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Factory Discipline

GREGORY CLARK

Before the Industrial Revolution in Britain most workers controlled their pace, timing, and conduct at work. Factory discipline radically changed this. Employers now dictated how, when, and in what manner work was done. Why did discipline triumph? Was it required by the need to tightly coordinate workers with new technologies? Or was it successful because it coerced more effort from workers than they would freely give? The empirical evidence shows that discipline succeeded mainly by increasing work effort. Workers effectively hired capitalists to make them work harder. They lacked the self-control to achieve higher earnings on their own.

One reason that the Industrial Revolution was greeted with hostility by many was its association with a revolutionary change in the way work life was organized. Two changes occurred. In the first employers collected workers into workshops or “manufactories” that they owned. Although this caused some complaint, the alteration in working conditions was seemingly minor. Workers in these workshops controlled their own hours, work pace, and conduct. They took breaks when they wanted and socialized at work as they wished. Moreover, they were not paid any more than equivalent domestic workers per unit of output, implying that they did not find the conditions of the workshop unpleasant. The second and later change was the imposition on these concentrated workers of “factory discipline.” With factory discipline the employer dictated when workers worked, their conduct on the job, and that they steadily attend to their assigned tasks. Under discipline workers were rewarded not only according to their output, as in the workshop, but also—or even exclusively—based on their behavior in the workplace. Workers were heavily penalized for small deviations from the approved rules of conduct. They seem to have strongly resented factory discipline, and evidence from the market is that they were paid a substantial premium to work under such conditions.¹

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The first draft of this paper was completed in 1985. An early version was presented at the Cliometrics Conference at Miami University of Ohio in 1986 in less than ideal circumstances. It has since gone through numerous revisions. Seminar participants at Stanford, the University of Pennsylvania, Harvard, Kansas, Yale, Michigan, the University of California at Berkeley, and the University of California at Davis all made helpful comments and suggestions. I thank in particular my colleague Peter Lindert for his generosity with his time. I thank both the referees and Naomi Lamoreux for their patience.

¹ I present this evidence later in the article. There is an unfortunate tendency to conflate centralization and discipline in the literature on the factory and to describe any workshop as a

Discipline has been viewed in two distinct ways. Critics of capitalism have argued that the imposition of discipline reflected a failure of capitalism to deliver appropriately humane work conditions. It had earlier been possible to allow workers autonomy. That possibility remained even after the technological changes of the Industrial Revolution. Whereas the advocates of capitalism celebrate its ability to give individuals "freedom to choose," critics argue that factory discipline represented the end of freedom for workers. They now had one choice only—work under the stipulated set of conditions or not work.² Discipline was designed to *coerce* workers into doing more than they would have freely chosen if they had maintained control over their hours of work and work intensity. The capitalist under discipline drove workers, as depicted in the popular literature on the factory and on the assembly line. The profitability of discipline lay in the ability of the employer under discipline to extract more work per unit of pay. I call this point of view the *coercion* theory.

Defenders of capitalism have responded that although discipline in itself is unattractive, it was a necessary cost of the new production techniques developed during the Industrial Revolution. These techniques involved the use of mechanical power, more machinery per worker, and an extensive division of labor. Proponents of this view agree with James Philip Kay that, "Whilst the engine runs the people must work—men, women, and children are yoked together with iron and steam."³ In other words, discipline resulted from *technological* necessity. Without the imposition of discipline, the whole production process could grind to a halt because one worker was absent, drunk, or conversing with his fellows. Thus Karl Marx quotes Henry Ashworth, a large cotton manufacturer, as noting that "When a labourer lays down his spade, he renders useless, for that period, a capital worth eighteen pence. When one of our people leaves the mill he renders useless a capital that has cost £100,000."⁴ A modern expression of this view is the following:

In the factory, life had to be regulated. Unlike the artisan's workshop, the steam-driven factory could not co-exist with undisciplined labour. It was dangerous to the operative as well as bad for productivity to mix drinking and horse-play

"factory." As we shall see from the wage evidence, they were quite distinct from the viewpoint of workers.

² Such critics in recent years have included Samuel Bowles, Richard Edwards, Herbert Gintis, William Lazonick, and Stephen Marglin, who argue that under capitalism the work organization that is profitable will not be that which is efficient. A classic work in this literature is Marglin, "What Do Bosses Do?" which argues that factory discipline was designed in part to increase workers efforts beyond that which they would freely supply to firms.

³ Kay, *Moral and Physical Conditions*, p. 24.

⁴ Marx, *Capital*, Vol. 1, p. 529.

with minding a machine. Moreover, to the capitalist, time was money and his machinery could not be left idle while his workers stayed in bed or took a day off work.⁵

I call this argument the *coordination theory*. It asserts that the unpleasant features of discipline were simply one unfortunate corollary of new, more productive technologies.⁶

Advocates of the coordination view also argue that coercion was not possible so long as labor markets were reasonably competitive, as they seem to have been in most industries in Britain during the Industrial Revolution. In a competitive labor market, no employer can arbitrarily impose bad work conditions. If markets are competitive, what survives will be what is efficient. Employers were quite flexible about choosing discipline or incentives—the same employer might use incentives in one part of his factory and discipline in another—and they saw themselves as responding to market forces. Workers chose discipline because manufacturers who organized labor in this way were able to reduce costs and offer higher wages. Workers, in this view, preferred discipline and high wages to freedom and low wages. Their protection was and is the market. From this perspective the critics of capitalism are utopian dreamers.

This is a powerful line of reasoning familiar to all economists. The labor markets of industries that imposed discipline during the Industrial Revolution appear on casual inspection to have been competitive. In 1838, in the parish of Manchester alone there were 163 working cotton mills, employing 39,000 workers. Fourteen other parishes in Lancashire had more than 10 working cotton mills, including Oldham with 200, Bury with 114, and Whalley (adjacent to Manchester parish) with 113. A cotton worker in Manchester in 1838 would have been within walking distance of at least 100 potential employers vying for his or her services. In the town of Nottingham in 1844, just before the factory was introduced into the framework knitting industry, there were 56 employers holding 3,490 knitting frames between them.⁷

Casual inspection can be deceiving, however. In this article I derive clear empirical predictions from the coercion and coordination arguments and use these predictions to test whether discipline triumphed because it was required for coordination or because it coerced workers into giving more effort than they desired. The results of each of the four empirical tests I present support the coercion theory and suggest that

⁵ Royle, *Modern Britain*, p. 238.

⁶ Thus A. P. Usher argues that the division of labor could only be effectively carried out with "the subjection of the whole body of workmen to a systematic schedule" so that "no group of workers need be obliged to wait for the group engaged on the earlier stages of the work" (Usher, *An Introduction*, p. 347). For a similar comment by a contemporary mill manager, see *GB1842*, pp. 72–73. Other advocates of the coordination theory include Mantoux, *Industrial Revolution*, pp. 384–85; Lipson, *Short History*, p. 78; Thompson, "Time," p. 71; and Landes, "What Do Bosses Really Do?" pp. 606–7.

⁷ *GB1839a*, p. 4; and Church, *Economic and Social Change*, p. 36.

the demands of coordination on Industrial Revolution technologies were generally unimportant. These findings indicate that, contrary to appearances, the labor markets of the Industrial Revolution were not competitive, because, as I will show, coercion is not possible in a competitive market.

A number of possible imperfections in the labor market might have encouraged coercion. The imperfection I find most plausible is that workers were unable to respond appropriately to the incentive systems that gave them more freedom. Unconstrained, they were unable to achieve their optimal combination of effort and wages. With the new capital-intensive techniques of the Industrial Revolution, employers could pay workers a high premium to submit to discipline because they were able to get more output out of both workers and machinery. But if discipline triumphed by forcing workers to work harder, then the very imposition of discipline implies that workers lacked self-control. If workers had full self-control they could, with appropriate incentives, have always reproduced the efforts of those under discipline, while retaining their independence.

Whatever the market imperfection that allowed discipline to coerce workers, the critics of capitalism are correct that a better organization of work than factory discipline was and still may be available. But they are incorrect in thinking that capitalism as a system is what prevented an uncoerced organization of work from prevailing. The failure of the market lay not with the ownership of capital by a class of bosses, but in the behavior of workers who were not able to discipline themselves in response to financial incentives. Whatever the workers themselves thought, they effectively hired the capitalists to discipline and coerce them. Even in the factories of the Industrial Revolution they were the ultimate masters of their fate, but weakness of the will meant they delegated that mastery to the capitalists.

DISCIPLINE VERSUS INCENTIVES: HOW THE SYSTEMS OPERATED

When we look at the organization of work from the perspective of the twentieth century, the prevailing system, factory discipline, seems the natural and timeless way of organizing work. Under factory discipline workers face a very constrained choice. In return for their wage, they surrender to the employer complete command of their labor for a fixed period each day. The employer sets the pace of work and also dictates how workers will conduct themselves on the job. In some cases workers will be offered piece rates, but even then their hours of work will be controlled, as will their conduct while at work, and a minimum pace of work will be expected.

In the nineteenth century, workers under factory discipline were dismissed, fined heavily, or locked out for the day for a whole variety of

infractions. These included arriving a few minutes late in the morning, being absent from their machine, talking or eating at work, drinking beer, and whistling, singing, and engaging in other forms of horseplay.⁸ Even workers on piecework were often subject to strict discipline. For example, 21 of 32 linen mills in Belfast in the 1890s locked out pieceworkers who were a few minutes late, and 29 imposed fines for minor unpunctuality.⁹ Pieceworkers who were five minutes late were fined up to one hour's wages. Yet in four of these mills, pieceworkers were already under a payment scheme that gave bonuses of 3 to 10 percent on earnings for achieving a minimum output level.¹⁰ In one mill, workers who were not there by starting time on any day were locked out, had to pay a fine of about 2 percent of weekly wages, and also lost any chance of the 8 percent bonus on earnings for the week. In a number of cotton weaving sheds in Lancashire, temporary weavers would come to the mills in the morning and would be given the looms of any permanent weaver who was late, even though the weavers were employed under piece rates. In one mill, if a permanent weaver was five minutes late, she lost her looms for the day.¹¹

A puzzling aspect of factory discipline was that instead of rewarding workers according to their output, it used the behavior of workers as a measure of performance. Thus in one early cotton mill, workers were already being fined during the years 1805 to 1813 for such infractions as "Idleness & looking thro' window," "Calling thro' window to some Soldiers," "Riotous behavior in room," "Riding on each other's back," "Dancing in Room," "Going out of the room in which she works to abuse the hands in another room," "Neglecting his work to talk to people," "Making a noise when order'd not," "Using ill language," "Terrifying S. Pearson with her ugly face," "Talking &c.," "Sewing in Mill time," and "Sending for ale into the room &c."¹²

The use of such discipline in industries like cotton weaving is puzzling, because where output is easily measurable, discipline seems to give employers no gain and to impose some costs. Discipline systems rewarded and penalized workers, even when they were on piecework, on the basis of their inputs to the production process rather than their outputs, even though inputs like hours of attendance, sobriety, and demeanor were linked rather loosely to outputs. In one cotton weaving

⁸ See, for examples, *GB1892*, p. 302; *GB1893*, pp. 69, 163, 237, 326; Leach, *Stubborn Facts*, p. 13; Fitton and Wadsworth, *Strutts*, pp. 234-40; and *GB1834*, pp. 551-52. Employers sometimes went so far as to ban beer shops from the vicinity of their factories (Pollard, *Genesis*, p. 194).

⁹ *GB1893*, pp. 341-45. Dismissal for lateness was another penalty that was probably almost universally applied, but the frequency of its occurrence was not recorded in this source.

¹⁰ *Ibid.*, p. 341.

¹¹ *Ibid.*, p. 127. Marx notes the case of power weavers in 1863 who were fined 18 d. for being ten minutes late in the morning—the equivalent of eight hours wages—as illustrative of the exploitative nature of capitalism (Marx, *Capital*, Vol. I, p. 425).

¹² Fitton and Wadsworth, *Strutts*, pp. 234-37.

shed in 1923, the outputs of 13 experienced weavers, each of whom operated three looms on the same type of cloth, were averaged over one month of working. The best weaver got 93 percent of potential output from the looms, and the worst 70 percent, even though they worked the same number of hours. Thus even with the imposition of discipline significant differences in output among workers remained. In this weaving room the best weaver could start work two and a half hours later each day than the worst and still produce as much.¹³ Why was it not easier to reward workers simply through a piece rate, rather than adding on other penalties that were only casually related to performance? There might well have been workers who would have produced high output, even though they were irregular, profane, or bibulous.

This disciplinary system, moreover, was not a timeless way of organizing work. As has been shown by others, it was itself a creation of the Industrial Revolution and seems to have originated largely in the new factories that were established because of changes in textile technologies after 1760.¹⁴ Less widely stressed is the fact that other methods of organizing workers coexisted with factory discipline into this century in Britain. These systems allowed workers to control their work pace, work hours, and personal conduct on the job, even when capital was owned by the employer and the workers were employed in large workshops. In the "workshop system," for example, workers were paid a piece rate for their output, but were required to pay a fixed sum per week for the rent of their machines, the floor space they used, and even sometimes explicitly for managerial overhead. Workshops opened longer than the 10 to 12 hours per day of factories—sometimes 16 or 17 hours per day—and workers worked when they wished during these hours. While the cotton weavers in power-driven factories of Lancashire were being disciplined and regimented in the 1890s, some of their compatriots in the silk weaving industry were still employed using incentives under the old rent and charges system. There were also workshops in handloom weaving in the nineteenth century, many of which employed the rent and charges system and exercised little discipline over workers. Bootmakers who rented space in cooperative workshops in London in the 1890s, chain- and nailmakers who rented space at forges in 1906, wood sawyers and turners in East London sawmills, and Sheffield cutlery workers who rented a place at a grinding

¹³ Wyatt, *Variations*, pp. 28–29. In silk weaving, the efficiency of weavers varied from 55 percent to 82 percent on one class of cloth and from 39 percent to 71 percent on another class. Woolen weavers under factory discipline in the early nineteenth century showed similar variation in the length of time it took them to weave cloth (*GB1840a, Part 2*, pp. 440–46). Even in small groups of ten or so weavers, the slowest typically took 50 percent longer than the fastest. In each of three woolen factories in 1839 the fastest weaver could start 3.5 hours each day after the slowest and still complete as much work.

¹⁴ See Pollard, *Genesis*, pp. 181–92.

wheel from their employers or from "public factories"—all had freedom to determine work pace, hours, and personal conduct.¹⁵

Employers were largely indifferent to workers' performance and conduct within the workshop because their profit came mainly from the fixed rents, which were independent of output per worker. For example, in framework knitting in the 1840s workmen rented a machine worth 120 s. for 1 s. a week, a gross rate of return on capital of about 43 percent per annum.¹⁶ Slow workers were as valuable to the firm as fast ones. Consequently, there were few restrictions as to hours or even the amount of output required per week. Many establishments in the hand-powered industries that were called "factories" by contemporaries were in fact such incentive-based workshops.¹⁷

Workers in the workshop system frequently kept irregular hours, often taking off Monday ("St. Monday") and even Tuesday and working long hours on Thursday and Friday.¹⁸ The hand-frame knitting industry, in which more than 30,000 workers were employed in workshops in the 1840s, illustrates the irregularity of both work schedules and earnings.¹⁹ Knitting shops often opened for 14 to 17 hours a day, and the workers remained free to come and go and to converse with each other at work. The supervisor of over 50 workers in a knitting workshop stated that the men worked erratically, some working only three or four days in the week, some earning considerably different amounts from week to week.²⁰ One worker noted that "there is no regular superintendence whatever." Another reported that he began "in a general way about 6 o'clock" and continued till the shop master "locks up at 10; and I am in general there every day, for I have no money to go to a public house with."²¹ The variability of the weekly earnings of workers in the knitting shops was indeed large. In one workshop with 54 workers in 1845 there would typically be a worker who produced 75 percent more than the average for the week and a worker who produced 75 percent less than the average. The variation was less extreme in other cases but was still substantial.²² At the same time, many workers earned the same amount from week to week.

¹⁵ Booth, *Life and Labour*, pp. 141, 168–70; Smith, *Sweated Industries*, pp. 52–53; and GB1892, QQ 19,394–19,397.

¹⁶ GB1845, p. 46. This return is probably so high because it includes a return for managerial inputs.

¹⁷ See, for example, GB1839b, pp. 701, 703.

¹⁸ Thompson, "Time," pp. 70–79; and Reid, "Decline," pp. 76–84.

¹⁹ GB1845, *Evidence, Part I*, p. 5. Probably the majority of knitting frames were in workshops by 1845. The 1850 census records 65,462 people who gave their occupation as stocking makers, the main output of knitting machines being stockings.

²⁰ A list of their weekly earnings over 15 weeks confirms their irregularity. The workshop was open from 6 A.M. to 10 P.M.. See GB1845, *Evidence, Part I*, pp. 72–73, 140, Q 2314, 144, Q 2407.

²¹ *Ibid.*, pp. 24, 39, 46.

²² GB1845, pp. 319–21; and GB1854–5, pp. 575–77. The output of individual workers always varied by much more than the output of the group of workers, showing that the variations cannot be attributed to fluctuations in demand.

Even in some industries where there was a straight piece rate—such as metal manufacturing, potteries, hand brickmaking, and coal mining—workers had considerable control of work conditions. A large lock manufacturer, whose workshop of 200 employees was open 16 hours per day, reported that the workpeople

came when they had a mind—went when they had a mind: his workshops were always open. As they all worked by the piece, it was of no consequence to the employer when they did it, that was entirely their own affair.²³

Potteries were among the largest factories in Britain by the mid-nineteenth century, and employed an extensive division of labor in producing their wares. Yet they remained largely undisciplined. In 1908 it was reported by a factory inspector that

The potteries are places by themselves with hardly any supervision. The trade was conducted in the old days independently by the men themselves, and the ordinary discipline of the factory or machine shop is not brought to bear upon them.²⁴

Even as late as 1931, a potter could report that “we have no set time for stopping and starting here.”²⁵ Similarly until at least 1914, miners in many areas were able to absent themselves from work when they wished. A Scottish pit owner noted in 1907 that “there is no hard and fast rule that the miner must work so many days a week. A miner takes an idle day whenever he wishes, but, of course, if he persistently does that, the manager may dismiss him.”²⁶

In the workshop system many workers did not have to produce any minimum output per week, a situation that could create production problems in shops where some coordination was indeed necessary. One method of organizing workers where coordination was more important was to pay a piece rate, with or without a rental charge for capital, and require at the same time either a weekly work quota or a minimum weekly output.²⁷ In other cases if the worker did not return the work within a specified period, a large payment was deducted from his or her earnings. The use of a quota of output per worker allowed workers freedom as to how they conducted themselves on the job and when they came to work. At the same time it protected the employers' investment in machinery and ensured some coordination of the stages of the process.

²³ GB1843, *Second Report*, p. 51.

²⁴ GB1908, Q 778.

²⁵ Whipp, *Patterns*, p. 70.

²⁶ GB1907, Q 641.

²⁷ Coventry ribbon weavers working for master weavers in workshops were employed in this way for it was reported that “The journeyhand weaver considers that so his work be done, he is at liberty to work what hours he pleases.” GB1840a, *Part 2*, p. 286. Outdoor worsted weavers in Yorkshire were required to complete a given quota per week. In the Staffordshire coal mines in the nineteenth century, many miners were required to produce a weekly stint, which they could produce in whatever hours it took. Church, *History*, p. 241.

In the early textile factories there seems to have been a period of experimentation in which different methods of work organization were employed in different mills. Some used severe forms of factory discipline. But in others, work was organized without the new discipline. For instance, in the hand spinning factory managed by Henry Houldsworth in Manchester in 1795, mule spinners were paid by the piece and worked in the traditional pattern of small efforts on Monday and Tuesday followed by extra long hours towards the end of the week. By 1816 Houldsworth enforced a strict 75-hour week in his mechanically powered Scottish cotton textile factories, though women cotton pickers who did not use machinery were allowed to come and go as they wished.²⁸ Yet by the mid-nineteenth century, discipline had triumphed in the factory textile industry, with all workers having to attend at fixed hours and obey strict codes of conduct. In such a competitive industry as textiles, with hundreds of mills competing to sell largely undifferentiated output in a geographically compact area, there must have been some competitive advantage that discipline conferred. What was it?

Other industries also show signs of going through periods of experimentation with different types of work organization. In some, such as handloom weaving of cottons or silk or hand-frame knitting, the factory system was tried unsuccessfully before mechanically powered machines were introduced. In others, such as power silk weaving in Coventry, the workshop system was tried but was replaced by the factory. What was the competitive advantage of factory discipline, and why did that advantage appear only with some technologies?

Though this article is based on the experience of British industries in the nineteenth and early twentieth centuries, it is important to note that in the United States some hand industries were also centered in large workshops in which the workers retained many of their traditional freedoms. For example, by the beginning of this century cigars were often manufactured in factories of considerable size, such as Waitt and Bond in Boston who employed 648 workers in 1913. In firms like Waitt and Bond, where male workers were unionized, opening hours were limited to eight hours per day as a result of *union* pressure, but within these hours there was no constraint on the performance of workers except that they produce good quality, and that they maintain on average a reasonable output. Workers came and left when they wanted, socialized at work, and set their own output levels. In the sectors of the

²⁸ *GB1816*, pp. 230–35. A popular view is that discipline was imposed in factories because many women and children were employed there, and they had less ability to object to discipline. It is therefore important to note that many of the undisciplined workers in the nineteenth century were women and children. The Children's Employment Commission of the 1840s is replete with examples of women and children employed with incentives in conditions of relative freedom. Examples include pinmaking, file cutting, straw plaiting, rag cutting, and various workers in the potteries.

cigar industry that employed female nonunion workers most firms also operated without strict discipline. In Detroit, where many such workers were employed, "women were allowed to leave any time." In the other large center of womens' employment in the cigar industry, Eastern Pennsylvania, "in a few cases hours were rigidly enforced, especially in larger firms, while in others they were more casual, where 'there was no time to stop and no time to start.' " The American Cigar Company did employ factory discipline in its factories, setting rigid work hours, and preventing women from talking to each other while working. But American Tobacco was unusual. In other companies "rules and regulations were much more casual. . . . In the Lehigh Valley, janitors unlocked some factories as early as 5 A.M.; women could 'go in as early as they please' and often did so."²⁹

We also have detailed evidence of indiscipline within "factories" in the hatmaking industry and among coopers in the late nineteenth century.³⁰ There are indications that indiscipline may have also existed in other sectors such as the various clothing industries, coal mining, and among stove mounters, potters, printers, and shipyard workers.³¹ Thus the same puzzle that I posed for Britain also applies to America. Why were some workers, typically hand workers, allowed freedom within the factory setting, whereas others were subject to strict discipline?

THE COORDINATION THEORY OF DISCIPLINE

As I have noted, the prevailing view of the need for factory discipline in the nineteenth century is that new technologies made it imperative to coordinate workers more carefully. According to this argument, the technologies that emerged from the Industrial Revolution typically involved more fixed capital per worker, a greater division of labor, and machines driven by a central power source. Under the existing incentive systems, there would be increased coordination costs in the use of such technologies. Power would have to be available for longer hours if everyone was not kept to the same schedule. Moreover, greater stocks of inventory per worker would have to be kept at each stage of the production process to ensure that production did not grind to a halt because of the absence of one worker. These greater coordination costs

²⁹ Cooper, *Once a Cigar Maker*, pp. 198, 208, 180, 175.

³⁰ Bensman, *Practice*, pp. 75-76; and Coyne, *Development*, p. 21.

³¹ Evidence on discipline practices in American industry in the nineteenth and early twentieth centuries is hard to find, and I have not done a systematic survey. Earlier writing on handicraft industries in the United States tends to come from writers who are concerned to stress the exploitative nature of handicraft, or "sweated" industry—low wages, long hours, bad sanitation—or the triumph of union organization in overcoming such conditions. Only with the emergence of the "new labor history" of Herbert Gutman, David Brody, and David Montgomery did American labor history become concerned with the culture of the workers and the control they exercised over their work lives. But my reading of the American evidence largely confirms the generalization I have drawn here that hand "factories" tended to be undisciplined.

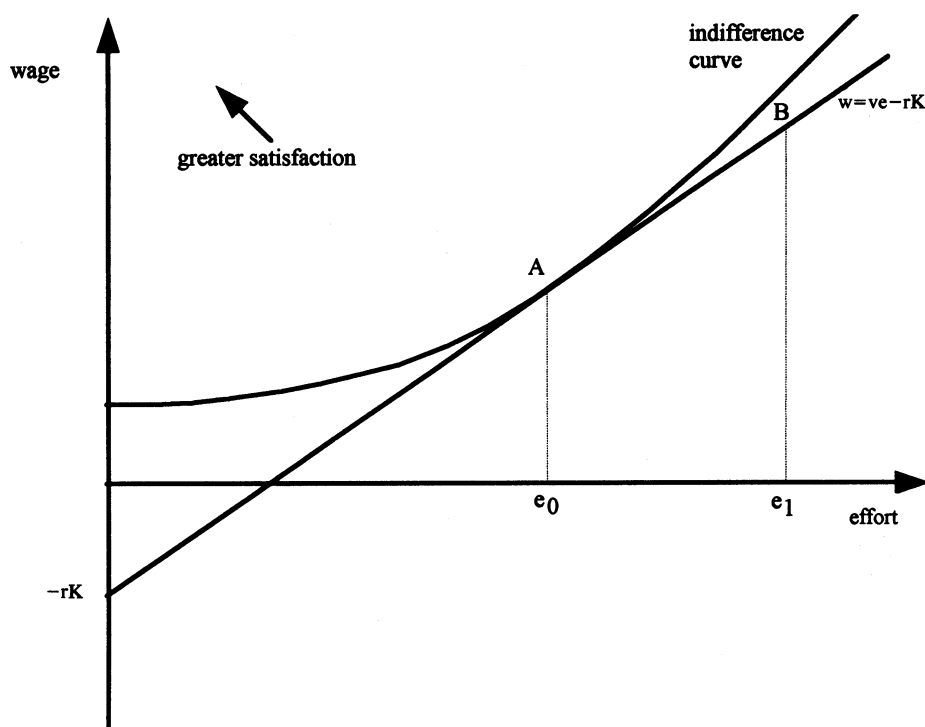


FIGURE 1

THE CHOICE OF EFFORT LEVEL

Notes: A is the optimal choice of effort and wage. The imposition of effort level B puts the worker on a lower indifference curve than at A.

Source: See the text.

forced employers to keep all workers to the same production schedule and to ensure steady work at all times.

Under this view what happens to the efforts of the average worker when factory discipline is introduced? To consider this question suppose workers care about two things: the wage they receive, w , and the amount of effort they put in, e . Their satisfaction can be indexed by $U(w, e)$ where U increases with w and declines with e . Figure 1 shows a typical indifference curve. If the labor market is competitive so that workers are paid their marginal product, then w and e will be connected as follows:

$$w = v.e - F \quad (1)$$

where F is the rental cost of the fixed capital, and v is the value of each unit of effort to the firm. If workers do nothing, their value to the firm is $-F$ since they tie up machinery and other capital. The more they do, the greater their value to the firm. If there is no consideration of coordination with other workers, the optimal choice of effort and wage

will be on the highest indifference curve as is shown in the figure. Formally the worker will choose e to

$$\max U(w, e) \text{ subject to } w = v.e - F \quad (2)$$

The optimal choice of effort and wage in Figure 1 is at point A. Note that the capitalist does not need to specify the amount of effort the worker puts in. Merely by paying according to the marginal product, which the employer will be forced to do in a competitive market, workers will make their optimal choices of effort. If there is an increase in the amount of fixed capital per worker while workers are kept on the same indifference curve, then the worker will choose more effort and a higher wage. Thus we will expect to see in a competitive labor market that workers with more expensive machinery will work harder than those not employing capital. But again the capitalist simply needs to set the payment schedule, as in the workshop system, and let the worker choose. If the capitalist forces the worker to put in too much effort, as at point B, she will be forced to pay wages higher than the marginal product of the worker to keep him on the same indifference curve. Thus the capitalist loses money.

If there is more than one worker and each needs to do the same amount of work per week or per year because there is a division of labor and work is flowing from one worker to the next, the capitalist may have to announce work targets for each worker, finding it too costly to allow complete freedom of effort to individual workers. But when the capitalist sets the collective work effort, the profit-maximizing choice will be the effort the average worker would have freely chosen. Suppose that a capitalist tries to impose a higher effort level than workers would freely choose, say again at point B in Figure 1. Now the workers, even though they could be paid a higher wage, are on a lower indifference curve, and must be paid more to get them back to their old utility level. Thus in a competitive market there is no profit to the capitalist in trying to distort workers' effort choices away from what they would have chosen outside the factory using the same technology.

This is an important prediction of the coordination theory of discipline. Discipline will not distort the average choice of work intensity away from what independent workers choose using the same technology. Workers in factories will not work any harder than those using the same technology in the workshop or in their homes. The popular belief that factory workers were forced to work harder than they wanted must be mistaken, because the economic factors determining the choice of effort are the same to both sets of workers.

A second prediction we can make about discipline as coordination is that the disciplined factory has lower costs because it reduces coordination costs. Factories had to pay higher wages to get workers to work

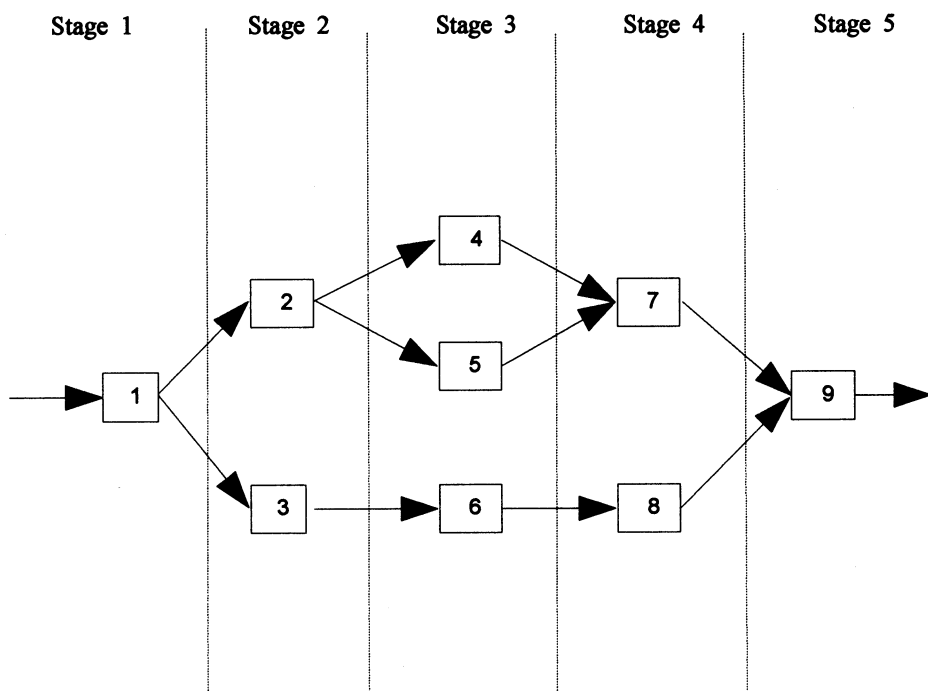


FIGURE 2

AN EXAMPLE OF THE STAGES IN THE DIVISION OF LABOR IN PRODUCTION

Notes: In this example there are nine workers, but the work flows through five stages in the division of labor.

Source: See the text.

in conditions of discipline. There must be savings in coordination costs that at least equal these increased wage costs.

A third prediction we can make with the coordination theory of discipline is that discipline will be imposed where the costs of not coordinating are high. One of the major costs of not coordinating workers' schedules tightly is that the firm has to keep inventories of work in progress between each stage of the production process to ensure that work does not halt because one worker is absent from the production process. Suppose the work in the firm flows through N stages in the division of labor, as is shown in Figure 2. If the annual output of the firm is pQ , then the cost of holding enough inventory at each stage of the production process so that production is not interrupted if any worker is absent for an hour would be

$$N \cdot r \cdot \left(\frac{pQ}{H} \right) \quad (3)$$

where H is the number of hours required to produce this output, and r is the annual cost of holding inventory (as a percentage of its value). Writing this cost as a fraction of the annual wage bill wL gives us

$$\frac{1}{H} \cdot \left(\frac{pQ}{wL} \right) \cdot Nr = \frac{1}{H} \cdot r \cdot \left(\frac{N}{\beta} \right) \quad (4)$$

where $\beta = (wL)/(pQ)$ is the share of wages in the total value of output of the firm.

Thus the cost of using inventory to coordinate workers, as a fraction of the wage bill, will depend on the number of stages in the division of labor and on the value of output relative to the wage bill (which in turn will depend on the capital per worker and on the value of raw materials). The more stages in the division of labor, the more piles of inventory there have to be kept per worker. The higher the value of the output relative to wages, the greater the capital cost of storing inventories relative to wages. Because r and H vary relatively little over time, we can index the inventory cost of not having discipline by N/β . Discipline should be chosen in industries where N/β is large. With no division of labor in production and only labor as an input, N/β equals 1, and the costs of not coordinating are minimal. Such industries were generally not disciplined. In power weaving in Britain circa 1840, where discipline was universally used, N/β equaled 31. Does this inventory cost parameter predict which industries are disciplined and which are not?

The fourth prediction of the coordination theory is that in a competitive labor market, the penalties for deviating from the set production schedule or the approved behavior will be related to the costs to the employer. In a competitive labor market, the penalty for being a few minutes late, for example, times the probability of detection will equal the cost to the employer. That is,

$$\text{penalty} \times \text{probability of detection} = \text{cost to employer} \quad (5)$$

This is another application of the principle that the wage equals the marginal product of labor in a competitive market. If the penalty is too high it will be bid down because firms will earn more by having irregular workers. They will therefore compete for these workers by offering to impose lower penalties for lateness. Because lateness is perfectly detectable, the penalty for being late should equal the cost. If capitalists were imposing penalties equal to two or three hours of a worker's wages for being late, this must represent the costs to the employer of such unpunctuality. Is this so?

A COERCION THEORY OF DISCIPLINE

The coercion theory of factory discipline argues that discipline was profitable primarily because it forced workers to increase their efforts,

not because it reduced costs by coordinating their labor. According to this view the employer mainly profited from discipline by increasing output per worker above what workers would deliver when employed on incentive systems. I will defer until later my discussion of how this strategy by employers could be profitable in competitive labor markets. Let us consider first the empirical implications of the theory.

Clearly the coercion view predicts higher efforts under discipline. Applied to a labor market in which firms are competing to hire workers, it has further interesting implications: it can give an account of why discipline was introduced only in the period of the Industrial Revolution and why it succeeded only with certain technologies. Suppose that workers under discipline produce an output of q_1 , whereas those who are undisciplined produce only q_0 . Disciplined workers, however, have to be paid a "disgust premium" of d per week in addition to the standard wage of undisciplined workers, w . Then if rK is the fixed cost per worker, the cost per unit of output without discipline will be

$$(w + rK)/q_0 \quad (6)$$

whereas the cost per unit with discipline will be

$$(w + rK + d)/q_1 \quad (7)$$

Discipline will be profitable only if

$$(w + rK + d)/q_1 < (w + rK)/q_0 \quad (8)$$

$$\Rightarrow \quad d < (w + rK)(q_1 - q_0)/q_0$$

If the required disgust premium d is large, then with no fixed capital, discipline would raise costs. The extra output generated by the disciplined worker is not enough to pay the disgust premium. But as the fixed capital cost per worker rises there is an extra saving from disciplining workers resulting from the increased utilization of fixed capital and the consequent lower fixed capital costs per unit of output. The capitalist can then pay the disgust premium and still have lower costs.

The coercion view can thus provide an alternative explanation of the adoption of discipline as a response to the new technologies of the Industrial Revolution. Greater amounts of capital per worker increased the savings from driving workers harder. This explanation has different empirical predictions from the coordination argument because it implies that discipline could be profitable even with the employment of techniques where there is no need for coordination. It also implies that even when techniques with an elaborate division of labor, and hence high coordination requirements, are employed there will be no discipline unless there is significant fixed capital per worker. Figure 3 shows the coercion interpretation of the imposition of discipline after the Industrial Revolution. Workers who are uncoerced produce output q_0 , and get

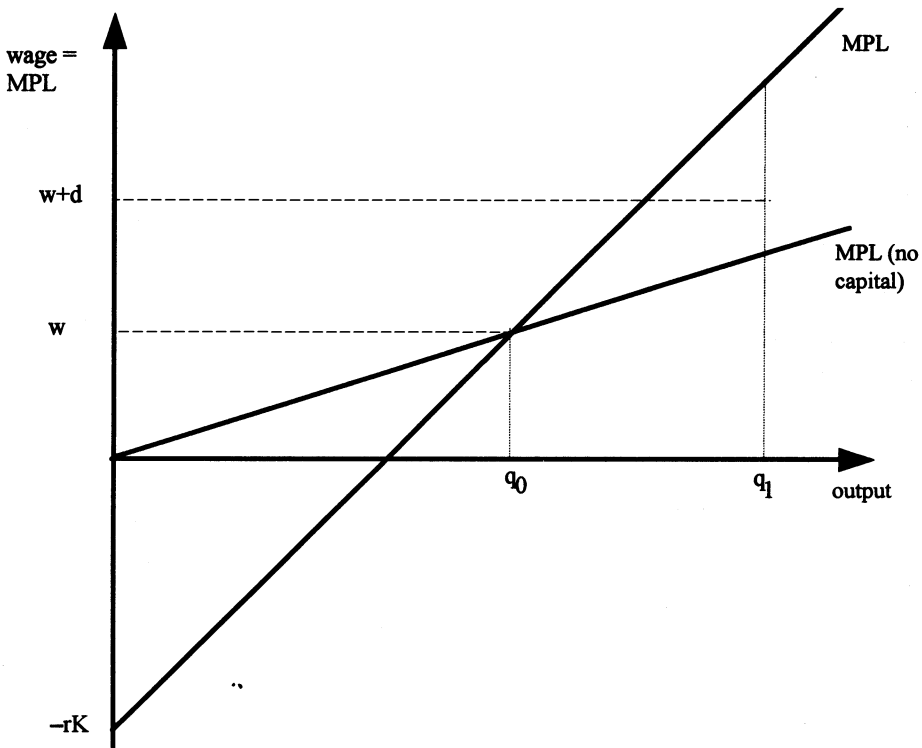


FIGURE 3

THE COERCION ACCOUNT OF DISCIPLINE

Note: With discipline output per worker increases. With no capital per worker this is not enough to pay the extra wage that must be paid to get workers to accept discipline. But with a large fixed cost per worker the rise in marginal product from extra output is greater.

Source: See the text.

a wage w . Workers who are coerced produce output q_1 , but they have a marginal product that exceeds $w + d$ only where there is significant fixed capital per worker. If there is no fixed capital per worker and if discipline raises output by 33 percent, the capitalist can afford to pay a premium of exactly this amount to workers who work under discipline. But suppose the fixed capital cost is 50 percent of the wage bill (under incentives). Then the capitalist can pay workers under discipline 50 percent more than free workers. Thus the coercion view predicts that discipline will only be used with techniques where the fixed capital cost per unit of output is high compared to the wage cost. The coercion theory also predicts that savings on coordination costs alone will not be enough to pay the disgust premium associated with discipline. Finally, the theory implies that the penalties on workers for deviating from the approved production schedule will exceed the costs these deviations impose on the firms; for if discipline is adopted to override workers'

TABLE 1
COORDINATION AND COERCION THEORIES: PREDICTIONS

	Coordination Theory	Coercion Theory
Effect of discipline on worker efforts.	No effect	Increased effort
Source of cost savings from use of discipline.	Lower inventory and power costs	Lower capital costs per unit of output.
Relation between penalties and costs for worker actions.	Penalties = Costs	Penalties > Costs
Technologies where discipline is found.	N/β is high	Large fixed capital costs, rK , relative to wages, wL

Notes: As discussed in the text N/β measures the value of the work flowing past the average worker each hour relative to the wage he receives.

Source: See the discussion in the text.

moment-to-moment choices, then there is no reason for the penalties imposed to equal only the costs incurred as a result of deviant behavior.

Table 1 summarizes the views of the two theories on the four empirical issues I have discussed.

DID DISCIPLINE INCREASE WORK EFFORTS?

What happened to work efforts in establishments where discipline was imposed compared with firms using the same technology under conditions of incentives? We can answer this question in various ways. The first is by considering the weekly wage of workers in factory and nonfactory settings compared to the net-wage payment per unit of work. If q is the weekly output, w the weekly wage, and v the payment per unit of output, then

$$q = w/v \quad (9)$$

Factory workers in the early nineteenth century were typically paid much more *per week* than handworkers in homes and in undisciplined shops. For example, the Hand Loom Weaving Commissioner for the South of Scotland noted that "the weavers in factories average nearly double what the weavers make on the same cotton fabrics when woven at home."³² Table 2 lists the weekly wage with and without factory discipline in a variety of cases. The weekly wage premium of the factory was always substantial, equaling nearly 60 percent on average. The higher weekly wage could have resulted from a greater amount being paid in wages per unit of output (because the factory economized on coordination costs). But although there is evidence that the factory paid a higher piece rate, the wage premium per unit was much less than 60 percent, suggesting most of the difference resulted from greater efforts.

³² GB1839b, Part 1, p. 6.

TABLE 2
WAGE PREMIUM OF FACTORY WORKERS PER WEEK, 1838, 1839

Type of Work/ Year	Disciplined Factory (s. per week)	Shop (s. per week)	Domestic (s. per week)	Discipline Premium (%)
Hand woolen weavers, males, Gloucester, 1838 ^a	11.8	6.5	7.3	71
Hand woolen weavers, males, Yorkshire, 1838 ^b	18.7		12.7	47
Hand silk weavers, males, Coventry, 1839	20.0	13.5		48
Silk ribbon weavers, males, Congleton, 1839	15.0 ^d		9.6	56
Silk ribbon weavers, males, Leek, 1839	16.0 ^d		10.5	52
Silk weavers, males, Derby, 1839	19.9 ^d		10.25	94
Worsted weavers, women, Yorkshire, 1838 ^c	10.3 ^d		5.0	106
Cotton hand weavers, Scotland, 1838	9.0		5.75	57
Mean difference				66
Median difference				56.5

^a This is an average for weavers in six towns and for three types of cloth in each town.

^b The factory weavers in this case are not explicitly stated to be working under discipline, but as they were not required to pay loom rents this is likely. The firm also was noted as requiring "good conduct" from their weavers.

^c Young women and girls on power looms in the factory compared to six women working hand looms at home. Males on hand looms earned on average 9.5 s., less than young women in the factories.

^d The factory looms were powered.

Source: *GB1840b, Part 5*, pp. 382–95; *GB1840a, Part 3*, pp. 530–33, 562–66; *GB1840a, Part 4*, pp. 277–83, 338–39, 346, 348–50; and *GB1839b*, pp. 6–8.

In Gloucester, for example, there was a substantial woolen weaving industry in the 1830s, with about 911 weavers employed in 32 disciplined factories and about 1,755 outdoor weavers.³³ The net-wage payments per piece on three types of cloth in six different towns are shown in Table 3. As can be seen, the workers who retained their independence—the master weavers who owned their own looms and the journeymen who worked for the master weavers in undisciplined workshops—received on average about 20 percent less per piece of the same type of cloth in wage payments. The factory labor force was composed about equally of former masters and former journeymen.³⁴ Similarly in Leeds, only one employer seems to have employed weavers in a factory under conditions of discipline. On a given type of cloth, the wages of these weavers per "string" were 30 d. with no deductions. Outdoor weavers

³³ *GB1840b, Part 5*, pp. 376, 386.

³⁴ Interestingly despite the higher piece rates in the factory only 11 of 195 factory weavers interviewed felt that their condition had been improved by the factory system.

TABLE 3
NET PAYMENT PER PIECE OF FACTORY AND OTHER WEAVERS, 1839
(shillings per piece)

Cloth/Location	Factory	Outdoor Weavers	
		Master ^a	Journeyman
Coloured, 1800 beer ^b			
Chalford	33.0	29.0	26.6
Dursley	34.9	29.0	26.6
Nailsworth	30.7	24.5	23.0
Stonehouse	36.2	28.5	27.2
Stroud	39.6	24.0	23.8
Wootton	38.2	34.8	31.0
White, 1800 beer			
Chalford	29.0	21.5	21.7
Dursley	28.0	27.0	25.4
Nailsworth	22.0	16.0	18.1
Stonehouse	30.5	26.0	25.4
Stroud	32.2	21.7	22.0
Cassimere, 1300			
Chalford	28.6	27.1	19.3
Dursley	28.2	25.0	18.1
Stonehouse	27.5	27.0	20.5
Stroud	32.3	26.9	19.5
Overall as a % of column 1.	100	83	74

^a This is calculated by deducting an implied loom rent of £6.95 per year for broad looms and £2.6 for narrow looms.

^b The beer denotes the number of threads in the warp. The master weavers owned their own looms and other looms on which they employed journeymen.

Source: *GB1840b, Part 5*, pp. 392–95.

were paid at maximum 28 d. for the same cloth, and the deductions for loom rent, floor space, heat, and lighting would amount to 3 d. per “string”, showing that the domestic wage per length of cloth was only 83 percent of the factory wage.³⁵

In the silk-ribbon weaving trade we also see a piece-rate premium paid to workers to accept factory discipline. In 1838 the net hand price per piece in Congleton was 12.8 d., whereas the equivalent factory piece rate for power looms was 16 d. In Leek, the hand rate was 13.8 d. and the factory rate 16 d.³⁶ The handlooms were very similar to the power looms in construction and operating speed, the only difference being that the power looms had more shuttles per loom, so they could produce more ribbons at once. In Congleton, there were 254 silk-ribbon weaving power looms in factories under conditions of discipline in 1838, and 100

³⁵ *GB1840a, Part 3*, pp. 531–34.

³⁶ *GB1840b, Part 5*, pp. 338–39, 345–46. The net hand price is calculated by deducting loom rent and the rent of floor space. The factory rate has been multiplied by 1.23 to reflect the fact that the factory looms, which were powered, had more shuttles than the hand looms and hence produced 23 percent more cloth per hour.

outworking handlooms. The outdoor weavers again earned 83 percent of the factory piece rate.

The premium paid to work under discipline was attached to the actual discipline of the factory, and not to the mere fact of working outside one's own home. For example in Bedworth, in the Jacquard weaving of silk, workers were employed either on owners' looms at home or in shops where there was no discipline, or in their own homes on their own looms. The net price paid per half-piece of cloth (the traditional week's work) was the same for the home and workshop workers.³⁷ Similarly in Coventry, there were many silk weaving shops in 1838, but the weavers were employed under conditions of lax discipline.³⁸ There were 1,983 looms in the loom shops, and 3,967 looms worked by families or small owners, some of them employing journeyhand weavers on their looms.³⁹ The Coventry pay scale on Jacquard looms gave a worker in the shops a net wage of 15.1 s. per piece, a worker employing his own looms at home 17.6 s. (once loom rent and other expenses were deducted), and a journeyhand worker weaving at one of the domestic masters houses 15.1 s.⁴⁰ The loom owner who worked his own loom got as much labor income per piece as a journeyhand employed in the domestic setting or a worker employed in one of the larger loom shops. There was no premium paid for working outside the home in these undisciplined shops.

In the machine knitting industry, there were estimated to be more than 42,000 frames in operation in Britain in 1842. Many of these frames were in the homes of operatives, but a large number were in shops of as many as 40 to 60 frames. In all of these shops there was a complete lack of discipline. The payment per dozen socks to the outworker was universally as great or slightly greater than the payment to the shop-worker (both workshop and domestic workers paid the rent on their machines). No wage premium per unit of output had to be paid to congregate workers in such undisciplined shops.

Thus there was a wage premium per unit of output that was offered workers to accept conditions of discipline, which seems to have been about 17 percent of the wage of factory workers. The premium shows that what workers objected to was not their physical congregation in factories, but the imposition of discipline they encountered there. Because the advantage in weekly earnings by factory workers was about 60 percent, the much smaller piece-rate premium implies that the

³⁷ *GB1840b, Part 5*, p. 280.

³⁸ One factory owner noted, "The men are not tied to very close hours. . . as they are paid by the piece, and therefore needs no very strict surveillance, they cannot say precisely what the hours are." *GB1840b, Part 4*, p. 283.

³⁹ *Ibid.*, pp. 41, 47.

⁴⁰ *GB1840b, Part 5*, pp. 277-80.

factory workers were producing 36 percent more output per week than undisciplined workers using the same equipment.

There is also plenty of direct testimony that disciplined workers produced more.⁴¹ The quoted rates of increase of work intensity with discipline vary widely, but all suggest a substantial increase. In the Derby silk weaving industry, for example, the workers reckoned that if a worker worked continuously during scheduled factory hours he would produce 48 percent more than the average undisciplined handworker.⁴² These results show that if workers in factories had continued to work the traditional hours of the hand industries, they would have worked only 45 to 53 hours per week, instead of the 60 to 70 demanded by the disciplined factories.

Another source of evidence that discipline increased labor intensity comes from experiments in Britain in the early twentieth century that show that with a given set of workers, the imposition of tighter discipline increased weekly production, even for workers on piece rates. Eight workers working fixed hours on piece rates were subjected on alternate days to a regime of imposed silence. On the days of silence they produced 7.6 percent more, though they greatly disliked these days. Ten workers on piecework had one worker isolated from the others on a rotating schedule. The isolated workers produced 36.4 percent more on the same task than when with the group, but again they disliked the periods of isolation. In another study, a group of workers increased their output by 6.7 percent on days when silence was imposed.⁴³ These results suggest that discipline would indeed have a causal role in driving up labor effort.

WHY WAS THE DISCIPLINED FACTORY MORE PROFITABLE?

We see above that there is evidence that discipline increased work efforts. Here we pose a slightly different question. Could savings in coordination costs alone explain the higher piece rates that had to be paid to disciplined workers? I have estimated that the piece rate for workers in disciplined factories was 17 percent higher than for workers in comparable undisciplined settings. Another way to estimate the

⁴¹ *GB1840a, Part 3*, p. 634; *GB1840b, Part 4*, pp. 10, 283–84; *GB1854–55*, pp. 153–54, 174, 193, 199, 362; and Mann, *Cloth Industry*, p. 243. The reason for the greater factory efforts may have been that the domestic or workshop workers combined their work with small-scale agriculture or other by-employments. But if it was economically desirable that with more capital-intensive techniques workers should concentrate on one occupation, the market system would have led to that outcome without any need for factory discipline to achieve it. Independent workers faced with higher rental fees for more expensive capital would themselves have chosen to concentrate on one occupation. Whatever output per worker was imposed in the factory would be chosen by independent workers operating the same technology.

⁴² *GB1840b, Part 4*, p. 349.

⁴³ Wyatt et al., *Effects*, pp. 11, 25; Wyatt et al., *Incentives*, pp. 36–37; and Burnett, *Experimental Investigation*, pp. 6–7.

premium is to consider what workers on piecework had to be paid in order to get them to submit to more disciplined work. Welsh miners at Dowlais in 1846 were offered a piece-rate premium of 3 to 10 percent simply to work regular shifts without any of the other concomitants of discipline, but the inducement was rejected.⁴⁴ Female laundry workers in the 1890s were offered premiums of 6 percent on their piecework wages if they kept factory hours, but many still worked irregularly. Piecework cigar makers got a bonus of 4 percent per year for keeping regular hours, as did ragpickers in Scotland, but many still absented themselves.⁴⁵ This evidence suggests that at a minimum, factories would have to pay 4 percent per unit of work to get workers to submit to conditions of discipline. If the purpose of the factory was merely to coordinate, did savings in coordination costs allow factories to pay 4 to 17 percent more per unit of output?

To answer this question consider factory steam weaving in cotton. I choose cloth weaving because of the wealth of information on costs and techniques in that industry and because it underwent a complete transformation from undisciplined to disciplined methods of work organization with the introduction of powered looms during the Industrial Revolution. Cotton weaving was also an industry where the transition to discipline in the early nineteenth century occurred in a competitive labor market, without any potential distorting influences from labor unions or employers associations.

Let there be two weaving mills competing in the same labor and output markets. The first, ARKWRIGHT MILLS, is organized with strict factory discipline.⁴⁶ Workers follow a given schedule of six days of 11 hours per day, with no socializing at work and a constant work pace. Workers are fined or dismissed if they turn up even five minutes late for work. The second, FREEDOM MILLS, allows workers as much freedom as possible consistent with producing the same 66 hours of output per week. It uses the workshop type of organization. Workers can come and go when they want; they can behave as they want, and they can vary the intensity of labor when they wish. To give the workers this freedom the mill opens for 79.2 hours per week (13.2 hours per day instead of 11) and simply requires that by the end of the week each worker turn in a given stint of work.⁴⁷ With this arrangement, even though workers are required to turn in 66 hours of work, they can take off all of any day in the week or they can begin work up to 2.2 hours late each morning. They can come and go from the mill as they wish. The

⁴⁴ Lambert, "Drink," p. 296.

⁴⁵ *GB1893*, pp. 18, 296.

⁴⁶ Arkwright was a noted exponent of the virtues of factory discipline.

⁴⁷ These hours are chosen so that each worker can have one complete day off in FREEDOM MILLS if they so wish.

TABLE 4
COST OF PRODUCING 100 YARDS OF COTTON CLOTH ON THE COORDINATION
THEORY, 1840
(pence)

Costs	ARKWRIGHT MILLS	FREEDOM MILLS
Labor	57.7	47.3–55.4
Coordination costs		
Supervision	3.6	4.3
Power, heat	3.7	4.1
Precautionary inventory	0.0	0.7
Capital costs: fixed capital	19.2	19.2
Total costs	84.2	73.7–83.8
Output per worker	100	100
Wage per piece offered in a competitive market	100	97

Notes: The factory has 128 looms attended by 64 weavers. The only costs listed are those that are affected by different work organizations. The marginal cost of power is calculated to be 55 percent of the average cost due to fixed costs in heating up the boiler and because each machine running adds to coal usage.

Sources: Montgomery, *Cotton Manufacture*, pp. 114–25, 208–19; Ure, *Cotton Manufacture*, pp. 305–14; and Lardner, *Steam Engine*.

only difference between ARKWRIGHT MILLS and FREEDOM MILLS is the tighter coordination of workers in the disciplined mill.

There are three costs incurred by the looser coordination in FREEDOM MILLS. Because the factory opens longer, there has to be more supervisory input per worker. Also because of the longer hours of operation, steam power and heating have to be provided for a longer period each day; that is, more has to be paid for the engineman and for coal. Finally, if there is a division of labor, larger inventories of work in progress have to be kept so that workers are not prevented from working by a lack of materials when workers earlier in the process are not present. Unlike the forebodings of Ashworth quoted above, even with a complex division of labor, the mill will not grind to a halt when one worker is absent as long as sufficient inventory of work in progress is kept at each stage of the production process.⁴⁸

In Table 4, the first row records the labor bill in each of the mills. As can be seen, FREEDOM MILLS starts with a significant labor cost advantage of between 4 and 17 percent. The disciplined mill has lower supervision and power costs, however. But these extra costs in FREEDOM MILLS are very small relative to the wage savings. For each extra hour of operation the power costs are 0.06 percent of weekly wages and the supervision costs 0.09 percent of wages.⁴⁹ With the

⁴⁸ Both Marglin, "What Do Bosses Do?" and Williamson, "Technology," make this point.

⁴⁹ Coventry silk weavers in independent cottage factories in the 1850s paid about 0.1 percent of their net weekly earnings for the running costs of steam power per hour (Prest, *Industrial Revolution*, p. 113). In cotton mills around 1910, the power costs of steam-powered mills per hour

advent of electric power in the late nineteenth century, power could be turned on for each machine individually, eliminating most of the additional power costs from extra hours of operation. The continuation of discipline even after machines were individually powered suggests that power costs cannot be the key to explaining factory discipline. Because supervision costs were of equal magnitude in handpowered factories, neither can extra supervision costs from indiscipline be the key.

In FREEDOM MILLS, 13.2 hours of extra inventory will be the maximum required at each stage of the production process as a result of the looser discipline. If the worker has to meet a target at the end of each week of 66 hours output and the workshop opens for 13.2 hours each day, no worker can get more than 13.2 hours ahead of any other in his work. Thus to ensure that each worker not be held up because the worker preceding him in the production process worked more slowly, there would have to be no more than 13.2 hours of inventory at each stage of the process.

Using equation 4 the extra inventory cost of the FREEDOM mill will be the cost of keeping 13.2 hours of inventory per worker, that is

$$\frac{13.2}{3300} \cdot r \cdot \left(\frac{N}{\beta} \right)$$

The annual cost of holding inventory, r , would be the rate of return in manufacturing, which we can generously consider as 10 percent, because cloth does not deteriorate and has very high value in relation to its volume (thus requiring little storage space).⁵⁰ In factory weaving there were three and one-half stages in the division of labor. Warping, sizing, and winding were each done to half the material, which was all then woven and inspected. Since β , the share of weaving wages in the value of final output, was about 0.112 in weaving, the cost of the indiscipline of FREEDOM MILLS as a fraction of wages is a mere 1.25 percent. Thus the inventory cost of allowing workers in power weaving in 1840 the options of taking up to one day a week off or of coming to work each day up to 2.2 hours after the mill opened was a trivial fraction of wages. On the basis of the coordination theory, if workers valued freedom the employers could give it to them very cheaply.

In practice, the amount of inventory estimated by this formula is an upper bound. For example, workers tended to take leisure at the beginning of the week, and almost all would be at work on Thursday, Friday, and Saturday. This regular pattern of absences would reduce inventory requirements. Also there were frequently many workers at

of operation were only about 0.065 percent of total weekly wages (Clark, "Why Isn't the Whole World Developed?" p. 146).

⁵⁰ The interest rate for long term secured loans was only about 3.5 percent.

TABLE 5
COST OF PRODUCING 100 YARDS OF COTTON CLOTH ON THE COERCION
THEORY, 1840
(pence)

Costs	ARKWRIGHT MILLS	FREEDOM MILLS
Labor	57.7	47.3-55.4
Coordination costs		
Supervision	3.6	5.6
Power, heat	3.7	5.4
Precautionary inventory	0.0	2.2
Capital costs: fixed capital	19.2	25.6
Total costs	84.2	86.1-94.2
Output per worker	100	75
Wage per piece offered in a competitive market	100	79

Sources: See Table 4.

each stage of the production process, which would smooth the fluctuations in output from each stage within the week.

The enumerated savings are all that would be generated by factory discipline according to the coordination theory. The inference to be drawn is that the disciplined factory could not survive in a competitive labor market. The total costs of ARKWRIGHT MILLS in Table 4 are greater than those of FREEDOM MILLS. Indeed, even if the premium that had to be paid per unit of output to discipline workers to give up their freedom was as little as 3 percent, the disciplined factory could not survive. Given my estimated premium of between 4 and 17 percent, there would be no way for the disciplined factory to make profits.

The previous example also indicates that if these coordination costs were significant, the remedy would be for the capitalist to make the workplace available to workers for a shorter period. This would eliminate most of the coordination costs without the imposition of such objectionable features of discipline as locking the factory doors during work hours, banning social intercourse at work, and placing limits on acceptable conduct.

Can the coercion theory explain the increased profits from imposing discipline? Table 5 shows the relative costs of the ARKWRIGHT and FREEDOM mills according to the coercion theory. We have seen that although disciplined workers were paid 56 to 66 percent more per week, they were paid less than 20 percent more per piece. This implies they produced about 30 to 38 percent more per week. Where discipline is not imposed, as in FREEDOM MILLS, it is not possible to match the output per worker of the disciplined mill, and output per worker is only 75 percent of what is achieved in the disciplined mill. This implies that where the disciplined mill workers work a full 66 hours, the undisciplined workers put in only 50 hours per week. The lower output of

FREEDOM MILLS drives up costs sharply. Most importantly, fixed capital costs increase by 33 percent because the machines in the disciplined mill produce one-third more and the lower work effort also drives up overhead costs from supervision, power, and inventory. Table 5 shows the total effects on costs. Now ARKWRIGHT MILLS has lower overall costs than the undisciplined mill, despite the latter's lower labor costs. The kinder, gentler capitalist owner of FREEDOM MILLS would be driven out of business by his authoritarian competitors.

Suppose that cotton weaving involved no fixed capital. Then most of the cost savings from increased efforts under discipline would be lost, and ARKWRIGHT MILLS would not survive in a competitive labor market. The condition for discipline to succeed is that there exist significant fixed capital costs per worker. Houldsworth, whom we noted as having employed hand mule spinners with incentives and power mule spinners with discipline, noted that

"it must always be of importance that work-people should be steady and attentive to their work, but as the capital occupied by a hand-spinner was so much less than that which is now occupied by a power-spinner, it of course was not of the same importance."⁵¹

TECHNOLOGY AND DISCIPLINE

The final test of the competing explanations of discipline is to consider what happened during the Industrial Revolution to techniques that had high inventory costs because of the absence of coordination, but small amounts of fixed capital per worker. The coordination theory suggests that discipline would be used with these techniques also. But the coercion theory argues that these techniques would remain undisciplined, because only small gains would be achieved through improved coordination alone. Unfortunately, there are no comprehensive data on comparative coordination and fixed capital costs of different technologies in the nineteenth century that would allow for a test of the two views. But we can examine specific industries that combined an extensive division of labor with low fixed capital per worker.

The pottery industry in the nineteenth century is exactly the kind of industry that falls in this category. The typical article would start with preparing the clay, grinding flint, and mixing a paste of clay and flint, which took six steps. The paste would then be stored to mature. Before being formed, the paste would be wedged and beaten to make it smoother and to remove air bubbles. Then a baller would weigh out the correct amount, a thrower would form the rough shape, and a runner would take the piece to a drying oven. When sufficiently dry, the piece would be given its final shape by the turner, and a handler would then apply handles and other noncircular elements. The piece would then be

⁵¹ *GB1816*, pp. 234-35.

dried and placed in clay vessels, called saggars, for the biscuit firing. After being removed from the biscuit oven, the piece would be inspected by sorters to remove defective ware before being scoured by fettlers or towers to remove imperfections picked up in the firing. It would then be placed in the biscuit warehouse. It could be decorated in several ways. One was by printing a pattern from a paper transfer, in which the paper was removed by washing the ware in water before dipping it into an alkaline solution. The glaze was applied in the glost oven after the ware was placed in another saggar. On removal from the oven, the piece was inspected again, polished, and finally crated for transport. One ceramic item could easily pass through 29 different hands in this process.

The extreme division of labor in pottery is reflected in a statement by a manufacturer in 1908 that "there would be fifty, sixty, or a hundred different departments, and work passes from one department to the other. In many of those departments the thing is simple, the person works alone."⁵² Similarly, a 1913 survey of a group of factories found 87 occupational groups in the production of earthenware.⁵³ This extensive division of labor meant that the value of work flowing past a given worker would be very high in relation to his wage. "In many cases the value of the finished article is 100 times the individual wage for doing a portion of it."⁵⁴ On the other hand, fixed capital per worker was very small because, apart from the steam-powered grinding machinery and a few steam-powered potter's wheels, most of the work was done by hand or with simple handpowered machinery.

We have already noted that a measure of the inventory cost of not coordinating across industries relative to wages would be N/β where N is the number of stages in the division of labor and β is wage share in total costs. For cotton weaving N equals 3.5 and β equals .112, so that N/β equals 31. In the mid-nineteenth century the value of output was about double the wage bill, so that β equals .5 in pottery.⁵⁵ Though there were at least 29 steps in the division of labor, some of the work would be done by coordinated work teams such as the thrower and the runner who took the ware to the drying oven. But there were still at least 20 independent sets of workers involved in the production of simple earthenware at a large factory. Thus N/β equals 40, which is higher than in power cotton weaving. The cost of the FREEDOM mill arrangement in the potteries would be 1.6 percent of wages from extra inventory alone, compared to 1.2 percent in power weaving. There were also some extra fuel costs from keeping the factories open longer than necessary

⁵² GB1908, Q 17,077.

⁵³ Whipp, *Patterns*, p. 48.

⁵⁴ GB1908, Q 17,087.

⁵⁵ It is lower than in weaving because the value of the raw materials in pottery was small, and there was very little capital per worker. See Thomas, *Rise*, p. 133.

because the potteries did use some steam power and fuel was used to operate drying ovens and to heat workshops. The total coordination cost of indiscipline in the potteries cannot have been any less than the 3 percent of wages calculated for the cotton weaving mill.

For individual workers the relative inventory cost of allowing them freedom to determine their work hours and pace is measured by the value of work flowing past them each hour relative to their hourly wage. For power weavers this ratio was 6.7. Platemakers, on the other hand, could make 70 saucers per hour, which would be worth, when completed, about 262 d. The hourly wage of the throwing team was about 6.9 d., implying that the ratio of value to wage was about 38.⁵⁶ The inventory cost of having undisciplined throwers was about five times the cost of having undisciplined weavers.

Yet potters were allowed their traditional freedoms well into the twentieth century. In the 1840s some pottery factories employing undisciplined labor were open for 84 hours per week, even though the amount of work done probably did not exceed 60 to 63 hours. The undisciplined potteries must have kept large stocks of inventory to accommodate the uncoordinated workers. The coordination theory again fails. But the indiscipline of the potters is consistent with the coercion theory, given the very small amounts of fixed capital per worker in the industry.

Pinmaking in the nineteenth century also had an extensive division of labor but very little capital per worker, as the machinery was simple and handpowered. In the mid-nineteenth century pinmaking involved 14 distinct steps. The value of the output was again about double the wage bill, which implies that N/β equaled 28, nearly as high as in power weaving.⁵⁷ Yet the pin factories of Warrington in 1843 were open for 13 or 13.5 hours daily, and within these limits, the workers had "no restrictions as to time . . . they come and go just when they please."⁵⁸ On Mondays less than half the workers were at work.

The indiscipline of miners is also consistent with the coercion theory. Until 1914 mining in Britain was largely a hand industry with a surprisingly small amount of fixed capital per worker. Thus in the late nineteenth century, fixed capital costs per ton of coal at the pithead were only about 20 to 25 percent of wage costs.⁵⁹ Compare this to capital costs of 35 percent of wages in powered cotton weaving by 1840, and even more in powered spinning. Increasing output per miner through strict discipline would not have saved enough in capital costs to

⁵⁶ *GB1843, Second Report*, pp. C 4, C 48; and Drakard and Holdway, *Spode Printed Ware*, pp. 36-37.

⁵⁷ Ure, *Dictionary*, pp. 961-62; and Babbage, *Economy*, pp. 166-68, 184-85.

⁵⁸ *GB1843, Second Report*, p. 59. The potteries, which also had loose discipline, employed at least 25 different specialists in manufacturing simple ware.

⁵⁹ Church, *History*, pp. 53, 176-79, 502-9.

pay a discipline premium comparable to that paid in cotton weaving and other industries in the nineteenth century. Moreover, fixed capital in the mines was largely embodied in the shafts, the winding machinery, and the underground roads. Sixty percent of the workforce in the mine in the late nineteenth century were faceworkers who hewed coal by hand. Because hewers were undisciplined they produced less per week than if they had been forced to work at regular hours under close supervision. But deficiencies in coordination could be compensated by giving each miner a smaller part of the coal face to work. In effect, the fixed cost per hewer was quite small, despite the extensive use of steam power in the industry to wind up the coal. Had all coal hewers decided to work 33 percent more it would not have been possible to get more output out of a given pit, because of the limited winding capacity of the shaft. There were coordination costs from the indiscipline of coal hewers, but few capital costs; consequently, miners were undisciplined.

PENALTIES AND COSTS WITH DISCIPLINE

In a competitive labor market, no employer will be able to impose penalties for deviations from approved conduct that exceed the cost to the firm of these deviations. Otherwise they will lose profitably employed workers to other enterprises. Consider the fines or lockouts that were imposed in industries such as cotton weaving when workers were a few minutes late to work. A not unusual fine would be two hours wages for ten-minutes lateness, about 3.6 percent of the weekly wage. Or, because of fear of prosecution under the Truck Acts, employers would simply prefer to lock the workers out for a couple of hours if they were ten minutes late. Did a worker who came five minutes late conceivably impose costs on the firm equivalent to two hours wages?

Suppose we offered workers who were often penalized for being late the following contract. They would not be penalized for being up to an hour late because the factory would be open to them an hour longer each day. But they would have to pay the cost of keeping the facility open longer; that is, they would have to pay the cost imposed on the firm by their irregularity as compared to the mass of workers. The cost that would have to be charged to each worker if all had to use this option would be 0.023 percent of their weekly wage for each day they came late, based on the figures in Table 4. Now only some workers, let us suppose 10 percent of the labor force, would be late on any day. Then the workers who came late would have to pay 0.23 percent of their weekly wage for the extra costs they imposed each day by forcing the firm to stay open longer to accommodate them. For a 66 hour week this would be equivalent to a penalty equal to nine minutes of work for each hour a worker came late. With this arrangement, the workers who were the most regular would get paid slightly higher wages than those who

were irregular. But the difference would be negligible. The required penalties imposed on irregular workers would be very small, less than one-tenth of those actually imposed. Disciplined factories thus consistently violated what would be expected in a competitive labor market: that workers who came late would be penalized in accordance with the costs they imposed on the firm.

From the perspective of the coercion theory of discipline, employers would not exact small penalties for coming late to work because the whole point of discipline is to impose heavy penalties for deviations from the planned schedule, forcing workers to do more work than they might choose at any point in time.

WHAT MARKET IMPERFECTION MAKES COERCION POSSIBLE?

We have seen that discipline appears to have involved crucial elements of coercion. Such a finding implies labor-market imperfections. Workers cannot be profitably coerced in competitive labor markets. There are two reasons for this. Attempts to drive workers above the efforts they would freely choose results in employers having to pay wages in excess of workers marginal products and, consequently, incurring losses. Moreover, fully rational workers controlled by incentives would always be able to reproduce the workplace of disciplined workers, if this was what they desired, without having to suffer the unpleasant aspects of discipline. FREEDOM MILLS can always achieve the same work intensity as ARKWRIGHT MILLS with rational workers simply by setting a minimum quota of work to be performed each week that is the same as the disciplined factory actually achieves. Simply by raising the stints of undisciplined workers most of the wage gains of the nineteenth-century disciplined factory would have been attainable.

Alternatively, factories could have employed one of the compensation systems then in practice that encouraged workers to economize on the use of capital. One of these involved charging a lump-sum "machine and power" rent each week, as was done with many handpowered machines, and paying a higher piece rate. With the increase in capital intensity, the fixed charge per worker would be increased, encouraging the worker to utilize the capital more intensively. There were certainly a few cases in which powered machinery was accommodated by simply increasing the "rent and charges," without depriving workers of their traditional freedoms. Such a rental system lasted at least until the 1890s in cutlery grinding in Sheffield, with the fixed charge for power and factory space averaging almost 33 percent of the net wage.⁶⁰ It is reported that as late as 1907, some clothing workers paid weekly rent

⁶⁰ GB1892, Q. 19,512.

and power charges for sewing machines used in factories; and even today hairdressers (and taxi drivers) sometimes pay a flat fee for their chair (or taxi) and collect all the customer's payment, leaving employers indifferent to how much they work.⁶¹ If workers were minimally rational, both these schemes—stints and fixed rental charges for capital—should have allowed firms modeled by FREEDOM MILLS to offer workers most of the traditional freedoms of the workshop without significantly reducing the wage the factory could offer.

What is the nature of the labor market imperfection that accounts for employer coercion of workers? Stephen Marglin in "What Do Bosses Do?" suggests that it is the rising labor supply curve faced by individual firms.⁶² Employers force workers to work harder than they wish in order to avoid hiring more expensive labor. This explanation is unsatisfactory on a variety of grounds. It does not explain why discipline was only adopted with some techniques during the Industrial Revolution. It also implies that individual firms faced a more upward sloping supply curve for labor with the rise of new industrial centers such as Manchester, even though their labor markets seem to have become deeper. Moreover, miners remained largely undisciplined even though isolated pit villages would be the classic case of markets with upward sloping labor supply curves.

Another possible imperfection in labor markets would be that factory workers had the power to extract from their employers a premium above the market-clearing wage. The market for domestic and workshop labor seems to have been competitive. Domestic workers had little or no ability to enforce higher wage payments on employers. Workers who were disposed to undercut agreed-upon wage scales would be impossible to observe, given that they took work from different manufacturers, and did the work in their own workplaces. But perhaps the congregation of workers in centralized workplaces with the advent of mechanical power increased their capacity to enforce collective agreements with employers. If such workers were able to extract a wage premium from their employers, then the latter would no longer be bound by the logic of the competitive market in setting work rules and work intensity. If Manchester mills could not compete against each other by reducing wages, they could nevertheless compete to see who could extract the most work at premium wages. Given they had to pay a fixed piece rate, as in the weaving industry in the late nineteenth century, they could reduce capital costs by driving up output per worker. And unlike what would happen in a competitive market, the attempt to drive workers would not result in higher labor costs.

⁶¹ Black, *Sweated Industry*, p. 42. In some woolen weaving mills in 1893 piecework weavers paid a rent to have warp-stop mechanisms, which increased output attached to their looms (*GB1893*, p. 144).

⁶² Marglin, "What Do Bosses Do?"

The problem with this explanation is that it does not explain why some centralized workers such as in potteries, mines, framework knitting, and cutlery remained undisciplined. It also does not explain why the same employer would employ some of their factory workers under discipline and others under incentives. Moreover, if all the firm cared about was output per worker, it could simply set output targets and retain only the most productive workers, leaving it up to them to achieve the targets. There would have been no need to fine heavily for lateness, lock workers out, or penalize workers for misbehavior at work, as long as output quotas were set.

I suggest that the real labor-market imperfection that accounts for employers' recourse to the coercion of their workers may actually be found in a limitation on worker rationality. The coordination theory assumes that the worker is able to freely choose the effort level that will maximize his or her satisfaction, $U(w, e)$. However, an examination of worker choice under conditions relevant to the issues discussed in this article would seem to challenge this assumption. Suppose the worker at week's end has an optimal amount of effort he wishes he had put in, e^* . But also suppose that the worker is imperfectly able to achieve this optimal level of effort. Suppose, finally, that there is a split between his short-run goals and his long-run goals, such that in the short run he would rather take more leisure than in the long run. One way we can conceive of this split occurring is to remember that almost all production activities yield not current satisfactions but some future reward to which this moment's effort contributes some small increment. In a world of perfectly rational actors this presents no difficulty. The individual simply decides whether the disutility of each current effort is greater than the resulting addition to utility at some later date, discounting future pleasures by some factor if necessary. A problem arises, however, if the utility of the future outcome resulting from the current small effort is indistinguishable from the outcome without that effort, because the difference is small and human perception and calculation are limited. This is the limitation on worker rationality. If the current moment's sacrifice makes no appreciable difference to the future, why make the effort? What is true of this moment's sacrifice is true seriatim of any other moment. Delaying the start of work in the morning by five minutes on a particular morning will not have any discernable effect on your earnings at week's end, nor will delaying another five minutes once you are already five minutes late. Consequently, workers face the analog of the classic free rider problem for public goods within their own person. Future benefits are the consequence of the collectivity of current sacrifices, but each momentary sacrifice in itself makes an insignificant contribution to these benefits. Why undertake any current sacrifices?

This problem has been noted in the context of savings behavior and is

the classic one facing dieters.⁶³ Dieters are asked to forego a current satisfaction for the sake of some small future weight reduction, a difference that on its own will be imperceptible. Each bite is inconsequential, and consequently almost all diets are unsuccessful. But if each bite were to produce some discernable outcome, the appearance of a corresponding small lump of flesh, dieting would be much easier. A solution to this problem of self-control is to arrange to raise the costs of avoiding each momentary sacrifice. This is exactly what factory discipline does for the workers. By locking them in the factory and banning most social intercourse, the possibility of seeking a few moments pleasure rather than working is eliminated. The cost of pleasure is not now some imperceptible future loss of income, but a heavy fine or the loss of one's livelihood. The workers dislike discipline, but they stay in the factory because at the end of the week their wage is 60 percent greater than that they can achieve without discipline.

What we can say about the psychology of worker choice under conditions of indiscipline remains, of course, only suggestive at this point. What we can assert, however, is that the triumph of the factory was through a means that is entirely unexpected to economists, though not perhaps to some historians. It was not a triumph driven purely by technology, but relied on subtleties of human nature that are not normally explored in economics.

CONCLUSION

I have argued above that the competitive advantage of factory discipline on the new machine-powered technologies of the nineteenth century was its ability to make a given set of workers work harder than they would choose under incentive systems. I estimate that discipline pushed up the work rate by about 33 percent in the nineteenth century. Workers disliked the imposition of discipline and to get them to work under such conditions, capitalists had to pay a substantial premium on weekly wages that I estimate to be about 56 to 66 percent. With the hand technologies of the eighteenth century and earlier, discipline could not succeed because the gains to the employer from increased output per worker were less than the wage premium. But when new techniques appeared, imposing substantial amounts of fixed capital per worker, more work per worker produced substantial savings through more intensive use of capital. Thus discipline displaced incentives, but only on the appropriate technologies. Where the technical conditions were right, incentive systems survived into the twentieth century.

⁶³ Thaler and Shefrin, "Economic Theory," discuss the use of precommitment devices in saving. The existence of any degree of pure time preference is itself a demonstration that individual rationality is imperfect.

Though factory discipline was coercive, forcing the worker to do what he or she would otherwise not have done, the worker was in no sense exploited by the introduction of discipline. The workers voluntarily entered into the temporary servitude of the factory and were appropriately rewarded for its disamenities with higher wages. Had they been able to exercise more self-control, factory discipline could have been avoided for most technologies in the nineteenth century.

Appendix: Data Sources and Reference Codes, Official Publications

- GB1816* Great Britain, *Children Employed in the Manufactories of the United Kingdom*, Sessional Papers, House of Commons, 1816, vol. 3.
- GB1834* Great Britain, *Children's Employment Commission. Supplementary Report*, Sessional Papers, House of Commons, 1834, vols. 19, 20.
- GB1839a* Great Britain, *Factory Inspectors' Reports*, Sessional Papers, House of Commons, 1839, vol. 42.
- GB1839b* Great Britain, *Reports of the Royal Commission on Handloom Weavers, Part 1*, Sessional Papers, House of Commons, 1839, vol. 42.
- GB1840a* Great Britain, *Reports of the Royal Commission on Handloom Weavers, Parts 2, 3*, Sessional Papers, House of Commons, 1840, vol. 23.
- GB1840b* Great Britain, *Reports of the Royal Commission on Handloom Weavers, Parts 4, 5*, Sessional Papers, House of Commons, 1840, vol. 24.
- GB1842* Great Britain, *Report of the Select Committee on Payment of Wages*, Sessional Papers, House of Commons, 1842, vol. 9.
- GB1843* Great Britain, *Children's Employment Commission. Second Report and Appendices*, Sessional Papers, House of Commons, 1843, vols. 13–15.
- GB1845* Great Britain, *Reports of the Royal Commission on Condition of the Framework Knitters*, Sessional Papers, House of Commons, 1845, vols. 23–25.
- GB1854–5* Great Britain, *Committee on Stoppages of Wages (Hosiery)*, Sessional Papers, House of Commons, 1854–5, vol. 14.
- GB1892* Great Britain, *Reports of the Royal Commission on Labour, Vol. 6*, Sessional Papers, House of Commons, 1892, vol. 34.
- GB1893* Great Britain, *Reports of the Royal Commission on Labour. The Employment of Women*, Sessional Papers, House of Commons, 1893, vol. 23.
- GB1907* Great Britain, *Report of the Committee to Enquire into the Probable Effect of a Limit of Eight Hours to the Working Day of Coal Miners*, Sessional Papers, House of Commons, 1907, vol. 15.
- GB1908* Great Britain, *Report of the Truck Committee*, Sessional Papers, House of Commons, 1908, vol. 59.

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