 10 per year in the 1850s to: "23 in 1864; another 30 in 1865; and crescendoing to 152 in 1869 and 362 in 1872" (Brose 1997, pp. 357). In 1872, the class struggle in Berlin was intensified by several clashes between unionized working-class members and the police. On the international scene, the International Workingmen's Association had been founded in London in 1864, which was followed up with congresses in Geneva (1866), Lausanne (1867), Brussels (1868), and The Hague (1872).

In the early 1870s, Siemens faced a problem of readjusting to labor disruptions during the war and higher wages, amidst a backdrop of increased industrial activity in Germany and worker solidarity. To avert potential labor problems, Siemens created a pension fund in 1872 on the 25th anniversary of the firm's founding.[4] The starting capital was 180,000 Marks. An additional 15 Marks was contributed per year per worker, and 30 Marks per year per official, conditional on the employee serving uninterruptedly for the year. The worker did not have to contribute personally. A worker's entitlement to a pension existed, however, only after

[4] The English firm, Siemens Brothers, run by Wilhelm (William) Siemens, also introduced a pension plan in 1872 (see Scott 1958, pp. 248).

Table 1 Participation, income and payout of Siemens' pension fund

Year	Employment (both in and out of fund)	White-collar workers (in fund)	Blue-collar workers (in fund)	Inflows (annual)	Outflows (annual)	Assets
1872/1873	581	49	329	13,545	787	155,257
1879/1880	754	87	584	23,371	5,156	256,855
1884/1885	1,437	146	1,053	33,212	23,644	328,557
1889/1890	3,084	290	1,897	58,730	38,276	367,207
1894/1895	5,389	622	3,850	109,992	84,852	496,711

Employment: Feldenkirchen (1994, pp. 162, Table 2)

Other data: Conrad (1986, pp. 157, Table 45)

Conrad (1986) reports that the inflow figures include accrued interest and Siemens' contributions

working ten full years with the company. The amount of the pension depended on the tenure of the worker, their position in the company and their gender. After 30 years of continuous service with the firm, a worker was eligible for the maximum pension of 2/3 of their wage. A worker could continue to work, in which case he would receive the pension in addition to his regular wage.[5]

The expected benefits for an eligible worker who did not strike were substantial. Consider a German man aged 15 in the 1870s who began to work at Siemens. Although mortality rates were substantially higher than they are today, this worker could expect to live for a further 42.4 years (see Berghahn 2005, Table 58, pp. 328). If he were to serve uninterruptedly at Siemens for 30 years (and did not strike), then he would begin to receive his pension at age 45, regardless of whether or not he continued to work after age 45.

The pension fund was also used for the support of widows and orphans of the firm's employees. The rules of the pension fund meant than an employee who went on strike lost his entire pension entitlement. In case an employee was fired, due to a lack of work, he received a paper, which gave him preferential treatment to be rehired when business conditions improved. The pension fund participation rate of Siemens' employees was always high. The participation rate started at 65% at the inception of the fund in 1872 and thereafter fluctuated between 70 and 90%. Around 85% of employees in the fund were blue-collar workers (Arbeiter), presumably the group most at risk of going on strike (see Table 1).

The pension fund was created with the view to, at least in part, avert industrial unrest. Werner believed that "the strike mania, which seriously injures industry and especially the workmen themselves, is best coped with in this manner" (von Siemens 1966, pp. 248–257). He claimed that the pension fund was a great success in binding employers and employees to create a "company spirit". Although the Anti-Socialist Law of 1878 effectively eliminated trade unions from within the Reich, it could not stop workers from reorganizing as craft unions (Fachverein). Moses (1982, pp. 69) states that, by 1881, 15 craft unions had been formed in

[5] Conrad (1986, pp. 49) calculates the pre-1870 annual wage for a Siemens' employee as 450–900 Marks.

Berlin, and (pp. 72) "in the years 1883 and 1884 not only the number of strikes rose but so did also the number of different trades involved, encompassing wider areas."

Pension schemes had been introduced earlier in Britain (see Hannah 1986). A plan for merchant seamen began in 1749, and the London and North West Railway began a pension plan in the 1840s for clerical workers, with other railways following. The Gas Light and Coke Company began a plan for clerical staff in 1842 and extended it to manual workers by 1870. These plans seem to have been similar to mandatory life insurance; payments were made to workers even if they had participated in industrial unrest. Hannah argues that a factor in the railways' decisions was a "desire to counteract the growing influence of trade unionism" (Hannah 1986, pp. 11).

The start of government-mandated social welfare programs in Germany began with limited coverage of the workforce for sickness insurance in 1883. In 1884, accident insurance was mandated, and in 1889 Bismarck introduced the Workmen's Old Age Insurance Law. The old-age law required firms to contribute (in addition to their own pension fund, if applicable) to a state-mandated pension fund (see Bjork 1966). The costs of the old-age pension did not primarily fall on the government but "were borne by the workers themselves and by their employers" (Lindert 2004, pp. 174). By 1891, the German government contributed only around 6% of the insurance funds (see Lindert 2004). Indeed, Lindert argues that the potentially redistributive effects of the Old Age Insurance Law were dampened due to employers' abilities to reduce future wage rises. The national Old Age Insurance Law was perhaps even more restrictive than Siemens' pension plan, in that only ex-workers over the age of 70, later reduced to 65, were eligible (see Khoudour-Castéras 2008).

Kocka (1971, pp. 140) attributes the welfare paternalism system of Siemens to "traditional and humanistic beliefs, concern about a loyal and permanent core of skilled employees, and the attempt to pacify the challenges of organized labor." We broadly agree with Kocka, but find that the benefits of pacifying labor are nearly enough to justify the introduction of the pension plan to Siemens, without needing to rely on managerial humanism.

Spencer (1984) examines the paternalistic practices of the Ruhr coalmines and steel mills in the late-nineteenth and early-twentieth century. Similarly to Siemens, the Ruhr industrialists emphasized that benefits were provided at the discretion of the company. The benefits were rewards for loyal service, not a supplement to regular wages. For example in 1898, the Kölner Bergwerksverein gave a gift to employees who had served with the company for 25 years. Any worker who had participated in a strike during the 25 years was excluded from receiving the gift. She finds that health insurance and old-age pensions were the most widespread and important part of the firms' welfare practices. Spencer (1984, pp. 75) claims that although government-mandated sickness and old-age pension schemes were introduced in the 1880s, "private employer-sponsored insurance plans continued to thrive and even expand… insurance could be used to reward or punish workers and to bind them to their jobs." Many firms, including Siemens, provided workers with benefits over and above the legal minimums. A worker who resigned or was dismissed almost always lost all entitlements to the old-age pension contributions of

the firm that were above the legal minimums. The widespread (ab)use of this by firms, in particular Krupp which was estimated to have deprived 60,000 workers of pensions between 1894 and 1907, led to a court challenge by unions in 1911. After 1911, firms could no longer decline to provide accumulated pension benefits to workers who left a firm. The welfare paternalism practices of the Ruhr industrialists did not develop in a vacuum, rather they followed developments in other industries, notably the electro-technical industry: "Otto Heinemann, head of the Krupp Bureau of Worker Affairs, reported that he and a colleague were sent to study prevailing methods at other large German firms, including Siemens and Allgemeine Elektrizitäts Gesellschaft (AEG) in Berlin" (Spencer 1984, pp. 85).

The Krupp welfare plan began with a voluntary health insurance plan in 1836, institutionalized in 1853. In the early 1860s, a health fund for dependants was established and later extended, with a company hospital used after 1872. The beginnings of the pension fund were in 1858, although the pension fund was only separated from the health insurance fund in 1885. The fund paid between half and a full wage to incapacitated employees (not retired employees as in Siemens' plan) depending on length of service with Krupp, the minimum period of service for eligibility was 15 years for employees engaged in heavy work. Workers contributed 1% of their wages, with the firm adding 0.5%, later raised to 1%. It was only by 1895 that able-bodied workers of 65 and older (or who had served at least 40 years with Krupp) were entitled to the company pension. Additional funds were made available to deserving workers in need who were not covered by other company assistance. The advantage of these additional funds was that they: "could be dispensed at the discretion of the firm's management—thereby maintaining in existence a prized arbitrary factor" (McCreary 1968, pp. 35). Alfred Krupp was quite explicit in stating in 1871 that the company's plans were to reward faithful service, bind the employee to the firm, and to deter workers with industrial secrets from departing (see McCreary 1968). After the national welfare programs had been introduced in the 1880s, the firm expanded its voluntary programs (that is, those exceeding the national legal requirements) undoubtedly in large part to maintain an arbitrary and compelling influence over a worker's welfare (McCreary 1968, pp. 47). Although not explicitly stressed by McCreary, the avoidance of industrial unrest was also a factor in Krupp's plans: "In 1871 another element—that of possible revolt—entered Krupp's Consideration" (McCreary 1968, pp. 45). At the same time as Werner von Siemens was considering starting a pension plan, Alfred Krupp was worried about industrial unrest. We do not believe it is a coincidence that Siemens began their pension plan during a time of unrest in Germany. Although both Siemens and Krupp had fairly extensive welfare plans, they were not major drains on company resources. McCreary (1968, pp. 24) states that "the extensive financial contributions of the firm never represented but a fraction of the firm's income." The same is true of Siemens. The cost of the pension fund in the 1870s was around 0.5% of sales and 2% of profits. Not a large cost certainly, but not insignificant either.

For the first decades of Siemens' life, there were no serious domestic competitors in the electro-technical market. The firm of Emil Rathenau, Allgemeine Elektrizitäts Gesellschaft (AEG), founded in 1883 under the name of Deutsche

Edison-Gesellschaft soon became a serious competitor in the field of power and lighting systems. Siemens and AEG along with General Electric and Westinghouse in the US "continued to dominate one of the world's most significant industries during the whole period from the 1880s to the 1940s" (Chandler 1990, pp. 464). Although it would be interesting to examine the welfare paternalism policies of AEG in conjunction with those of Siemens, we are hampered by the fact that "much less has been published about AEG than about Siemens" (Chandler 1990, pp. 471).

3 Why was the pension fund adopted?

We discuss three potential explanations for the introduction of the pension fund as part of the internal welfare system by Siemens. First, the fund may have been introduced to reduce shirking and elicit extra effort by employees by effectively raising wages through the provision of the pension fund. The increased benefits to employees may have acted as an efficiency wage. Second, the pension fund may have acted as an implicit contract between the firm and employees. The firm would look after employees in their old age, as long as employees worked faithfully for the company for many years. Third, the rise of socialism and a greater leverage by employees over the firm may have meant that employees were able to extract more of the productive surplus as wages rather than it going to the firm as profits.

3.1 Efficiency wage theory

The theory of efficiency wages states that a firm will pay a wage above the market clearing level in order to limit shirking and engender extra effort by employees (see Stiglitz 1976; Lucas 1979). Creating a pension fund is similar to raising the wage rate, because if workers care about their future, they will take into account the benefits of being taken care of during their retirement. Raff and Summers (1987) argue that the "five dollar day" policy (the daily wage for workers), instituted by Henry Ford in 1914, acted as an efficiency wage by increasing productivity, profits, and queues for jobs at the Ford factory. Khoudour-Castéras (2008) find that, at the macro level, Bismarck's introduction of non-wage benefits in the late-nineteenth century were very important in retaining German workers within the country, by reducing the emigration rate.

The mid-1870s were marked by an economic downturn in Europe, which followed the failure of many banks in Vienna and the Franco-Prussian War. The war caused the loss of many skilled workers for Siemens due to enlistment: "the workshop was depleted by the calling-up of numbers of men" (von Siemens 1966, pp. 62). Many firms experienced an abrupt productivity decline; therefore, a possible explanation for the adoption of the pension fund was that it would provide a wage premium over the prevailing market wage. According to efficiency wage theory, providing a sufficiently high-wage premium prevents people from shirking, because it increases the opportunity cost of getting caught. By paying an efficiency wage, overall productivity is raised because fewer people shirk. However, overall

profits increase only if the monetary gains from increased productivity outweigh the costs of paying higher wages.

Why would Siemens pay a wage premium through such a complicated institution as a pension fund? The choice of an indirect method of raising wages may have been because Siemens had a higher discount rate than workers during difficult times. By postponing the payments associated with the wage increase into the future, there was the possibility that both firm and worker could have gained by the creation of the pension fund. An alternative is that the cost of such a wage premium, via the pension fund, may have been lower relative to a direct wage increase. This may have been due to the rules governing the pension fund, which could have been set in a way that minimized the expected payments. Both of these explanations are plausible. The pension fund rule was that the employee was eligible for a pension only after spending 10 years with the company, thus the firm's expected payments might have been much lower than if a wage premium were paid directly.[6] The second explanation is possible since, in a recession, credit-constrained companies are likely to be more sensitive to an immediate cost increase than in a boom. Thus, during the recession of the mid-1870s, Siemens would have preferred to defer increased wage payments to the future, when business conditions were expected to improve.

3.2 Human capital theory

Human capital theory suggests that when employers and employees repeatedly interact over a long time, it may be optimal to design long-term implicit contracts to encourage human capital acquisition and reduce employee turnover and strikes (see Lazear 1979; Prendergast 1993). The rules of Siemens' fund were that an employee was eligible for a pension only if he or she did not strike during his or her employment with the firm. The longer an employee remained with the firm, the higher the pension fund payments he or she was entitled to. Thus, the combination of piece rates and subjectively determined bonuses, as used by Siemens, may have been tried jointly due to efficiency complementarities (see Baker et al. 1994; Ichniowski et al. 1997). The optimality of structuring remuneration solely by piece rates is critiqued by Gibbons (1987) who finds that in the presence of hidden action and hidden information, if neither the firm nor the worker can commit to future behavior, then piece rates (and in fact any compensation scheme) cannot remove the incentive for workers to shirk. These results suggest that a firm which hires workers for long periods of time, as Siemens certainly did, may find it optimal to design contracts where the reward to employees depends on the employees' behavior over time. The simplest interpretation of the action of Siemens is that the company provided a reward, the pension, based upon years of uninterrupted service in return for a content workforce that was unwilling to strike. This is the finding of Raff (1988) who looks at the "five dollar day" at the Ford Company. He argues the hypothesis that Henry Ford tried to "buy the peace" is most consistent with the data.

[6] Of course, if workers shared the same "low" beliefs about the expected payment, then the wage increase would not play any role in workers' decisions of how much effort to supply.

Hannah suggests the human capital theory was a main element in British employers' decisions to reward long-serving employees with *ex gratia* payments. Hannah (1986, pp. 8) argues that "pensions were part of a system of reciprocal obligations well understood by the members of the communities where the institution flourished."

Siemens' pension fund may have been adopted to act as a control mechanism, which was used to enforce "good behavior" among workers. Good behavior meant reliable service to the company, not striking for higher wages or better conditions, and a positive attitude in the workplace: "the continually growing firm must depend on securing the hearty, spontaneous cooperation of all the workers for the furtherance of its interests" (von Siemens 1966, pp. 247). The 1870s were an era of increased workers' unionization when many labor unions were begun in leading companies throughout Germany. Hohorst et al. (1975) state that although in 1869 there were approximately 77,000 organized workers in Germany by 1903 there were approximately 1,100,000 organized workers. Kocka (1969) mentions a strike of August 1871 in Norddeutschen Wagenbau Fabrik, which was unsuccessful, but provided grounds for creation of the Berliner Arbeiterbund (Association of Berlin Workers).

Strikes can cause huge damages to companies—especially those for which labor is the major input and that rely on producing a high-quality product. Freeman and Medoff (1984) and Kleiner et al. (2002) document a correlation between poor industrial relations in a firm and the firm's labor productivity. Krueger and Mas (2004) link the industrial dispute at a Bridgestone/Firestone plant with the production of defective tires. They find that the production of defective tires peaked around the period of the industrial dispute when replacement workers and returning strikers worked side by side. Although the percentage of defective tires was small, peaking at 0.25% in 1995, it led to a major product recall and cut the market value of the company in half. Siemens would have faced a similar risk as Bridgestone/Firestone; hence, industrial unrest could be very costly. Timely production and installation of telegraph lines was required to generate business from new and repeat clients. The breakage of an undersea telegraph cable (due to poor quality) was extremely expensive and required complete replacement.

The establishment of the pension fund and the associated rules were equivalent to workers placing a security deposit with the company. Since the pension was not to be paid out unless the worker remained with the company for at least 10 years, the employees' accumulated pension funds played the role of a bond. This bond would be forfeited if a worker's behavior were considered damaging to Siemens. Thus, through the pension scheme, the company would have increased the workers' opportunity costs of striking and hence, ceteris paribus, decreased the overall probability of a strike.

Evidence of decreased worker turnover, after the introduction of the pension, would support the human capital/long-term implicit contracts theory. Siemens did collect some data on individual workers in the nineteenth century, such as their name, place of birth, and entry and exit dates at the firm.[7] Unfortunately,

[7] The books with these data are called "Arbeiterstammrollen".

correspondence with the Siemens Archives indicates that most of these data are unusable. The format of the collected data changed markedly between the 1860s and 1890s, and, in addition, the books in which these data were collected after 1873 are too badly damaged to use. Schmidt (1993) reports the average tenure of workers at Siemens by sex and job type, but she reports tenure figures only in 5 year intervals.[8] Her data seem too noisy, however, to allow us to draw any conclusions with respect to the effect of the pension fund on workers' turnover: workers hired before 1864 stayed at Siemens on average for 19 years, those hired in 1869 stayed for 2.5 years and those hired in 1874 stayed for 14 years. In subsequent years, the average tenure fell again to about 3 years.

3.3 Redistribution of profit

The third possible explanation for the voluntary introduction by Siemens of the pension fund is that an increase in the bargaining strength of workers allowed them to pressure Siemens into a more generous compensation package, part of which was a pension fund. The importance of bargaining strength in the determination of wages and profits is clear. Marshall (1920, pp. 626–627) states that "nearly the whole income of a business may be regarded as a… **composite quasi-rent** divisible among the different persons in the business by bargaining…There is de facto some sort of profit-and-loss sharing between almost every business and its employees." The rise in German labor's bargaining power during the mid-nineteenth century culminated in the 1870s in "the free choice of work and the right of assembly" (Feldenkirchen 1994, pp. 142). Increased unionization triggered a new system of bargaining between the employers and their employees. Through organization in labor unions, workers increased their bargaining power over the company and might thus have been able to obtain a larger share of company's profits. However, if greater employee power did force the creation of the pension fund, it seems inconsistent that the workers would have allowed the pension fund to include a "no strike" condition to access pension benefits.

4 Estimation approach

To analyze why the company introduced the pension plan, we estimate a structural model of Siemens' production function to see in which way, if at all, the introduction of the company pension plan affected output and productivity. We choose to specify an explicit model of production and estimate a production function in order to address the potential endogeneity problem that the pension plan may have been introduced when profits were high, rather than vice versa. Our first goal is to obtain an estimate of labor's contribution to Siemens' output and quantify the direct cost of a strike by the employees. Our second goal is to separately estimate the worker productivity at Siemens and investigate how its evolution over time was affected by the introduction of the pension fund. A standard baseline

[8] Schmidt (1993, Table 15, pp. 353).

model of a Cobb-Douglas production function using ordinary least squares (OLS) is straightforward; however, it introduces an upward bias of around 20% to labor's contribution due to the endogeneity of labor choice. The OLS approach is therefore unsatisfactory since coefficient estimates may be biased if there are factors unobserved by the econometrician, but observed by the firm before deciding on some of its inputs, of which worker productivity might be a leading example. Olley and Pakes (1996) examine the telecommunications industry in the second half of the twentieth century and quantify the bias associated with the endogeneity of firm's inputs by assuming that the variable input (labor) is set after the company observes the realization of labor productivity. They propose a semiparametric approach to correct for the bias, a technique that has been widely used since. We build on their setup to obtain consistent estimates of the production function coefficients and, more importantly, we modify their model to test for the effect of the introduction of the pension fund on labor productivity.

Ideally, we would like to find out the effect of creating the pension fund on Siemens' profits. This is not an easy task, since we have to deal with the counterfactual of what the profits would have been, if the pension fund had not been implemented. Our model of the production function of Siemens allows us to simulate counterfactual output levels, allowing for capital-labor substitution by the firm, but it does not allow us to estimate counterfactual profits directly. We use historical data on profit margins and the cost of establishing the pension fund for Siemens to put a conservative lower bound on the benefits of reducing strike activity with the aid of the estimated production function.

Our results imply that the prevention of a 2-week strike, which is the average time of labor unrest in Germany in that time period, would have covered the annual cost of the pension fund. Moreover, we use our estimation technique to investigate the impact of the pension fund on labor productivity, and thus we are able to directly address the efficiency wage hypothesis.

4.1 Model

A simple OLS model of the evolution of Siemens' profits where the introduction of a pension fund is captured by a dummy variable suffers from a potential endogeneity problem: the decision by Siemens to adopt a pension fund could (and it most likely did) depend on the history of profits. Similarly, how many workers Siemens hires in year t may depend on the previous history of profits and also on Siemens' (inside) knowledge of contemporaneous labor productivity, which an econometrician does not observe. Moreover, as mentioned earlier, our aim is to conduct counterfactual experiments using our estimates of the production function such as: by how much would the profit of Siemens have declined, if the workers had decided to strike for 2 weeks (the average strike length in late-nineteenth century Germany). For these types of counterfactuals, it is very important that we first obtain a consistent estimate of the effect of labor in the production process of Siemens.

We assume that the total output, Q, of Siemens can be written as a Cobb-Douglas production function involving labor, L, and capital, K, i.e. $Q_t = AK_t^{\alpha}L_t^{\beta}$, where A is a technological constant. We choose the Cobb-Douglas specification due to its

flexibility, in that it allows for different returns to scale and marginal products of capital and labor. It is also the most widely used specification in the industrial organization literature on production function and productivity estimation (see for example Olley and Pakes 1996 or Levinsohn and Petrin 2003).[9] Since we believe that the labor choice is correlated with shocks that are observed by the firm, but unobserved by the econometrician, we adopt an approach proposed by Olley and Pakes (1996) to correct for this endogeneity bias. The estimation procedure relies on a control function approach and is detailed in Estimation details in the appendix. The estimation method consists of two stages: the first is a linear regression of output on labor input and a control function controlling for capital input and the unobserved labor productivity using past investment decisions and the second stage is a GMM procedure to recover the coefficient on capital and impact of pension fund on productivity.

Once we obtain an estimate of the production function, we can calculate counterfactual output levels. In particular, we can calculate what the cost to Siemens would have been if Siemens' workers had gone on strike for a certain period of time. This will most likely be a lower bound to the true cost of a strike to the firm, since the loss of reputation, loss of future contracts, and costs of negotiating with striking workers would all add to the firm's expenses.

5 Data and results

We collect data on Siemens and the German economy from various sources. We obtain annual labor force data from Feldenkirchen (1994, Table 2, pp. 162), sales data from Feldenkirchen (1994, Table 3, pp. 163), and owners' profits from Feldenkirchen (1994, Table 11, pp. 170). We obtain data on the capital stock between 1861 and 1880 from Kocka (1981, footnote 34, pp. 124–125). Data on the capital stock between 1881 and 1891 are from Ernst Waller's (1960) book, Studien zur Finanzgeschichte des Hauses Siemens (SAA 20.Ld 366, Volume III in Siemens' Corporate Archives). We collect data on German strikes from Mitchell (1998, Table B3, pp. 173). We also use Mitchell (1998, Table J1, pp. 906), for German constant price GDP. The data for Siemens are summarized in Table 2. The data cover the period 1850–1896 for most of the variables.[10] Time series plots of the labor force, capital, and sales are depicted in Fig. 1. All observed variables exhibit fairly steady growth over time. As a preliminary examination of the data, we report in Table 3 an OLS regression of Siemens' profits on its workforce and whether or not the company and nationwide pension funds had been adopted. This simple regression suggests that profits of Siemens covaried positively with the introduction of the company's pension fund, while we do not observe a significant relationship with the nationwide pension fund introduction. There are several possible explanations for

[9] The Cobb-Douglas production function is very flexible since it is a first-order Taylor-series approximation for all differentiable production functions. One can consider the Cobb-Douglas to be an approximation for the "true" (possibly more complex) production function.

[10] Data on the capital stock for Siemens are available from 1861 to 1891. We infer investment from the data on the capital stock and as assumed depreciation rate of 10%, see appendix (Model).

Table 2 Descriptive statistics

	Mean	SD	Minimum	Maximum
Labor force	1,333	1,858	49	7,697
Sales[a]	6,502	10,182	213	53,498
Capital[a]	168	124	35	385
Profits[a]	721	742	3	2,850

[a] In thousands of marks

this finding (for example, due to omitted variables in that regression model), and this objection, together with our interest in the quantification of counterfactual profit levels in the case of a strike, motivates our estimation of the structural model.

The results of the production function estimation using the control function approach are summarized in Table 4.[11] The results summarize the first stage of our estimation, and they suggest that the endogeneity of labor-hired results in an upward bias to labor's contribution to firm output, which we anticipated in our earlier discussion. The results in specification (1) show that when we fail to account for labor productivity by ignoring $g(\cdot)$ from (Eq. 6), we obtain a higher estimate of β, 0.65, which can be interpreted as labor's share of output. Moreover, the estimated coefficient on the share of capital, α, is just 0.04 which would suggest that capital plays a minimal role in Siemens' production process and might be evidence of bias in estimation—possibly due to endogeneity. However, when we account for the endogeneity of labor hired (in columns (2) through (4)), our estimate of the importance of labor as a factor of production drops, and the importance of capital input increases substantially, as can be seen from our results of the second estimation stage reported in Table 5. The estimated coefficients on capital, α, range from 0.31 to 0.35.

In specification (3) in Table 4, we exclude a time trend from the price of Siemens' output (see Estimation details in the appendix for a detailed discussion of why to include a time trend in other specifications) because GDP grows at an approximately linear rate and thus is highly collinear with the time trend and our main objective is not the separate identification of those two parameters. In specification (4), we test the robustness of the depreciation assumption by specifying the inverse investment function approximating the productivity index as $\phi(K_t, K_{t-1})$, and neither the estimates nor the standard errors differ significantly from those obtained in specification (2). Interestingly, in all specifications, our point estimates suggest that even though our data comes from the nineteenth century, Siemens' production process exhibited similar characteristics to modern firms and industries: in particular, the contribution of labor to production relative to the contribution of capital is approximately two to one. Since our estimates of α and β sum up to slightly less than one, we estimate that Siemens was operating under slightly decreasing returns to scale.[12]

[11] The estimation method is described in detail in appendix (Model).

[12] The sum of α and β is not statistically significantly different from one, however.

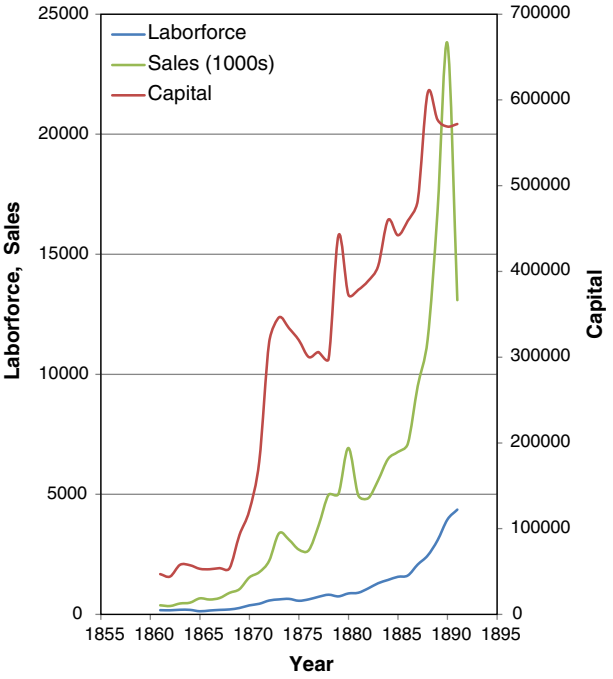

Fig. 1 Laborforce, capital and sales at siemens

Table 3 Preliminary regression analysis

Dependent variable: profits ('000s marks)		
	(1)	(2)
Constant	106.9 (1.45)	112.6 (1.79)
Workforce	0.16 (3.34)	
Sales		0.035 (5.53)
Siemens pension dummy	606.5 (4.47)	575.0 (4.95)
German pension dummy	295.1 (1.47)	282.1 (1.86)
Observations	47	47
Adjusted R^2	0.78	0.84

Most importantly, the effect of the pension introduction on the labor productivity reported in Table 5 is positive and significant in all specifications. This finding is quite striking given that as discussed earlier the first half of the 1870s were marked by an economic downturn and significant drops of labor productivity in German economy.[13] Unfortunately, we cannot estimate the level of labor productivity in

[13] Note that given that the economic environment would point toward the opposite finding, we can conclude that the effect of the internal welfare system on labor productivity was indeed significantly positive.

Table 4 Structural model estimates—1st stage

	(1)	(2)	(3)	(4)
Dependent variable: log sales ('000s marks) 1861–1891 (t-statistics in parentheses)				
Constant	2.10 (1.62)	2.66 (2.23)	0.50 (0.03)	2.66 (2.23)
log labor	0.65 (2.20)	0.61 (2.54)	0.56 (1.34)	0.61 (2.54)
log capital	0.04 (0.21)	NA	NA	NA
Time trend	0.12 (3.86)	0.17 (4.80)	–	0.17 (4.80)
Time^2	−0.002 (2.10)	−0.004 (3.43)	–	−0.004 (3.43)
Variables used in labor productivity index				
Investment	No	Yes	Yes	No
Capital	No	Yes	Yes	Yes
GDP	No	No	Yes	No
Capital, $t-1$	No	No	No	Yes
Observations	31	30	30	30
R^2	0.98	0.98	0.96	0.98

Table 5 Structural model estimates—2nd stage

Control function	$\varphi(I(t),K(t))$	$\varphi(I(t),K(t),\text{GDP}(t))$	$\varphi(K(t),K(t-1))$
log capital, $k(t)$	0.31 (1.36)	0.35 (1.74)	0.32 (1.26)
Pension dummy, $D(t)$	0.19 (6.94)	0.09 (3.62)	0.19 (6.78)
Productivity persistence, $\lambda(1)$	0.82 (6.72)	0.86 (9.99)	0.82 (6.78)

t-Statistics in parentheses

Each column corresponds to a different specification of the control function

every period, because (as explained in the appendix) the constant λ_0 included in the productivity equation cannot be identified separately. Nevertheless, we can quantify the benefit of this productivity increase by holding everything else fixed and obtaining the counterfactual level of sales that would have resulted had productivity not increased, and had Siemens (most likely suboptimally) decided to hire the same number of workers. We calculate that this would have decreased sales by approximately 9–17% in 1872.[14] If sales did drop by 9 (17)%, we calculate that the profit in 1872 would have fallen by around 44,000 (80,000) marks (using the average profit/sales figure of Siemens in the 1870s of 22.9%). These results show that the adoption of the internal welfare system or possibly even just the introduction of the pension fund in 1872 in itself led to an increase in labor productivity and profits, which in turn lends support to the efficiency wage hypothesis. Our finding of a jump in labor productivity holds even if there was a continual rise in productivity in Siemens over the course of the nineteenth century. Only if there were a one-off introduction of new technology by the firm in 1872,

[14] Sales in 1872 are 2,234 thousand marks and hence without a pension plan sales would drop by 387 thousand marks due to a drop in production $\left(\text{as}\left(2234 - e^{(\log 2234 - 0.19)}\right) = 387\right)$. For $D_t = 0.09$ the calculation is analogous.

Table 6 German industrial strikes

Year	Number of strikes	Workers involved ('000s)	Days lost ('000s)
1899	1,311	265	3,381
1900	1,468	321	3,712
1901	1,091	149	2,427
1902	1,106	150	1,951
1903	1,444	251	4,158
Average	1,284	227	3,126

would our result be biased upwards. We found no mention of an abrupt introduction of new technology by Siemens in 1872, thus we believe this alternative explanation is rather unlikely.

A second benefit of the pension fund was the decrease in the likelihood of strikes by the workforce. To quantify this, we calculate the average strike length at this time in Germany, then we estimate the effect of an "average" strike on the sales and profits of Siemens. Table 6 summarizes the data on industrial action in Germany around the turn of the twentieth century (from Mitchell 1998, Table B3, pp. 173), the earliest reliable data available.

If we divide the average number of days lost to strikes by the average number of workers involved, we can see that the average striking worker stopped work for 14 business days.

To calculate the benefit of having the pension plan, we need to calculate the cost of a potential strike. If we assume that by the creation of the pension fund workers were fully prevented from striking, then we can use the average strike duration from that period of German history to estimate the average yearly direct benefit of having the pension fund. We choose to calculate the cost of a strike in 1877, 5 years after Siemens introduced their pension fund. In 1877, Siemens employed 738 employees, and there were approximately 310 business days per year, resulting in 228,780 worker-days. If there were a 14-day strike by all employees, it would be equivalent to having only 228,780–10,332 = 218,448 worker-days or, alternatively, 705 employees for the full year. Using 0.56, which is our most conservative estimate of the coefficient on labor in the production function, we obtain the counterfactual annual sales (and production) in 1877 that would result after a reduction of 33 employees (holding everything else fixed) $S_c = e^{\left(\log 3712 - 0.56 \log \frac{738}{705}\right)} = 3618$.[15] A 14-day strike would therefore translate into a drop in sales of approximately 94,000 marks.

The average profit/sales figure for Siemens in the 1870s was 22.9%, so that a drop in sales of 94,000 marks would correspond to a drop in profits of around 21,526 marks. Moreover, it is quite possible that as Siemens was a relatively large, profitable, and fast-growing company, it would have faced a larger strike than the average. We only consider the direct savings associated with discouraging the workers from striking. The additional benefits of good customer relations, plus

[15] The alternative estimate of β, 0.61, or the OLS coefficient, 0.65 only strengthens our results.

the benefit of avoiding a potentially disastrous drop in quality (a la Bridgestone/Firestone in the 1990s) are very large but not easily quantifiable. On the other hand, we calculate the costs *per strike*, and it is unlikely that Siemens would have faced one strike every year.

To evaluate the cost of adopting the internal welfare system in order to compare it with the above estimated benefits, we focus on the most expensive part: the pension fund. The cost of running the pension fund involved two costs: a one-off start-up cost and an annual expense. The starting capital of the pension fund was approximately 180,000 marks, with interest deemed to accrue at 5% per annum. To annualize the start-up cost, we assume that Siemens issued an annuity for 180,000 marks at 5%, and used the proceeds as seed money for the pension fund. Therefore, the annualized cost of the start-up was 9,000 marks. Siemens also committed to paying a further 5 Thalers (15 marks) per annum for each worker who served continuously for that year (see von Siemens 1966, pp. 257). Therefore, the annual cost of adding 15 marks per worker to the fund would have been on the order of 11,000 marks in 1877, assuming that all workers were employed continuously. The total cost of running the pension fund, annualized setup expenses plus annual running costs, would have been approximately 20,000 marks.

The economic benefits of the internal welfare system, including the pension plan, were twofold. First, labor productivity was boosted by between 9 and 19%, which would have boosted annual profits by 44,000–80,000 marks in the early years of the plan. Second, for each strike of average duration that was avoided the company would have saved around 21,500 marks in profits. Attribution of the separate benefits (labor productivity and strike reduction) is difficult, it is possible that more (or less) of the benefit was due to a reduction in strike likelihood. Nevertheless, the total positive impact of the internal welfare system was substantial and is consistent with profit-maximizing behavior by Siemens.[16]

An unquantifiable extra bonus is the boost to the firm's reputation for quality and timeliness. During the nineteenth century, Siemens was little disrupted by industrial action, with the exception of a small strike by *Meisters* in August 1872 (see Burhenne 1932, pp. 24). Siemens continued to enjoy better relations with workers than most other German firms during the early part of the twentieth century: "In contrast to the Siemens workers, workers of other large firms in the electrical industry… participated in a decisive way in strike actions and in establishing oppositional workers' councils" (Costas 1992, pp. 269). She attributes this partly to the "system of internal voluntary welfare provisions" by Siemens (pp. 271).

To conclude our discussion of the early years of Siemens' pension fund, we note that it, in similar fashion to many early British pension funds (see Hannah 1986), turned out to have been under-funded, although this problem was not immediately apparent. The company was forced to make a further contribution of 1 million marks in 1897, and from 1898 to 1905 a further 150,000 marks per year and to

[16] Performing a similar calculation for 1882—10 years after the pension fund introduction—results in a (direct) benefit of 28,400 Marks per prevented 14-day strike and costs of 25,300 Marks (= 9,000 + 15 × 1,085).

double the annual contribution per worker (see Conrad 1986). In 1904, the pension fund was transferred to a stand-alone company.

6 Conclusion

A company's decision on how to hire and retain loyal and hardworking employees is crucial to its success. The choice of wages and benefits needs to provide the correct incentives, so that workers exert an appropriate level of effort, develop human capital, and provide labor services reliably. The welfare capitalism path chosen by Siemens was successful throughout the nineteenth century in avoiding strikes by its employees. In this article, we focus on the pension fund aspect of Siemens' welfare capitalism to examine the motives behind the company's approach to labor relations and to judge the effects of the fund. The study of Siemens' pension fund is important because the company was one of the first in the world to introduce a range of firmwide welfare capitalism practices. The harmonious relations between management and employees contributed to the rise of Siemens from a small producer and installer of telegraph lines in Prussia to a modern company that operates in 190 countries and employs close to half a million people.

An examination of the data suggests support for all 3 reasons postulated for the internal welfare system, including the pension fund adoption. The welfare system encouraged workers to remain with Siemens until retirement and develop firm-specific knowledge and refrain from striking (i.e., human capital reasons), and in addition labor productivity increased by about 10% (i.e., efficiency wages). There is also limited evidence of increased worker power, which led to a redistribution of profit toward the labor force, since most of the direct benefits from preventing a strike were passed onto the workers.

The annual increase in profits due to a rise in labor productivity was between 44,000 and 80,000 marks in the early years of the plan. Although this amount may seem small, the annual cost of the pension fund in 1877 was approximately 20,000 marks. In addition, strikes were avoided, and the reputation of Siemens as a company that could provide on-time delivery and high quality products was maintained.

We examine an important and fast-growing company in a country that was one of the first to develop a welfare capitalism system. The data suggest that the introduction and maintenance of a welfare capitalism system at Siemens can be explained by profit-maximizing considerations. The scheme increased labor productivity, reduced industrial unrest, and protected the good name of the Siemens firm. The success of such a system at Siemens may help to explain why welfare paternalism spread throughout Germany and to other countries.

Acknowledgments The authors would like to thank the editor, 2 anonymous referees, Ran Abramitzky, Fabio Braggion, Stephen Broadberry, Carsten Burhop, Mauricio Drelichman, Daniel Hammermesh, Leslie Hannah, Jürgen Kocka, John McDermott, Joel Mokyr, John Singleton, Johannes van Biesebroeck, and Malathi Velamuri for helpful comments. Alexandra Kinter from the Siemens' Archives was

extremely helpful in responding to queries. Frank Luo provided excellent research assistance. Responsibility for all errors and omissions remains with the authors.

Appendix

Model

We assume that the output, q, of Siemens can be written as a Cobb-Douglas production function involving labor, L, capital, K, and a technological constant, A:

$$Q_t = AK_t^{\alpha} L_t^{\beta}$$

As is standard, we estimate the production function by taking logarithms:

$$\log Q_t = \log A + \alpha \log K_t + \beta \log L_t$$

From now on, we let lower case letters denote the natural logarithm of the corresponding upper case variable. It is well known that estimating production functions directly by ordinary least squares might involve an endogeneity problem whenever the input choices made by the firm involve some variable that is correlated with output, but is unobserved by the econometrician (see Olley and Pakes 1996; Wolak 1994). If, for example, output depends not only on labor and capital but also on the productivity of the employed workers, ω_t, and productivity is observed by the firm, but not by the econometrician, then an endogeneity problem arises because the firm chooses its variable input (labor) based on the realization of ω_t. We assume that capital is a fixed input, in the sense that the firm has to decide on its capital level before observing labor productivity. If, as seems reasonable, labor productivity exhibits serial correlation then Siemens' choice of K_t will be influenced by the previous level of labor productivity, ω_t. That is, Siemens will tend to expand its capital stock and labor force during periods of high labor productivity. Therefore, the production function that we would like to estimate is:

$$q_t = a + \alpha k_t + \beta l_t + \omega_t + \varepsilon_t \tag{1}$$

where ω_t is unobserved by the econometrician, and we might expect $Cov(\varepsilon_t, \cdot) = 0$ and $Cov(\omega_t, l_t) > 0$, since a firm would tend to hire more workers when labor productivity is high.

Regressing q only on a constant, k and l will result in an upwardly biased estimate of β, which is the coefficient of interest to us since we wish to evaluate the impact of strike activity. In order to correct for this bias, we need to account for unobserved labor productivity, ω_t. One way to achieve this goal is to adopt a control function approach. Olley and Pakes propose inverting a firm's optimal investment function (since investment is observable) to get a handle on the unobservable productivity shock, by assuming that ω_t follows a first order Markov process. Further, we assume that capital follows a simple law of motion, standard in the macroeconomics literature, $K_{t+1} = (1 - \delta)K_t + I_t$, where δ is the rate of depreciation and I_t is investment. Siemens' financial statements do not itemize depreciation. Therefore, it is possible that the firm "smoothed" profits by using a high

depreciation rate in profitable years and a low depreciation rate in less profitable years. Benston et al. (2006, pp. 107) state that around 1870 "disclosure of a balance sheet and an income statement was required, although no formats were prescribed." Therefore, Siemens' investment may be mismeasured, which may cause biased coefficient estimates. However, given the available data sources, there is no way to adequately address this problem. Siemens' equilibrium investment function can be written as:

$$I_t = f(S_t, \omega_t)$$

where S_t includes all of Siemens' state variables other than ω_t. S_t will include K_t and possibly other variables that describe the overall state of the economy that are observable to both the firm and the econometrician. If $f(\cdot, \omega_t)$ is strictly increasing in ω_t, then we can invert $f(\cdot, \omega_t)$ and write $\omega_t = g(S_t, I_t)$.[17] Since both S_t and I_t are observable, we can correct for the unobserved part ω_t in (Eq. 1) using a consistent estimate of $g(\cdot)$. The intuition is that although we cannot observe labor productivity directly, we can estimate what it must have been by observing the investment decision of the firm since the firm tends to invest more during periods of high labor productivity.

What other state variables might we include in S_t? It seems reasonable to assume that the investment decision of Siemens is a function of the overall state of the economy. The overall state of the economy has a direct effect on the unemployment rate, and cost of labor, and thus on the level of optimal investment in a given year. We attempt to capture the state of the economy by the level of gross domestic product, GDP_t. Putting this together, we can write labor productivity at time t as:

$$\omega_t = g(\text{GDP}_t, I_t, K_t) \tag{2}$$

where GDP_t is gross domestic product, I_t is the investment by Siemens, K_t is the firm's capital stock, and g is the firm's inverted equilibrium investment function.

We substitute (Eq. 2) for (Eq. 1) to obtain:

$$q_t = \beta l_t + \varphi(\text{GDP}_t, I_t, K_t) + \varepsilon_t \tag{3}$$

where

$$\varphi(GDP_t, I_t, K_t) = a + \alpha K_t + g(GDP_t, I_t, K_t) \tag{4}$$

Equation 3 is a partially linear semiparametric regression model (see Robinson 1988). We use data on GDP in constant prices from Mitchell (1998, Table J1, pp. 906). To construct the investment variable, we make use of the law of motion for the capital stock, and we set the depreciation rate of capital at 10%. This model can identify β, which is the contribution of labor to the production process. We cannot, however, directly identify α as K_t also enters the function g, both directly and indirectly through the investment variable I_t. We will use moment conditions generated by the assumption of the stochastic process of ω_t to identify α. We also assume that Siemens is not large enough to affect market wages or the unemployment rate of the whole economy. If these last assumptions were violated, then

[17] Theorem 27 of Pakes (1994) provides sufficient conditions for this property.

our estimates of β could potentially be biased in either direction. To estimate (Eq. 3), we use a series estimator (a second order polynomial) for labor productivity:

$$\varphi(\text{GDP}_t, I_t, K_t) = c_0 + c_1\text{GDP}_t + c_2 I_t + c_3 K_t + c_4\text{GDP}_t I_t + \cdots + c_7\text{GDP}_t^2 + c_8 I_t^2 + c_9 K_t^2$$

(see Newey 1995), and thus we can obtain an estimate of that is asymptotically consistent.

With the approach outlined above, we also obtain estimates of the unobserved productivity, ω_t. We can use these estimates to test for the effect of the pension fund on labor productivity as predicted by the efficiency wage theory. If indeed, the introduction of the pension fund in 1872 or the adoption of some other part of the internal welfare system caused workers to shirk less, we should observe an increase in labor productivity after that year. We assume that ω_t follows an AR(1) process:

$$\omega_{t+1} = \lambda_0 + \lambda_1\omega_t + \eta_t$$

where η_t is a white noise error term with zero mean. Notice that since we write our model in terms of logarithms of the variables, ω_t, which is unobserved by the econometrician, but observed by the firm, may be interpreted as the productivity growth rather than level. In this way, λ_0 captures the growth trend and η_t the deviation from the trend. If the productivity increase in 1872 could have been foreseen by the firm (for example, since the firm was aware of the incentive effects of the pension fund), one of our identifying assumptions: $E[\omega_{t+1}|\omega_t] = \lambda_0 + \lambda_1\omega_t$ would not hold in the year when the pension fund was established. We therefore allow labor productivity to potentially change in the year the pension fund was introduced, and, in particular, change in a way that the firm may have been able to predict:

$$E[\omega_{t+1}|\omega_t] = \lambda_0 + \lambda_1\omega_t + \theta D_t$$

where D_t is a dummy variable equal to 1 in the year that the pension fund was introduced and 0 otherwise. If the pension fund suddenly increased labor productivity in a foreseeable way, as predicted by the efficiency wage hypothesis, θ should be positive.

Let $\hat{\varphi}$ denote the estimated contribution of labor productivity and capital to output that we obtain from the first stage of the estimation described above. Since by (Eqs. 2) and (4), $\omega_t = \varphi(GDP_t, I_t, K_t) - \alpha k_t - a$, we can define the unpredictable innovation in labor productivity, ξ_t, as:

$$\xi_t = \hat{\varphi} - \alpha k_t - a - E[\omega_t|\omega_{t-1}]$$

with

$$E[\omega_t|\omega_{t-1}] = \lambda_0 + \lambda_1(\hat{\varphi} - \alpha k_t - a) + \theta D_{t-1}$$

Since the capital stock for period t is determined before the innovation, ξ_t, is observed, and this labor productivity innovation is unpredictable, $E[\xi_t] = 0$, we have the following four moment conditions:

$$E\left[\xi_t\begin{pmatrix} D_t \\ k_t \\ 1 \\ \hat{\varphi}_{t-1} - \alpha k_{t-1} \end{pmatrix}\right] = 0 \tag{5}$$

The first moment condition identifies θ under the assumption that ω is first-order Markov up to a level shift due to the pension fund introduction. The second moment condition identifies α because the decision on the level of log capital, k_t, has to be made prior to observing ω_t, and thus the capital stock at time t should be orthogonal to the unpredictable part of current period productivity, ξ_t. The third moment condition is implied by the restriction that the innovations have zero mean, and thus it only identifies $\lambda_0 + a(1 - \lambda_1)$. The last moment condition identifies λ_1 as last period's realization of productivity, $\hat{\varphi}_{t-1} - \alpha k_{t-1}$, should be independent of the current unpredictable productivity innovation, ξ_t.[18]

We now estimate the model by the standard technique of Generalized Method of Moments (see Hansen 1982). The estimation technique described above generalizes to other production functions. The necessary restriction is that production functions can be written as $y_t = h(k_t, l_t, \omega_t + \varepsilon_t)$ where h is strictly monotone in $\omega_t + \varepsilon_t$.

Estimation details

The basic model we aim to estimate is given by (Eq. 3) in Sect. 7.1. Due to the incomplete availability of quantity data and problems of aggregating the various goods and services that Siemens produced, we modify (Eq. 3) by adding log P_t to both sides:

$$\log P_t Q_t = \log P_t + \beta \log L_t + \varphi(\mathrm{GDP}_t, I_t, K_t) + \varepsilon_t \tag{6}$$

where $\varphi(\mathrm{GDP}_t, I_t, K_t) = \log A + \alpha \log L_t + g(\mathrm{GDP}_t, I_t, K_t)$. The dependent variable in all specifications is log P_tQ_t, the natural logarithm of sales in year t. We assume that the (unobserved) price of an aggregated product of Siemens, P_t, grows stochastically at a quadratic rate, i.e., $\log P_t = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \in_t$, where $\in_t$ is a white noise error term. Substituting the equation for log prices in (Eq. 6), we obtain:

$$\log P_t Q_t = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \beta \log L_t + \varphi(\mathrm{GDP}_t, I_t, K_t) + \eta_t$$

where $\eta_t = \varepsilon_t + \in_t$ is a white noise error term.

For the second stage of the estimation, we have the moments given by (Eq. 5) and an additional one: ξ_t should be orthogonal to time. To summarize:

$$E\left[\xi_t\begin{pmatrix} D_t \\ k_t \\ 1 \\ \hat{\varphi}_{t-1} - \alpha k_{t-1} \\ t \end{pmatrix}\right] = 0$$

[18] Since $E[\xi_t] = 0$ and α is a constant, $E[\xi_t \hat{\varphi}_{t-1} - \alpha k_{t-1} - a] = E[\xi_t(\hat{\varphi}_{t-1} - \alpha k_{t-1})]$.

where

$$\xi_t = \hat{\varphi}_t - \alpha k_t - (a + \gamma_0) - E[\omega_t | \omega_{t-1}]$$

and

$$\hat{\varphi}_t = \widehat{\log P_t Q_t} - \left(\hat{\gamma}_1 + \hat{\gamma}_2 t + \hat{\gamma}_2 t^2 + \beta \log L_t\right)$$

The coefficient α cannot be identified in the first stage of the estimation because capital also enters $g(\cdot)$. Similarly, γ_0 and a cannot be identified as there also is a constant term in $g(\cdot)$. In the second stage, only the term $\lambda_0 + (1 - \lambda_1)(a + \gamma_0)$ is identified using the third moment condition, and hence λ_0, γ_0, a and cannot be identified separately.

The results from the second stage of the estimation are presented in Table 5. The first, second, and third column of Table 5 correspond to the second, third, and fourth columns of Table 4, respectively. The estimated coefficients on capital, α, range from 0.31 to 0.35, which together with our estimates of β suggests that Siemens was operating under slightly decreasing returns to scale—but the difference from constant or even increasing returns to scale is not statistically significant.

The asymptotic variance/covariance matrix has been corrected for possible autocorrelation in error terms using the Newey-West HAC-consistent method with Parzen kernel (see Newey and West 1987). We use our model to test whether H_0:$\lambda_1 = 1$ which together with $\lambda_0 = 0$ would imply that ω_t would be a martingale), and both an LM-test and a D-test overwhelmingly reject these restrictions.

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