

## Reflections on Pin Factory Visits

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These remarks are complementary to Sue Helper's paper, which focusses mainly on the methodology and benefits of plant visits. In contrast, my comments are on the production process itself. What does one learn from these plant visits, starting from the context of a standard microeconomic production function and the standard macroeconomic literature on productivity change? My reactions are based on seven group visits to six establishments (one of them twice).<sup>1</sup>

Marty Feldstein at this session expressed his surprise that there were so few people on the factory floor. If he had said this and I had not participated in the plant visits, I would have reacted, "why is this surprising, since output in U. S. durable manufacturing increased by 600 percent from 1949 to 1999 while hours of labor input rose only 41 percent?"<sup>2</sup> However, I did participate in some of the plant visits, and this generates another reaction, how *extremely heterogeneous* are the plants in the presence of people on the plant floor. True, at LTV Steel the people visible on the plant floor closely approximated zero, and the only visible employees were those staring at computer monitors in raised computer-control "pulpits" spaced every 300 or so

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1. The plant visits were to Pollak (an auto parts manufacturer in Boston MA) twice; LTV Steel in Cleveland; the Ford plant at Lakewood OH which makes Ford Econoline truck bodies and does final assembly on the twin Mercury Villager and Nissan Quest minivans; Toyota auto assembly in Georgetown KY; Johnson Control Industries, a manufacturer of auto seats and seat frames adjacent to the Toyota plant; and Chiron, a biotechnology company in Emeryville CA.

2. These percentages are from the BLS quarterly data base on output and productivity and refer to the change between 1949:Q1 and 1999:Q4.

yards apart. And in the Ford body shop the welding was done by tireless but noisy robots, while likewise at Toyota the task of boring the engine blocks was carried out in rows of rectangular tank-like machines which functioned quietly and apparently without human intervention.

But at both Ford and Toyota much of the production process took place on assembly lines that would have made Henry Ford (the elder) feel at home, and were not unlike auto factories I recall visiting more than three decades earlier.<sup>3</sup> At the Pollak auto parts plant earlier in the 1990s humans seated at work stations were omnipresent, but in the same rooms only a few years later a return visit revealed mainly enclosed automated lines for small auto parts most closely resembling a complex model train setup or a large model car racetrack.

This heterogenous choice between people and automation naturally leads to two questions, (1) which processes tend to use human workers and which don't, and (2) how is the decision made to substitute capital for labor?

The best way to generalize about (1) is to quote our Ford tour guide, "the last thing we'll automate is the marriage of chassis and body. Humans are simply better than robots at finding, manipulating, and fastening the wires and tubes that need to be hooked together at the marriage stage." At both Ford and Toyota, most of the fastening was done by humans on traditional assembly lines. Other processes not involving fastening, like welding and boring engine cylinders, were done by machine. Making finer distinctions, joining large parts involving "heavy lifting" tended to be done by machines, while assembly operations involving relatively small parts still

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3. My previous auto factory visits were at BMC in Oxford, England in 1964 and at GM in Framingham, MA in 1965.

involved humans.

As for question (2) about the decision-process in substituting capital for labor, we found different approaches. The clearest presentation was at Ford, where each separate operation is an ongoing candidate for capital-labor substitution in a continuing, incremental process. My memory is most vivid of a single man moving large vehicle parts with the aid of an overhead swing. Our guide said "do you see that man? Last year there were two people, now there's one, and next year there will be none, for this process is planned for total automation." Engineers explained to us that every operation is a candidate for capital-labor substitution and that each competed with all others based on a "hurdle rate of return," then (1996) roughly 20 percent.

But not every substitution decision is incremental. Sometimes entirely new processes are substituted for old, most notably at the Pollak plant where hand assembly visible everywhere on our first visit was replaced by the "race-track" automated assembly line of our second visit. From our small sample few generalizations are possible. Ford automated process involving the assembly of large parts, e.g., body panels, while leaving to humans the fastening of nuts and bolts, while Pollak had succeeded in automating the assembly of switches and small gears involving numerous minute pieces of machined metal.

Perhaps the most surprising and interesting reaction is how different was the experience of visiting two auto assembly plants, Ford in November, 1996, and Toyota only 17 months later. Ford was much as I expected — lots of machines, lots of people, and engineers talking about hurdle rates of return in deciding where and when to replace people by machines. Toyota was totally different. Most of what we saw involved assembly lines with workers attaching different

types of items to the moving body or chassis, and there was much less (at least that we were shown) involving robots welding together auto bodies.

In fact, at Toyota we never heard the words "profit" or "rate of return," and we rarely even heard the word "productivity". Instead, the day's most frequently used word was "ergonomics." Both management and workers seemed obsessed with taking muscle strain out of routine assembly work and finding ways of replacing strain by comfort. An interesting aspect of ergonomics at Toyota's Georgetown KY plant is the evolving redesign of work processes to suit the strength and posture of women, who make up a substantial share of the Toyota U. S. workforce in contrast to the largely all-male Toyota workforce in Japan.

At one work position a worker moved a power fastener vertically at above head level, a motion sure to create severe upper arm strain, except that the worker had designed a large spring-loaded arm brace that took all the weight off the upper arm. A plaque next to the work stall identified the particular worker who received an award for this invention, which was made in the plant's own machine shop. Similarly, another worker operating at a low level, only two feet off the floor, had designed a complicated seat that moved both from left to right and from forward to back, allowing the seated worker to position herself effortlessly next to the wheel well of the car moving down the assembly line.

At Toyota ergonomics was a means to an end, in fact two ends, happy employees and high-quality cars. We were indoctrinated into the Toyota philosophy, that high quality products (as rated, for instance, in the *Consumer Reports* reliability surveys) made cars easy to sell, and thus consumer demand would "pull" out of the plant every car that could be made (implicitly at

whatever price was necessary to achieve the required profit margin). Engineers reported that they had often driven down a highway and noticed the poor "fit and finish" of trunk lids on competing cars of U. S.-owned brands, clearly visible from their moving cars. They compared their "pull" system with the U. S. "push" system, in which there was a large emphasis on marketing, advertising, and dealer price incentives to "push" out onto the market poor-quality automobiles which could not be sold without this marketing investment.

The Toyota executives whom we met at lunch (none of whom were Japanese) were quite conscious that they were moving more slowly than Ford at automating individual plant processes, and they had an interesting reason to explain their slow pace. The Toyota philosophy of *Kaizan* means continuous, incremental improvements, and there is one problem with excessive reliance on automation — "machines don't make suggestions."

The economics literature on investment has struggled for decades to cope with adjustment costs, and so we were a bit surprised to find that adjustment costs were on the front burner at both auto plants, especially at Toyota. The greatest possible disruption at an auto assembly plant occurs with the introduction of a new model. Both at Ford and Toyota, we were told of the elaborate plans made to establish pilot assembly lines up to two years in advance, so that every unexpected wrinkle in the manufacture of a new model could be ironed out long in advance. In fact, both plants planned for unexpected events, and at Toyota we were told that it was optimal to run the plant at 92 rather than 100 percent of capacity, as it would take too much extra labor to deal with the dislocation that would inevitably happen by an attempt to keep every line running at full speed all the time.

How did productivity show up at the auto plants? We did not walk away with any useful measures, except to be told that at Toyota the number of employees required to produce the 1998 Camry was about the same as the 1988 Camry, yet the newer model was much superior in almost every dimension, both in size and the complexity of features. Also, productivity measurement is bedeviled by the ebb and flow of outsourcing; in the case of the Georgetown plant much more of engine assembly and machining was done locally in 1998, whereas in 1988 most was done in Japan. Finally, with the same number of employees the plant was able to produce 45,000 spare parts per month, a new activity not performed previously.

Another set of questions was raised in our visits to two suppliers of auto parts, Pollak (which made small switches for doors and instrument panels) and Johnson Controls (which made auto seats and seat frames). What explains the lack of complete vertical integration in the auto industry? Several answers emerged, including one of the most obvious, the role of unions in raising wages in the wages in plants owned by the auto companies themselves as contrasted with the plants of independently-owned suppliers. Another relatively obvious answer was the ability of independent suppliers to diversify their customer base across several auto makers, thus protecting themselves against unforeseen shocks in the form of shifts in demand for particular final products or strikes at a particular customer.

Perhaps more interesting was the feeling we absorbed at both auto parts suppliers, that they had developed an admirable depth of expertise about specialized processes that might be of only marginal interest to executives of major auto companies. The CEO of Pollak who showed us around knew much more about the transition from electric to electronic auto switches than, we

would presume, the CEO of GM or Ford, or even a second-level Vice President at GM or Ford. Nevertheless, at Toyota there was more vertical integration than we had expected, having previously visited Pollak (a major supplier to Ford). Toyota made their own engines, bumpers, and instrument panels, although they bought completed seats from the Johnson Controls factory that we visited across the road. Also, the Toyota staff was quite proud of the role of their own machine shop in crafting some of the unique braces and other devices which solved ergonomic problems in particular assembly tasks.

A more general reaction relates to the extensive attention given by economists to research, development, and patents. Clearly, much of the effort directed at productivity improvement that we witnessed was not being achieved within any kind of formal research and development activity, but could be classified under the general rubric of "incremental tinkering." *Kaizan* and R&D may be complementary, but in one sense they are diametrically opposed models of productivity improvement. It is the essence of *kaizan* that it originates in suggestions by line employees and their supervisors, i.e., it takes place on the shop floor. In contrast, R&D connotes laboratories that are physically removed from the production process. Doubtless, the relative role of *kaizan* and formal R&D differs greatly across companies with a single industry and particularly across industries.

In fact, our only immersion in "pure" R&D occurred at our visit to Chiron, a biotech company, and this visit seemed little different than visiting the science building in a well-equipped university, with rows of offices containing young people staring at PC screens. As I remarked in our visit to this building, with its dramatic atrium and bright earth-tone colors, "this is just like

visiting an economics department, but with much better architecture."