The Rise and Fall of the Factory System:

Comments on Joel Mokyr*

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Work, leisure, and learning have all changed radically since the Industrial Revolution. One key change has been the steady movement of the location of our labor out of homes and farms and into plants and offices. In this paper, Joel Mokyr provides a thorough and enlightening account of what happened, why it happened, the implications for household welfare, and the reasons why it may all change back again. A central theme of this paper is that each production process requires a specific type and amount of knowledge or human capital on the part of the workers who operate them. With primitive or traditional production processes, the knowledge necessary for producing doesn't change much over time, and can be passed down from generation to generation in the context of home production. This changed with the Industrial Revolution when processes became increasingly sophisticated, and knowledge transmission became critically important to maintain or establish competitive advantage. Instead of trying to move this wealth of new information to the workers in their homes, increasingly from the late 18th century, firm owners began to move workers to the information in factories. In the early 21st century — as information technology explodes across the internet — the optimal mix of location is swinging back to homes, just how far is an interesting question upon which many have speculated, including Professor Mokyr in this paper.

Factories may have dominated the industrial landscape by the end of the 19th century, but Mokyr is careful to remind us of two important structural characteristics. First, that mixed production systems never disappeared: household production for the market in fact remained quite important until the early 20th century in many industrial countries. And, second, that the division of labor was quite advanced in the pre-Industrial economies of the 16th to 18th centuries even though most production took place in homes. Specialization, then, did not necessarily require a factory system. *Firms* as well as *plants* could and did practice the division of labor.

Only plants — large, centralized workplaces — were truly new.

Implications for Workers Moving to Factories

Workers caught up in the transition to factory life experienced significant alterations in their welfare. Commuting, unsafe and unpleasant work conditions, and the loss of joint production of market and household services are but three ways that welfare was reduced in moving work to factories. But not every change was necessarily negative. Mokyr notes that for the first time, education, training, and human capital accumulation of the worker became a primary concern of the employer. This development had major implications for both household welfare and economic growth. Workers found themselves pressured — or presented with the opportunity — to acquire highly specialized knowledge pertaining to the firm's production techniques, as well as general knowledge of practical skills and of moral and social conduct.

This insight, which he credits to recent work by Oded Galor and Omer Moav (2000), suggests that it is not enough to pay low-productivity workers a low wage. Rather, there is a threshold of technical knowledge and skill that they must possess before they have *any* value to the firm. Marginal productivity of labor all of sudden became discontinuous with the advent of modern techniques around 1800. The marginal product of labor may have been near zero for a large number of potential factory workers.

The drive to educate the workforce was intensified by an *evolutionary* process that differentiated firms from competing household production. Firms, unlike households, can go out of business if they fail to keep up. This undoubtedly created a real spur to their desire to learn about new techniques and teach them to their workers. Although the argument applies to *firms*, Mokyr argues that by putting workers under one roof — in a central workplace or factory — it was easier to compare one's productivity and to identify those that were suitable for

improvement.

A puzzle, to which I return below, is why workers moved so easily out of homes and into the factories.

Old Explanations for the Rise of the Factory System

Three principal reasons have been advanced to explain why the factory system arose when it did to supplant the household-production system.

The first reason was that new technologies created economies of scale. Did these argue for greater *firm* size, or greater *plant* size? As Mokyr points out, some of these (finance, marketing, insurance) could be handled by extending the size of firms while maintaining household workers. Others, which used huge power sources, or large and intricate machinery, or continuous flow processes, required a centralized workforce. At least some of the movement to factories, then, was due entirely to the change in technology.

The second reason for centralization concerns incentives and monitoring costs. Essentially, new technologies made piece-rates inefficient. As production techniques became more sophisticated, involving higher fixed capital costs per worker and more valuable intermediate inputs, employers realized that it was in their interest to pay a time-rate so that the capital and inventory was not idle, nor used in an inappropriate or destructive manner. But this can only work when workers can be monitored. And they can be most efficiently monitored in a factory setting. Additionally, economies of scale stemming from new production technologies didn't just make it efficient to have more workers together. It also made it efficient to work in *teams* or on assembly lines. It is very difficult to pay a piece wage when the worker is part of a team (or even conceive of homework for the market in this case).

The third traditional explanation for the transition to a factory system is based on power

and exploitation. Capitalist employers, according to this argument, paid too little per piece, so workers would not work enough unless forced to do so. Bringing them together in a factory allowed the employers to more easily force extra effort. ("Capital is dead labour, that vampire-like, only lives by sucking living labour…. The capitalist maintains his right as a purchaser when he makes the working day as long as possible." Marx, 1906, p. 257-59.)

A New Explanation for the Rise of the Factory: The Transmission of Knowledge

Knowledge about how to produce things began to increase rapidly from the last quarter of the 18th century. This presented firms with a dual problem: how to *incorporate* existing knowledge into their production techniques; and how to *generate* new knowledge to maintain or establish a competitive edge.

Inevitably, specialization became finer. Mokyr points out that no single person, or even household, could know all there was to know about how to produce goods with the most efficient new techniques. In order to utilize new knowledge, workers had to divide the tasks and specialize. Recent research by Gary Becker and Kevin Murphy (1992) models the division of labor formally. As general knowledge H rises, in their model, so does the size of the efficient production team, with each member specializing in a smaller number of tasks. This result is based on a trade-off between coordination costs and workers' opportunities to divide their effort between working on their special task and gaining knowledge about this task (it also requires that more H raise the marginal productivity of more team members).

Mokyr's view is not quite the same as the Becker-Murphy view. Mokyr's argument depends on the existence of a *minimum* amount of worker knowledge necessary to run the firm. As the *technical* knowledge embodied in the production process rises (what he calls "epistemic knowledge"), workers must themselves have a greater *operational* knowledge (or skill) to run it.

The way to get that is to break into groups, split up the tasks into smaller, more manageable subsets, and acquire more knowledge about fewer problems. With virtually no information technology (that is, the ability to communicate and monitor across distance), the factory system became the only way to efficiently organize, divide, and internalize such operational knowledge. Thus, while the Becker-Murphy paper specifically referred to teams and firms, Mokyr uses the argument to explain the pre-eminence of factories, in the sense of centralized workplaces.

In addition, Mokyr assigns a role to each worker as a teacher of others. This is another reason why a central plant was superior to a network of home workers. Even though, as Mokyr clearly states, the division of labor was quite well advanced before the factory system became widespread, only plants allowed firms to pass on the operating knowledge in two directions: across space to make sure others could perform the task, and across time, down from one generation of workers to another to ensure continuity.

The following equation summarizes the central idea of the paper:

$$S^* = f\left(\overset{+}{H_{min}}, \overset{+}{A} \right) , \tag{1}$$

where:

$$A \equiv \frac{A_C}{A_I} .$$

Here, S^* is optimal plant or factory size, and H_{min} refers to the minimum human capital required to run the "best-practice operation in a competitive world". The variable A is the ratio of internal *coordination technology* to external *information technology*. In Mokyr's terms, A is "the relative efficiency with which information flows inside a firm relative to between firms". The Industrial Revolution corresponded to a rise in H_{min}.

The need for factories becomes attenuated when knowledge flows more easily *across* than *within* firms in the industrial landscape; that is, when *A* falls. This is the basis for the conjecture, explored below, that market production will increasingly migrate out of centralized workplaces and back to homes.

Factories, Learning, and Growth

Assigning factories a central role in the transmission of ideas has important implications for the way that we think about growth. In recent models, growth is due to the interplay between *human capital* and *technological ideas*. The two reinforce each other: a higher average level of human capital generates more specialized technologies, which in turn makes it easier to acquire more human capital. Growth results from the continuous rise in both.

If factories are important, then people with general organizational skill — those we sometimes call *entrepreneurs* — occupy a critical place in the growth process. Without someone to amass or borrow capital, to take risk, to organize and coordinate labor, both specialization and human capital growth will stall. By giving factories an important part in perpetuating knowledge, Mokyr draws our attention back to the generalist entrepreneur, who is necessary for all the specialist tasks to come together. Whether entrepreneurs are exogenous and genuinely rare (Hirschman, 1961), or elastically supplied, depending on the institutional environment (Baumol, 1990; Murphy, Shleifer, Vishny, 1990), their lack may be the key to stagnation. Some balance is needed between those that know more and more about less and less, and those who know how to coordinate them.

Why Did Workers Abandon Household Jobs?

One puzzle that Mokyr notes is that a movement to factory work appeared to be welfare reducing yet was plainly accepted by many workers. Why? There are perhaps two reasons that it

was rational, besides that noted in the paper. First, workers may have been aware of the importance of knowledge in factories. They knew it was, if not the only way, at least the most efficient way to accumulate specialized human capital that would allow them to become personally more productive and *eventually* increase their wage. If it is true that knowledge is transmitted by people working in close proximity, as Mokyr suggests, then work in the factory may have been the only way to demonstrate one's aptitude and acquire new skills.

A second reason concerns a background process that is not discussed in the paper: population growth. If it is true that many of the new technical processes were subject to increasing returns to scale, then population growth — which accelerated in the 18th century in Britain — would reduce the wage of those working in a traditional occupations and simultaneously create the *potential* for both positive profits and higher wages if workers joined factories in sufficient numbers (Goodfriend and McDermott, 1995). Here, again, we see a possible role for an entrepreneur, a rare individual with organizational and general skill, who can put ideas into practice by constructing a factory, hiring workers and coordinating them in teams.

Production Location in the Future

Factories achieved huge scale by the early 20th century and, while the form of the large industrial units appears to have shifted to office towers and high-tech campuses, overall scale was still huge at the end of the 20th century. That could now be changing. With the computer age and the imminent availability of cheap bandwidth, information is getting very cheap to produce, store, and move. Relative to moving people, as noted by Mokyr, it is getting very cheap indeed. The variable A in Equation (1) has been falling. Does that mean that workers will increasingly work fewer hours in a central workplace and produce more market output from home? Although it seems clear that more and more people will take advantage of such opportunities, I have

doubts about a massive shift toward telecommuting.

As I read this section of the paper, I kept thinking how plausible it sounded: the worker of tomorrow could pick which hours to work, when to relax, when to come into the office, when to stay home. Then I realized that it was the exact description of my own work habits. In a university job this works well, but it may have less to do with information technology than with the fact that professors are really paid *piece-rates*. If we teach a certain number of classes and publish a minimum number of papers, we get paid, regardless of the time we work. It might be difficult to extend this kind of arrangement to other occupations, for all the reasons noted by Mokyr, especially monitoring. Monitoring remotely can be difficult to do without violating norms of privacy. It is possible, of course, as a new generation grows up online that humans will feel less guarded with their privacy, allowing much tighter remote supervision.

Second, joint production in the home of household and market goods might well *diminish* in the future, as specialization continues for household services along with other goods. Day care, technically advanced mobile cleaning services, mobile dog grooming, advanced technologies for frozen and prepared foods, internet food shopping and delivery, all allow workers more time *away* from home. Female labor force participation has increased tremendously in the last four decades as women have reduced the production of household services. Nevertheless, it does seem likely that some parents, especially women, will find it optimal to use telecommuting to spend more time with their children.

Third, productivity in personal services grows slowly compared to that in manufacturing; while as incomes increase the demand for such services rises. This results in a growing relative price for services, and a steady shift in the workforce toward service and leisure industries. This trend, I think, accounts for the near-universal deploring of the quality of service these days, since

many service workers are neither good at service work, or very happy about having to take this kind of job. It also means, though, that in the future many workers may have to serve people directly in ways that might be hard to do remotely (personal trainers, customer service representatives, mechanics, craftsmen).

Fourth and finally, it is unclear how the new technologies will affect Mokyr's key variables, H_{min} and A. Although we know that A_I has been rising and will continue to do so, it may also be true that A_C and H_{min} are rising. The minimum production-operating knowledge may continue to be quite sophisticated, so that workers need constant instruction and updating. Moreover, new technologies may reduce coordinating costs within firms — a rise in A_C .Then it is a race to see which of the three rises faster. It is not clear how it would turn out. As Mokyr notes, citing Gavin Wright, "In the limit we could devise an economy in which technology is designed by geniuses and operated by idiots". In that case, home production for market may indeed take off. But I am uneasy with that conclusion. It seems to me that a large part of the population may, unfortunately, substitute information and computing power for their own brain development, but these workers will not be the kind that will be left alone to telecommute. These workers will require considerable oversight in something like a factory.

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