# Technological Mutations and Henry Ford

Focussing primarily on Europe, this paper examines the evolution of the production technology associated with Henry Ford. Key elements identified are mass and flow production, the progress of which are traced from the early nineteenth century. The concentration of standardised demand, necessary for mechanisation and therefore mass production, was in war-related production and often state industry. Flow production involved linked processes and could be undertaken with malleable materials such as pastry and wood pulp but required the development of powerful machine tools to extend on a large scale to metal products. These tools were developed in the US towards the end of the nineteenth century under the stimulus of skilled labour shortages and raw material abundance. European conditions required compromises with this American technology, both because markets were less extensive and because skilled labour was more abundant. Some of these compromises might be described as 'flexible production', for example the early development of internal combustion motor vehicle technology in Europe. But the same technologies and organisations could not compete in supplying the mature, standardised, products. The Ford production line was created experimentally, through many trials and errors. Success bred complacency and institutional sclerosis, allowing General Motors to get ahead in the US during the later 1920s and European producers to develop their own high volume models and production styles. Japanese competition in the form of Toyotism or lean production adopted a different approach to their workforces; an alternative organisation rather than machine technology. German arrangements, running second to the Japanese in efficiency in the 1980s, also depended on the skills of their workforce even though often used in unskilled tasks. Despite employing similar machine technologies, national styles of production and productivity persisted, because national infrastructures, especially training systems, continued to differ.

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Published in 1932 and still in print today, Aldous Huxley's *Brave New World* describes a futuristic world state in the year AF632 (AF='after Ford'). The T is the sacred symbol of the world states' ten zones, each ruled by 'his fordship', a controller. A testament to the influence of Henry Ford, it is actually genetic engineering and infant socialisation that are the key principles of the 'Brave New World' rather than the production line, with which Ford is so often identified.

The present paper is concerned with how the production technology associated with Henry Ford actually has mutated, primarily in Europe. The following section offers a few remarks about the idea of 'Fordism' and attempts to restrict its scope. Section 2 takes the central popular notion associated with Henry Ford in the 1920s, mass production, and distinguishes it from flow production, which is actually the more important concept. Examples of British mass and flow production industries in the nineteenth century are considered. They show the importance of American machine tools from the 1890s for the development of flow production in the metal working trades, as well as the role of demand concentration for mass production. Developed especially to save labour in a skilled labour-scarce economy, US machinery proved as effective for the European motor industry context, described in section 3, as for that in North America. The following section (4) considers whether 'flexible specialisation' was an alternative or a precursor to mass production/Fordism. Section 5 examines whether there was a technological discontinuity between Fordism and the Japanese approach to motor vehicle manufacture, whether for example Fordism was intrinsically rigid and Toyotism flexible. Finally section 6 discusses whether Fordism is dead and why national styles of production persist.

## *1. Theorising about Fordism*

'Fordism' is the manufacture of standardised products in huge volumes, using special-purpose machinery and unskilled labour, according to Tolliday and Zeitlin (1986). Henry Ford utilised these three elements with the Model T more than any of his contemporaries, drawing upon the ’American system of manufactures’, they maintain. Most of the production strategy aspects of ‘Fordism’ are probably more accurately described as ‘Taylorist’. In F W Taylor’s system, the production engineer determined the time necessary for a task and the operator was given a financial incentive to achieve at least this speed. Human effort was reduced by conveyor belts and flow production.

Since the interwar years ‘Fordism’ has acquired an intellectual life of its own, albeit with fuzzy edges. At least four distinct levels of the Fordism concept can be identified (Jessop 1991).

1. mechanically paced, continuous production of long runs (roughly Tolliday and Zeitlin’s view),
2. mass consumption matching rising mass production in a macro-economic regime,
3. a mode of regulation by norms, institutions and networks providing the framework for mass production and mass consumption in wage bargaining, inter-firm relations, consumer credit, and aggregate demand management- for example by exploiting labour more intensively, offsetting otherwise falling profitability,
4. a pattern of social cohesion - especially standardisation of consumption by nuclear family households through the market.

Obvious difficulties with Fordism as a general sociological concept include that manufacturing mass production does, and did, not pervade the whole economy. A ‘Taylorised’ division of labour, with dedicated machinery and economies of scale are as relevant to tax collection, battery farming and supermarkets. However there seems little point in identifying modern tax collection technology as ‘Fordist’.

Mass production can of course make a difference but is probably not the key innovation explaining growth in any period; electricity, microelectronics, cheap fuel or synthetic materials might have been more important in any ‘Fordist’ period.

There is no single institutional configuration comprising the Fordist mode of regulation. On the production line it can mean ‘machine pacing’ rather than piece rate incentive payment, but at the level of society as a whole there is no distinctive institution. Jessop (1991) proposes that Fordism be defined as wages indexed to productivity growth and inflation, with the state accepting a key role in managing demand, and state policies encouraging mass consumption norms. Yet this has little to do with the historical experience of production with which Ford is identified. These features may reflect a rigid macroeconomic approach without an understanding of the price mechanism in stabilising the economy and promoting efficiency, but to call them Fordist begs the question as to whether mass and flow production were ever so rigid as to require this form of support.

Without a reasonable or useful definition of Fordism, discussions of the transition to post-Fordism are even more problematic. So use of the term Fordist in the present paper will be restricted to the first meaning above - namely a method of production. Even this concession is primarily stylistic though. As will be argued, the term Fordist reflects an excessively American-centred view of technological evolution and possibilities.

During the 1980s ideal types changed - flexible production with ICT and a multi-skilled workforce with flatter organisational hierarchies, coupled with macroeconomic policies based on rational expectations monetarism and supply side social engineering displaced earlier models. Whether these were thoroughly pervasive changes and why they should be called 'post-Fordism' remain open questions. There are many varieties of flexibility— in labour markets, working practices, machinery, and in restructuring- and mass production (as 'Fordism') continues to thrive when macroeconomic conditions are right (Sayer 1989). 'Post-Fordism' then is a superfluous concept from the perspective of the present paper.

*2. Flow Production versus Mass Production*

'Mass production' was an Americanism adopted towards the end of the First World War, as Henry Ford's output of model Ts soared. **'**Flow production' is a different and later concept (Woollard 1954). Flow production can be applied to small volumes or throughputs in repetitive engineering and mechanical trades. It involves a highly integrated system of processes; movements of components should resemble the flow of water in a watershed, a series of tributaries feeding into a river flowing to the sea. As a low volume example of flow production, Frank Woollard (1954 35) instanced a contemporary railway carriage assembly with a production of 4-6 a week, each coach moving every 7.33 hours.

The Brunel/Maudslay block production (for the Royal Navy's sailing ships) at Portsmouth during the Napoleonic wars was among the earliest British cases of mass production. Henry Maudslay's screw-cutting lathe gave such precision as to allow previously unknown interchangeability of nuts and bolts and standardisation of screw threads. He was also able to produce sets of taps and dies. In 1801-08, in conjunction with engineer Marc Brunel[1], he constructed machines for making wooden pulley blocks at Portsmouth dockyard. The Maudslay system in 1810 manufactured 100,000 blocks in three sizes (Corry 1990 405). 10 unskilled men were able to do the work of 110 skilled men under the manual arrangement. But there was no progressive and continuous processing or conveyancing between machines, as flow production requires.

The sequencing of processes in flow production of metal products required standardisation. Elsewhere in supplying the armed forces the absence of standardisation meant that there were 200,000 useless muskets awaiting repair in 1811 because parts were not interchangeable and each part needed customising[2]. In the US, the Springfield Arsenal and Harper's Ferry proceeded to address this problem by introducing interchangeable parts, supported by government subsidies[3]. In any case there was no obvious lineage with later manufacture; Singer sewing machines took a different line, adopting the 'European method' until the 1880s (Hounshell 1984). There was more continuity between bicycles and arms manufacture, for by the time of the bicycle boom, US machine tool development, particularly associated with Charles Norton, was well underway.

Where the standardisation necessary for interchangeability was concerned, Whitworth's screw threads were more important than gun manufacture in peacetime. Joseph Whitworth (1803-1887) established new standards of accuracy in the production of machine tools and precision measuring instruments, devising standard gauges and screw threads (Tweedale 1986). He first worked for Henry Maudslay in his London workshops before moving to Manchester and setting up in business as a toolmaker. Whitworth brought standardization to his company and the engineering industry as a whole by

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**1** Brunel was a refugee from the French Revolution. His son is better known in the UK for his ships, bridges and broad gauge railway system.

2 Nonetheless Birmingham produced around six million firearms during these wars.

3 Eli Whitney's (the inventor of the cotton gin for separating the seed from the cotton) contribution to interchangeable parts was modest, but he was a zealous advocate (like Joseph Whitworth below) (Smith 1990)

developing means of measuring to tolerances never before possible, so that shafts, bearings, gears, and screws could be interchanged (Musson 1966).

Standardisation was essential for flow production in engineering and the metal working trades but not in industries employing more pliable materials. While the pressure of war created a sufficiently concentrated demand for sailing ship blocks to trigger mass production with special machinery even in a state industry, it did not do the same for ships' biscuits. But when the mechanisation breakthroughs for biscuits came in the following decades, George Palmer introduced the key element of flow production, integrated processes. The first stage was another rare example of innovation in a state industry. Thomas Grant, a storekeeper at the Clarence Victualling Yard at Gosport, invented a form of machinery for ships biscuits in 1829, for which he was awarded £2000 by Parliament in lieu of patent (Corley 1972 51). Previously 45 men and nine ovens were occupied in the gruelling work of making 1500lbs of biscuit an hour at a cost of 1/6 per cwt. Mechanisation reduced employment to 16 men and boys, while producing 50% more a ton an hour at 5 pence per cwt[4].

Around 1838 Jonathan Carr designed a machine for cutting and stamping biscuits, based on the hand operated printing press dating back to Caxton. Huntley and Palmer's first commercial 'steam engine biscuit' of 1841 utilised all the foregoing types of machinery. The continuous flow element in George Palmer's system occurred when the 20-30ft sheets of rolled pastry were carried along a canvas band through the cutters. Spare dough continued on into a trough where it was collected and re-used. A boy standing in a hole in the floor so that he would be on the right level without bending, supplied the line with trays on to which the biscuits fell in regular order. A team of boys collected the trays at the end of the line, stacked them on trolleys and wheeled them to the ovens.

More technically sophisticated was the flow production of paper. This was possible early in the nineteenth century because the pulp was as malleable as pastry. The US began to overtake the UK in operating speeds of paper making machinery in the last decade of the nineteenth century. In the first decade of the twentieth century US manufacturers began

[4] The basic elements were steam driving power, a central furnace, a mixer, rollers, and a cutter. A chute fed weighed flour into the mixing machine and water was added from a cistern. A shaft through the centre of the mixer could be connected to the steam engine which then rotated 18 blades to mix the dough. Dough was removed by hand to be mechanically rolled to two inches thickness before cutting and baking.

to operate wider machinery and could increase throughput that way as well. Despite the common technical characteristics of the paper-making machinery, the US achieved almost twice UK labour productivity from at least the 1860s and, in turn, the UK was more productive in this respect than Germany (Magee 1997).

*3. American Machinery in Europe and Ford*

US machine tools began to impact generally upon European engineering in the 1890s, paving the way for mass and flow production in the metal working trades. A reason at one level for the US advantage in machinery is suggested by a discussion in the 1860s initiated by a US locksmith who had set up business in London after the Great Exhibition. Of British labour he remarked, to the agreement of his British (non-workman) audience, ‘if the workmen could do anything to make a machine go wrong they would do it and if the same amount of ingenuity on the part of the English workmen were exercised in producing labour saving machinery as he had seen displayed in producing the least amount of work in the longest time, England need never fear that other nations would go ahead of her in this respect’ (Rosenberg 1969 14-15) .

At a deeper level, America’s labour scarcity and raw material abundance stimulated interest in machinery to replace labour, even though the machinery typically used raw materials more profligately. The large market, when it was created, explained the more standardised US products. When there are economies of scale the costs of product variety are higher in a wider market. Britain's and Europe’s technological choices by contrast emphasised skilled labour and ‘flexible’ 'craft' production methods, according to Broadberry (1997) among others.

British engineering in the last quarter of the nineteenth century differed from US ‘system of manufactures’ because the British market favoured customisation (Zeitlin 1997). ‘Flexibility’ rather than mass production was ‘imposed’ throughout Europe because demand was not standardised. Effective competition for Britain was actually from Germany, though the debate among engineers was about US methods, whose novelty was so striking. The approach supposedly only collapsed after 1945 in Britain with a failed form of Fordism, when workers lost their skills and reacted against the imposition of US methods.

Since British economic growth attained historically unprecedented high rates in these years there must be some doubt about the alleged failure. Moreover the terms 'craft' or 'flexible production' are rather odd summary descriptions of nineteenth century British techniques –especially in view of the US locksmith’s views quoted above. In a sector of British international superiority, cotton spinning and weaving factories were not 'craft' as traditionally meant, nor were they particularly flexible, except that the intelligence was more in the worker and less in the machine than in the US. The evidence on the paper industry suggests no substantive difference in use of continuous flow, capital-intensive techniques between the US and UK in most of the nineteenth century, although the productivity gap was substantial and persistent. The implication that the motor industry only moved over to American methods after 1945 is obviously wrong. Even Morris adopted a moving production line in 1934 and probably of greater significance imported the Budd body pressing technique in 1928.

However the ‘British system‘ is described, American machinery, and the associated mechanisation of labour, is the key to Fordism in practice. Taylor’s time study of machine operators and his personnel measures were absorbed by much US industry but his production management recommendations were less widely recognised. His approach was in any case a logical extension of the ‘American system of manufactures’. Charles Sorensen maintained that no-one at Ford had heard of Taylor when they were experimenting with moving production lines (Foreman-Peck 1982).

Taylor had virtually no positive impact in Britain before 1914, and the response that there was, was primarily hostile (Littler 1982 94-5). It was the neo-Taylorist Bedaux system in the years between the wars that was most influential - and provoked the most labour resistance (Littler 1982 ch 8).

Henry Ford’s influence derived from the success of his multinational company and his ideology made a far greater impact on public consciousness than Taylor’s. His $5 dollar a day, his ‘peace ship’ to Europe during the first World War, his Amazon rubber plantation and town, his setting up factories for the Soviet government, not to mention his biography that was the trigger for Brave New World, all helped to maintain Henry Ford in the public eye. Ford presented himself as world benefactor, not a mere businessman. He claimed not to be concerned about making money but with improving everybody’s lives;

‘what we have, we earned… by unremitting labour and faith in a principle’

eliminating waste, by using lighter more durable materials, and by more directed labour time, in the farm as well as the factory (Ford 1923).

Ford had a social message as well. His $5 day included profit sharing that meant employees did not take home $5- some of the pay was conditional[5]. Ford’s ‘Sociology Department’ emphasised cleanliness and morality among employees, especially immigrants. The Ford English school aimed to integrate immigrants into the American way of life. One of the objectives of the $5 day was to cut down labour turnover, and so were the associated welfare and other programmes (Meyer 1980)[6].

Writing in 1925 one German saw the solution to his country’s labour problem as ‘Ford or Marx’ (Littler 1982 189 fn1). In fact both left and right appreciated the possibilities in a ‘Fordist’ engineering approach to social management, together with what the technology itself could deliver (Maier 1970). The Fordson tractor plant in Leningrad was a useful addition to Stalin’s farm collectivisation programme, as well as to Soviet arms production capacity. In the west, Fordism in particular and Americanism in general provided an alternative to class confrontation, the pursuit of national efficiency. Efficiency would be attained by standardisation and mechanisation of repetitive procedures on a massive scale. Once Hitler had decided Porsche’s car would become the future Volkswagen, produced by the party-state if necessary, American engineers from the Ford Motor Company designed the Volkswagen plant, close to the site of the Herman Goering (steel) Works. Their efforts earned Henry Ford the highest award the Nazi Party would give to a foreigner (Wegenroth 2000 116-117). Arguably VW and their Golf model continue to provide the closest approximation to ‘European Fordism’.

In Britain the majority of cars sold in 1920 were Model T Fords. These rolled out of the assembly plant at Old Trafford, Manchester at a peak rate of 1000 a week, helped by a conveyor system of production. British competition needed time to reorganise after war production. Quickly it transpired that Ford’s volume of production could not be absorbed. Moreover the introduction of a horse power tax, discriminating against the model T, and

[5] In 1914 50% of the $5 was profit sharing. By 1918 competition from other employers and boom conditions forced this down to 20% and in 1919 the $6 day was inaugurated.

[6] These programmes were eliminated in the downturn of 1921.

the development of indigenous cars behind a tariff barrier, soon eliminated Ford's hegemony in this market. Nonetheless with the return to management of Perceval Perry, an Englishman with Henry Ford's confidence, Ford eventually re-established a strong competitive position on the basis of special models.

The British Ford style included an element of 'welfarism' for employees. In return for working at a conveyor moving at half a mile per hour in 1941, employees could get access to the 14 acre sports ground for 3 pence per fortnight, and for 8/6d per annum, to an allotment area of 9 acres. In addition there were pension, death and disablement benefits (Duffield 1947 91,97). Pay was above union rates, presumably to discourage union membership (Ford Motor Co UK 1937), and British Ford workers did indeed abandon the attempt to obtain union recognition (Labour Monthly, March 1933).

*4. Flexible Production – An Alternative to Mass Production and Fordism?*

The most commonly proposed alternative to 'Fordist' mass production is 'flexible specialisation'. Advocates emphasise the plasticity of technology, that there were viable alternatives historically to mass production (Sabel and Zeitlin 1985). Customers became habituated to mass produced solutions but such techniques were not necessary to arrive at an industrial society. High skill, universal machine economies towards the end of the eighteenth century 'in many ways anticipated contemporary developments'.

Large-scale production repeatedly beat small on level playing fields over the centuries, But perhaps there were more opportunities for flexible production than there were for small scale production.. Much of the credibility of the 'flexible specialisation' counterfactual stems from an interpretation of current technological trends that identifies key features as increasing product differentiation, shortening production runs and more general purpose, rather than dedicated, machinery operated by a more skilled workforce. But as we will see the evidence for such a tendency is thin.

One British motor production style was, in a sense, flexible. Whereas the Ford approach was for machine pacing with high time rate wages, a British adaption entailed team bonuses and the continuation of a form of piece work on the production line (Lewchuk 1987,1989). The role of shop stewards in this system was particularly striking. Shop stewards were neither union officials nor members of management but, elected by the workforce, they had a responsibility to keep going the production system that provided their electorates' earnings.

This was a way of encouraging greater labour force participation in using localised knowledge for the ends of the company, something 'Toyotism' is supposed to have achieved most effectively. A difference was that it was only the immediate cash nexus that bound shop stewards to keep the system going. The abolition of piece rates and the adoption of 'measured day work' exposed the absence of any management control, and the impotence of supervisors and foremen. Lack of management control was also a disincentive to investment; assessing the profitability of new equipment was problematic because the way it would be worked was not within management's gift.

Perhaps the best example of effective European high skill, flexible specialisation is the early European lead in the motor industry. Here we see exchange of personnel between a number of engineering centres, colleges as well as firms, and production drawing upon a variety of small but specialised enterprises in different countries. The evidence for the success of the European model is early motor car output (Table 1). France was still producing more cars than the US in 1903, despite the differences in the sizes of their populations.

Although providing the fundamental innovations, Germany was not fertile ground for using motor vehicles but the French enthusiastically adopted the new product. The Europeans chose the best technology earlier and began exploiting it more quickly than did the Americans. Many well-trained engineers were experimenting to improve upon the fuel efficiency of Lenoir's 1860 non-compression (piped) gas engine and to find a more convenient power source than the steam engine. The most successful worked in a geographically confined area of Germany. At Deutz, Daimler was attempting to improve the Otto atmospheric engine, when the owner Nikolaus August Otto invented the first viable four stroke engine in 1876. Daimler's contemporary, Karl Benz, whom he never met, road tested in Mannheim his own motor car during 1886, the same year as did Daimler, but employing electric ignition. Also in 1886, Robert Bosch began manufacturing in Stuttgart, Daimler's home town. In due course, he converted Daimler to magneto ignition. Using a different combustion principle, Rudolf Diesel's engine was patented in 1892 and developed in Augsburg. His engine from 1927 was given an enormous boost by Bosch’s fuel injection system.

In 1900 more than half of the smaller US output was steam or electricity, whereas the largest car steamer producer in France, Serpollet, made only around 100. First the Daimler engine of 1884 eventually became the industry standard, followed by De Dion Bouton’s of 1895 (Caunter 1970). By contrast Ford’s story is apparently of solitary struggle to produce an internal combustion engine and then a car[7]. This distinction between a European model with low transaction costs and vertically separated production on the one hand and vertically integrated US production on the other, is already familiar from the different patterns of the US and UK cotton industries of the nineteenth centuries.

**Table 1 French and US Car Outputs 1898-1903**

| Year | France | U.S. |
|---|---|---|
| 1898 | 1500 | n.a. |
| 1899 | 2400 | n.a. |
| 1900 | 4800 | 4192 |
| 1901 | 7600 | 7000 |
| 1902 | 11000 | 9000 |
| 1903 | 14100 | 11325 |

Source: Laux 1992

High skill, flexible specialisation and production then was appropriate in the early phase of motor industry development. Once the product was standardised this mode of production became increasing difficult to maintain in the face of competition from high volume producers.

*5. Were There Technological Discontinuities between Pre-Fordism, Fordism and Toyotism?*

The notion that Ford’s production technology, or mass production adaptions in general, were intrinsically rigid and did not leave room for local initiative is as historically inaccurate as the belief that Ford invented mass and/or flow production.  In his biography Ford claims the inspiration for flow production came from the meat packing industry in

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[7] Ford (1923 28) maintains that in 1887 he built a four cycle engine with a one inch bore and three inch stroke operated with gasoline. In 1890 Ford began working on a twin cylinder engine because the flywheel of a single cylinder engine had to be too heavy.

Chicago where initially the cattle themselves provided the potential energy to drive their processing. But Frank Woollard (1954) observes that motor vehicle construction lent itself naturally to flow production, because once the wheels had been fitted to the chassis, the chassis could be rolled between successive work stations. Flow production in the motor industry everywhere was a gradual development. Originally the assembly track, the epitome or exemplar of flow production, was a simple chain or slat conveyor mounted at a convenient height for working on cars. Later overhead conveyors were added. Woollard introduced automatic transfer machines in 1923-5 at Morris Motors but production volumes were inadequate; they had to be dismantled and run as component operations. The idea came from the automatic factory proposed by H E Taylor in a paper of 1922 (Taylor 1922-3).

The standardisation essential for flow production, inhibited by the multitude of competitive engineering manufacturers, was necessarily also a gradual process. A British committee in 1910 made an attempt to advance matters but the voluntary principle ensured only the participation of half a dozen companies (Watson 1921-2). Even the US industry was sufficiently unstandardised that the transport corps of the US expeditionary force in France in 1918 were obliged to keep 13,000 sizes of bolts. Of course the British army's Mechanical Transport Department stock variety was much greater. Impetus was given to British standardisation by the recognition that US wartime success was due to standardisation. Yet the British Engineering Standards Association could only investigate at the request of industry and therefore progress was slow.

'Fordism' at Ford USA in some respects emerged as a form of institutional sclerosis. After the experimental phase of breaking down operations and synchronising subassembly flows, rigidity set in with the move from Highland Park to River Rouge. In this experimental period, Ford tried with line synchronisation to achieve full participation in the production process by multi-skilled workers. Charles Sorensen, Ford's right hand man, favoured line sychronisation rather than satisfying dealers' demands. A process control division regulated the flow of parts and a massive inspection division of 600 at Highlands Park provided the quality control. Clearing house tags, matching components to each final unit, performed a similar function to kanban signboards in JIT.

The Ford 'system' diverged from the starting point once total synchronisation had been achieved by focussing on high volume, high speed, scale economies, and producing for a speculative demand. The importance of shopfloor know-how was lost from sight – workers became single skill robots. But the US style in the 1950s did show some features now identified with Toyotism. Stocks as low as three hours were being quoted, even though nowhere in the UK attained these limits (Woollard 1954 73). Some flexibility was possible within the flow production of the 1950s. Ford handled all types of cars and trucks on one assembly line (Woollard 1954 84). Another US company produced 500 sizes and types of air cleaners on one line in sequences of 24 hours for each model. Austin in the UK managed three body types and right hand and left hand steering on the same line. The Austin A 40 line for 2000 vehicles in an 80 hour week controlled the supplies for each car with Hollerith cards. Colour changes could be made in 8 hours and 'normal variations' in 90-120 minutes.

As mentioned above, the British shop steward and team bonus arrangement was another attempt at securing identification with management goals. The importance of shopfloor knowledge was recognised. Woollard (1954 91) maintained that leaving gangs to find the best methods of assembly was most efficient, especially when combined with incentive payments. Morris expressed the same view in 1924 (Morris 1924)[8]. But Toyota actually aligned worker and management objectives with JIT, TQM and lean production more closely than either British or American arrangements (Shimokawa 1993).

Whereas Ford restricted it to specialists, Toyota's approach after 1950 was to give data on standardisation and process management to the workers. Sign boards as production information were introduced in 1955, spreading throughout Toyota by 1963. From there they diffused to component makers. Supermarkets in the US seem to have been Taiichi Ono's inspiration for tying working ratios to orders so as to avoid stocks piling up. Beginning around 1946, Toyota rearranged machines into the order of process into a conveyor system where the machinist for example would do welding if necessary as well.

Woollard's innovation of putting one worker in charge of two or more machines instead of just one did not go this far and in any case he was not employed by a major British car

[8] This does not however mean that team bonuses could not in due course be used to ruin a production system, with sufficient management incompetence (Bowden et al 2001).

manufacturer after 1932 (Lewchuk 1986). Woollard had discovered that grouping together machines for similar processes could be efficient for lower volume processes (1954 45). Scania-Vabis in Sweden in the early 1950s made around 2000 heavy vehicles per annum 30% was made by machines in group production – group cycle time fell 40 % so that although machine use was 10-15% less efficient, overall efficiency was greater and morale also was higher. 40% of production was in batches and the remaining vehicles were constructed individually.

If large enough, as sometimes alleged for Toyotism, a technological discontinuity should show up in the aggregate data. Fuss and Waverman (1992) show the period of Japanese overtaking does not correspond to adoption of the innovations above, but the changes would no doubt first be reflected in an increase in Toyota's domestic market share.

Relative competitiveness of national motor industries depends upon input prices, exchange rates, capacity utilisation, economies of scale and country-specific efficiency. The US has higher input prices than other producers and so needs greater efficiency if costs are to be at competitive levels. The country with the highest long term productivity growth at the industry level will ultimately be the most competitive because the efficiency effects will outweigh exchange rate movements, capacity utilisation changes due to demand shocks and factor price rises.

The industry is most efficient that has an advantage in car manufacture after controlling for input prices across the comparator group. In 1961 German car producers were more efficient than North American, showing on one interpretation that they were 'plus Fordiste que le Ford'. Actual unit costs in 1970 were lowest in Germany (Fuss and Waverman 1992). Controlling for factor prices, Germany was 27% more efficient than Japan and 17% more than the US. In the following five years the Japanese overtook the US, but not the Germans, in technical efficiency. By 1984 Japanese technical efficiency improved from a 5% advantage over the US to a 17% lead.

The annual growth rate of total factor productivity (TFP) in Japan between 1970 and 1984 was 2.5 times that of North America or Germany. Japanese TFP growth was 1.7% per annum faster than its rivals- over ten years cumulating to 18.4%. Between 1970 and 1980 the Germans shifted from an 8% technical efficiency advantage over the Japanese to a 4% disadvantage. This then was the period apparently when quality circles, kanban and engineering innovation began to bite. As a consequence by 1984 US output was only 10% greater than Japan's and Japan's output was twice as great as Germany's.

*6. Deutschpostfordism or Toyotism?*

Table 2 shows that Western Europe in 1990 and 2000 was by far the largest car producing region and Germany was the largest manufacturer in the region. Yet Japan still made almost twice as many units as Germany in 2000 and NAFTA as a whole only just overtook Japan in that year.

Perhaps the closest to Euro-Fordism or Euro-post-Fordism or *Deutschpostfordism* is the German industry's response in the 1980s to Japanese competition. It would however be a mistake to distinguish a European pattern then. There was a markedly different - and less successful- response by the British companies. So until 'natural selection' of market forces worked through, the pattern was not genuine Euro-Fordism but merely a series of adaptions and non-adaptions.

If Fordism's most distinctive characteristic is the assembly line then the end of the line could be a beginning of 'post-Fordism'. Juergens et al (1993) however judged that in the 1980s the line was not obsolete. Automated guided vehicles served as work platforms and transport for the workpieces while module assembly reduced the problem of line balancing and allowed line work to be more standardised. Yet the pace of the main line still determined the rhythm of work in the module areas because modules needed to be ready for installation in the appropriate car body. The predetermination of timing had not changed, and indeed enforcement was enhanced by computerised process control.

There was nevertheless a loosening up of Taylorism-Fordism, defined as machine pacing, standardisation of work performance by experts, and direct monitoring by line supervisors. Juergens et al (1993 377) list six signs of the dissolution of the Taylorist Fordist production regime; task reintegration (less specialisation of tasks and job enrichment), employee participation (decentralising control and responsibility), shopfloor self-regulation, more automation, reduction of line-paced jobs, and skilled workers employed for direct work. Whereas Womack et al (1990) believed all countries would converge to a lean production standard, Juergens et al concluded that national traditions exercised more influence over these changes than multinational corporate management. Skilled workers were employed more abundantly in Germany than in Britain. But the skill content of jobs was not rising. Instead qualification requirements were polarising. German apprentice training led to an over-supply of qualified skilled workers for residual work.

Perhaps this was the critical and persistent causal difference between the German and British styles. Twenty years later British vehicle assemblers were highlighting the excellence of the German training system (Automobile Industry and Growth Team 2002). They admired the much stronger emphasis on vocational training and higher technical standards, often in a particular specialism but with a good general background, of German students. UK senior manufacturing representatives considered the skill base of their lower supply chain tiers to be 'amateurish'. Particular problem areas included 'lean skills' among management and a lack of technician and diagnostic skills in most workplaces. There was a strong British industry lobby for a senior management automotive college similar to those in Germany. The Aachen and Fraunhoffer Institutes produced almost every senior manager in the German industry.

International competition slowly winnowed away less efficient uses of technology in British industry. Direct Japanese influence increased markedly in British-based industry in recent decades. Evidence of the mutation of the motor industry in recent years is that vehicle manufacturers and component suppliers at different levels in the supply chain now co-operate through the Society of Motor Manufacturers and Traders Industry Forum to improve the UK automotive supplier base. UK-based vehicle manufacturers and their workforces collaborated over the introduction of flexible working practices and re-education schemes aimed to improve productivity and the quality of output. Some companies avoided redundancies among the workforce by introducing flexible shift patterns that could cover production shortfall by allowing shorter hours when work was slack and longer hours when demand picked up. Other measures included changes in shift patterns and the introduction of a banked hours system. All of these policies were calculated to reduce costs, increase flexibility and increase line-up time. Table 2 suggests they did have a positive impact on competitiveness.

*7. Conclusion*

Remarkable as was Henry Ford's impact, a central focus on Ford can be misleading in an empirical study of European motor vehicle production and technology. Whatever definition is agreed, ‘Fordist’ production and technology was not invented by Henry Ford, it was not diffused by him alone, nor was it even exclusively contemporaneous with the growth of his companies.

Fordism involved both mass and flow production. The two genres could and did exist independently of each other. Flow production is possible for small volumes, and mass production historically has not been always been associated with flow organisation. American machinery, reflecting American resource endowments, was designed to save labour and to be worked by the unskilled. It allowed mass and flow production to be combined in the metal working trades so long as there was sufficient standardised demand. European conditions required compromises with this American technology both because demand was not so strong and because skilled labour was more abundant. Some of these compromises might be described as ‘flexible production’. Probably the greatest success for European flexibility was the early development of internal combustion motor vehicle technology – ahead of the United States. But the same technologies and organisations could not compete in supplying the mature, standardised, products.

The Ford production line was created experimentally, through many trials and errors. Success bred complacency and institutional sclerosis, allowing General Motors to get ahead in the US during the later 1920s and European producers to develop their own high volume models and production styles. A similar trauma later struck all western motor industries with the rise of Japanese competition in the form of Toyotism or lean production. Yet there were many points of similarity with the various adaptations of American technology. The Japanese tended to do it better because they adopted a different approach to their workforces. German arrangements, running second to the Japanese in efficiency in the 1980s, also depended on the skills of their workforce even though often used in unskilled tasks. Despite employing similar machine technologies, national styles of production and productivity persisted, because national infrastructures, especially training systems, continued to differ.

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**Table 2 World Car Production 1990 and 2000**

| '000 Units | | |
|---|---|---|
| | 1990 | 2000 |
| Western Europe | 14,423 | 14,595 |
| France | 3295 | 2878 |
| Germany | 4661 | 4695 |
| Great Britain | 1296 | 1631 |
| Italy | 1875 | 1376 |
| Spain | 1679 | 2318 |
| NAFTA | 7,725 | 8,377 |
| Japan | 9,948 | 8,363 |
| Asia (excl Japan) | 2,028 | 4,387 |
| Eastern Europe | 1,848 | 2,432 |
| Other Markets | 847 | 2,184 |
| Total | 36,819 | 40,338 |

Source EIU