Productivity Growth at Ford in the Coming of Mass Production: A Preliminary Analysis

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Introduction

Distinguished works by Meyer [7], Lewchuk [6], and Hounshell [4] carefully document and analyze aspects of the changes in the organization of production at the Ford Motor Company in the years in which mass production methods for automobile manufacturing were first being developed and implemented. Yet these books, even Lewchuk's, provide only a sketchy quantitative account of the productivity consequences of the changes. Only sketchy quantitative evidence was available to the authors at the time they wrote.

This is a frustrating state of affairs. Recent developments in the theory of the firm and of both theoretical and empirical study of economic growth give great salience to firm-level actions and their consequences. Yet we have no well-grounded answer to the question of how big these consequences might be even for epochal actions, and no real firm-level standards exist for comparison to the computations on industry-level, sectoral, and economy-wide data well-known to economists and other students of economic growth and development.

The Ford Motor Company in the years before World War I represents a paradigm case of such firm-level epochal actions. The paucity of relevant Ford data has recently become somewhat less extreme. This paper utilizes information that has come to light since the books cited above were published to expand, at least incrementally, what we know.[2]

The data used in this paper are annual. Given the macro literature, this is a reasonable place to start. But given the history of technology literature, it is not a reasonable place to stop. In subsequent work I expect to extend this sort of analysis to much higher frequency data in order to relate it to a finer-grained timeline of change in the organization of production. I also expect to explore inter-firm comparisons.

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[2]The ledger sheets behind the calculations in this paper were obtained from the Detroit Public Library. Beyond the usual balance sheet data, they also give observations in the other series cited in this paper.

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Incremental Basic Facts About Ford

Most quantitative discussion of productivity growth at Ford in the literature measures the average product of labor. A neoclassical economist who really believed the production function parable would certainly say that this leaves a tremendous lacuna, one that all the description in the world of the character of organizational change and the machinery that implemented it could not be presumed to fill. But the historian of technology who thinks it matters very much precisely what those investment budgets were spent on ought also to subscribe to this view. The whole literature about Ford accepts and discusses the significance of dramatic changes in workforce size, i.e. in the labor input. That there was also substantial change in the capital input no one doubts. If any sort of comparison to other factories or even industries is to be made, the scale of this investment, its progress relative to changes in the scale of labor and other commonly measured inputs, and its contribution to productivity growth must be tied down.

One can find in the literature occasional indicia of capital investment at Ford and its relationship to other magnitudes, but not much is done with them [6, p. 60]. The numbers are not even what they seem to be. There are two principal reasons for the latter fact. The first is that the numbers derive, directly or indirectly, from figures given in the company's periodic balance sheets. The part of those numbers that represents productive physical capital is generally a simple sum of investments valued at historic (i.e., nominal) cost. Such numbers do not correct for changes in the price level relative to which the prices of the investment goods themselves were set. This was a period in which the Consumer Price Index rose 12 percent over five years, a period in which the Bureau of Labor Statistics price index for the main raw material of investment goods could change by as much as 11 percent over a single year's time. (See Table 1.) It really could matter when purchases were made.

Table 1: *Price Indices in this Period*

Year	CPI	WPI	BLS Metals and Metal Products Index
1909	100	100	100
1910	104	104	101
1911	104	96	96
1912	107	102	106
1913	110	103	107
1914	112	101	95

Nonetheless, the balance sheets (and the information behind them) represent an attractive data source. Unlike the balance sheets of General Motors (even under the Sloan regime), for example, they give fairly disaggregated line items. Sloan's General Motors lumped into a single line item real estate, plant, and equipment. Ford actually distinguishes, for example, machines from tools. This could be important because machines generally have different operating lives from tools. They certainly have different operating lives from real estate. If assets that embody or are complementary to technical change have operating lives different from the average, this will matter.

But here too lurks a problem. The balance sheets do give values (often a single line item) for depreciation. But it is entirely possible that the depreciation was calculated according to rules suitable for an "average" business in the economy. (This is in effect what the Internal Revenue Service requested of Ford once it got a chance after the War.[3]) The balance sheets themselves do not reveal the method. They certainly do not combine a good method with corrections for price level changes. Yet this is what is necessary to get a measure of capital input in real terms.

I present in column (i) of Table 2 a preliminary annual measure of the firm's capital stock. I worked backward from the stocks given in the balance sheets to infer the within-period flows. I deflated the value of these investments according to the Wholesale Price Index. (This is, unfortunately, the finest disaggregate that seems relevant.) I added these real flows to the (real) value of the beginning of period stocks, depreciated by the perpetual inventory method using depreciation rates that varied by line-item. The rates were the ones that Ford claimed, in its correspondence with the IRS, more closely corresponded to their actual observation of working life than those the IRS proposed.

Table 2: *Deflated Depreciated Aggregate Capital Stock Figures*

	(i)	(ii)	(iii)
Year	Capital Stock	Calculated Capital Utilization Rate	Effective Capital Stock
1909	1,077,534	1.00	1,077,535
1910	2,135,911	0.86	1,835,301
1911	2,903,197	1.02	2,967,712
1912	4,299,717	1.04	4,458,965
1913	6,331,670	0.96	6,050,262
1914	8,324,791	0.67	5,611,526

Unfortunately, measurement of capital input cannot stop here. This installed capital stock could be more or less intensively exploited. Shifts can be longer or shorter (they were), and there can be more or fewer shifts. Column (ii) gives a capacity utilization rate derived from the number of hours the plant operated in each year. Column (iii) gives the product of columns (i) and (ii), an adjustment for capacity utilization that yields an aggregate of effective capital input.

This final column is only an input to my main calculation; but it still bears examination. Corrected though the numbers are, they still grow extremely briskly over the period: the 1914 figure represents a more than five-fold increase over 1909. But how much is that? One way of putting the series in context would be to compare it to an appropriate measure of the labor input. Comparing it to the measure of labor input most commonly used in the literature would be an apples-to-oranges comparison since that measure is a number of bodies – typically

[3]Photocopies of correspondence in possession of the author.

"average number of men on roll" – and is not corrected for hours. It is easy enough to calculate an apples-to-apples comparison from the balance sheet data source, however. Table 3 gives the ratio of effective capital to hours of productive labor in the right-hand column.

Table 3: *Effective Capital, Effective Labor, and the Capital-Labor Ratio*

Year	Uncorrected Capital/Production Labor	Effective Capital/Labor
1909	.43	.43
1910	.59	.51
1911	.47	.48
1912	.40	.42
1913	.30	.28
1914	.62	.42

From the 1910 peak to the 1913 trough, using the corrected capital numbers in the capital-labor ratio makes for about 9 percent less variation. But the qualitative features do not change. The relatively high ratio in 1910 should probably be attributed to the Company's move into new and expansive production facilities that year. The steady decline over the next three years presumably represents progressively more effective intensive use of the new plant and incremental equipment.[4] The steadiness of the decline is striking: teachers of introductory microeconomics routinely suggest that the ratio ought to have been steadily rising over the period. Apparently the micro data have stories to tell.

Single-Factor Productivity Analysis

Computations of the average product of each factor are given in Table 4. These patterns are stark and may be a little surprising. Between 1909 and 1914 the average product of labor nearly tripled. But the average product of capital roughly tripled too. Even between 1909 and 1913, we see the average product of capital growing. In fact, it grew faster than that of labor in this sub-period.

Table 4: *Average Products of Factors*

Year	Cars/Production Labor Hour	Cars/$ Deflated Depreciated Capital
1909	0.0054	0.012
1910	0.0053	0.010
1911	0.0068	0.014
1912	0.0077	0.019
1913	0.0086	0.030
1914	0.0149	0.036

[4]Since Table 3 shows capital utilization going down quite sharply in 1914, the relatively high 1914 entry in this table represents either a brisk response of employment to the gathering recession or a big burst of real investment. The actual burst was modest by Ford standards. Factory hours were down, and productive labor hours were down even more. This is a good example of the value of using such micro data in productivity-related measures. The input variation here was in hours: the average number of men on roll figure does not change much.

Taking a step back, one might take a static view of the numbers and simply say that they look like a production process with increasing returns to scale. Over the whole period, capital input grew roughly five-fold. Labor input grew roughly five-fold. Output grew roughly fifteen-fold. The increase in output was more than proportionate to the growth in inputs. Knowing what went on within, we surely believe that some of this is going on. Yet we know too much of the detail of technical and organizational innovation to believe that over the five-year interval that this effect is predominantly due to increasing returns, at least in the sense in which economists use the phrase, i.e., holding techniques constant and simply using resources more productively within a given set of techniques. Asset categories like Real Estate, Buildings and Building Fixtures, and Office furniture and fixtures were growing from a three- to as much as a seven-fold range over this period. But asset categories like Machinery, Tools, and Factory Equipment were growing from nearer to nine-fold to more than thirteen. Table 5 gives some figures. Techniques were changing, and flows of capital investment played a major role in changing them.

Table 5: *Deflated Depreciated Balance Sheet Breakdowns*

Balance Sheet Category	1909	1914	Increment
Real Estate	118,772	379,279	319 %
Office Fixtures and Furniture	13,903	92,130	663 %
Buildings and Building Fixtures	482,863	3,388,437	702 %
Machinery	307,845	2,669,367	867 %
Tools	93,618	980,664	1048 %
Factory Equipment	60,534	14,914	1346 %

Thus far, none of this should seem particularly novel to the reader of, say, Hounshell. But thus far it is merely foundational.

Total Factor Productivity Growth at Ford

The basic empirical question growth economists ask makes especially good sense in a setting with micro data this fine. The question is how much of the growth of output cannot be accounted for simply by the growth of inputs [9]. The reasons this is a good question here are three. Most technically, the methods generalize to multiple factors of production.[5] Perhaps more importantly, there is some hope of being able to recognize and measure the inputs properly with data from a single enterprise.[6] With a single enterprise, most importantly of all, there

[5]The historical literature suggests, for example, that it would be useful to distinguish between inputs of direct ("production") and indirect ("non-production") labor. The new data make this feasible.

[6]The Ford enterprise is particularly attractive for a related reason. This firm, like many others only more so, had a great deal of control over the price at which it sold its output. Over time, then, total revenue bore at best a complex relationship to total output. But during the period in question, the design of the Ford product did not change in ways that made a large difference to the costs of production. And firm records give the actual

is some hope of understanding the substance and timing of technical and organizational change. Aggregation of dissimilar firms will not cloud the statistics. Cause and effect relations may therefore be clearer.

The standard calculation starts by computing year-on-year growth rates of output and of the principle inputs. The input growth rates are combined in a weighted sum where the weights are each input's share in total cost, units of the inputs having been valued at marginal cost. The weighted average is then subtracted off from the growth rate of output, leaving a residual. This residual, Denison's famous "measure of our ignorance," is the object of study [3]. It is scaled as a percentage rate of change per unit time and as such is comparable across firms, industry, and time.

There are of course index number theory and empirical assumptions behind the details of the calculation.[7] Their force is that the base case to which comparison is being made is that of constant-returns-to-scale production. This is not quite the production technology of a shop of master mechanics using general-purpose machinery, not excluding mallets and files, assembling bought-in components in a building that had previously been a general purpose shed; but it is probably not far off. Relative to Ford practice by the end of the period, the approximation is probably reasonably good.[8]

Indeed, the most common complaint about the interpretation of such a calculation is the flip side of its virtue. The calculation pushes – by construction – all influences on productivity that are not growth in inputs into the residual. Unusually, however, that is not inappropriate here. Part of what was valuable about the innovations at Ford is precisely that they allowed for previously unrealizable economies of scale. The economies of scale are part of the payoff. In this particular context, they belong in the residual.

Some technical details of the calculation here are worth recording. The factors considered are materials, production wage labor, non-production wage labor, physical capital, and inventories.[9] The proper wage rate to be applied to

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physical output. Thus that variable – the dependent variable in the calculations at issue – can be fairly accurately measured.

[7]Again see [9]. An unusually high proportion of the paper's assumptions actually make sense in this example. (See the previous footnote and, for example, the remark ubiquitous in the literature that the wage component of Ford blue-collar compensation prior to the Five-Dollar Day represented the going wage in the area.) One might also argue, more pragmatically, that essentially all computations to which such a one could be compared make the same assumptions.

[8]Here we have a good example of a matter in which micro-level comparative analysis of cost structures and productivity growth would be useful. I hope to include such a comparison in [8].

[9]I take these last to be work-in-process inventories on the basis of the widely repeated observation that there were no real facilities to store finished output at the plant. A measure of buffer stocks would be preferable. It would also be smaller, thus making the residual larger. But in any case, the numbers are small and would not affect the results significantly.

It is a pity that no record seems to survive of energy expenses. But in fact this absence post-Five-Dollar-Day labor is not entirely clear. I continued to use what each group of employees was, on average, paid.[10] Possibly some of the non-production labor ought not be counted. In the present-day terminology (and industry accounting), it all should. In any case, I counted it all. Probably some of the salaried labor should also be counted. But there was no information on even the total salary bill, so I ignored this.[11] An opportunity cost needs to be imputed to the capital expenditure. I used the return on short government debt, a safe financial asset, for purposes of subsequent inter-firm comparability.[12]

Table 6 gives the basic Ford results. The year of the transition to the new purpose-built factory was one of considerably decreased effectiveness. Tremendous initial gains to the opportunities of the new facilities followed. Annual improvement in overall productivity for the two years after that was smaller though still prodigious and growing vigorously. The *annus mirabilis* after the move appears in the comparison of 1913 to 1912. This was the rough period when assembly line production methods for parts and components was being worked out. Assembly line methods for final assembly, the wide world's icon of the technical change, were first experimented with starting late in 1913 and were not ready for full-scale implementation until the end of the year [4]. They cannot therefore have had much impact on 1913 output.[13] Progress the following year – doubtless due at least in part to the deep recession that struck the economy part-way through – was quite anemic by comparison.

***Table 6:** Total Factor Productivity Growth at Ford*

Period	TFPG (annual rate)	TFPG (compounded 1909-)
1909-1910	-0.23	
1910-1911	+0.72	
1911-1912	+0.35	
1912-1913	+0.47	+0.27
1913-1914	+0.03	+0.22

only interferes with comparisons to calculations for operations in fairly recent times – none of the classic computations draw on such data.

[10]Getting this right might make a non-trivial difference in the results, but it will not make a huge one. Total labor costs are a relatively small fraction of total costs.

[11]Valuing it would be problematic in any case. For the same reason given in the previous footnote, however, I do not believe the results would be very sensitive to this one way or the other.

[12]One could instead use information from the balance sheet to figure our what the company actually was earning on its excess cash. But this might be the answer to a different question.

[13]In the Business History Conference meeting in Toronto some years ago, Lewchuk gave a talk in which he referred disparagingly to "final assembly fetishism." In terms of Ford's pre-War experience, this table shows him absolutely right.

A Cross-Sectional Context

The rates shown in Table 6 are extremely large relative to the figures that appear in the press and in technical publications today. They are, of course, about an exceptional plant. But what we are interested in is a measure of how exceptional it was. How do they stack up against what we know about total factor productivity growth in Ford's own time? The basic source here is John Kendrick's 1961 NBER study [5].[14] Table 7 tells the tale.

Table 7: Annualized Total Factor Productivity Growth at Ford Compared

Entity measured	ATFPG 1909-1914	ATFPG 1909-1919
Ford Motor Company	+0.22	
National economy (Real net product)		+0.015
Durable goods manufacturing		+0.007
Chemicals		-0.007
Furniture and fixtures		-0.005
Primary metals		-0.005
Electrical machinery		+0.003
Non-electrical machinery		+0.007
Textile mill products		+0.009
Fabricated metals		+0.018
Transportation equipment		+0.070

Total factor productivity grew on average at the modest rate of about one and one-half percent per annum.[15] The overall figure for durable goods manufacturing was about half this. Chemicals, Furniture, and Primary Metals did quite badly at rates in the vicinity of negative one-half of one percent per annum. Neither Electrical nor Non-Electrical Machinery managed as large a positive average as one percent. Fabricated Metals posted nearly two percent. (Apparel and Related Products and Tobacco, non-durable and so not in the Table, showed nearly three and nearly five percent respectively.) Transportation Equipment stands at the head of this pack. But even it stands only at seven percent even.

The Ford residual was thus extraordinarily big. It was big relative to the sort of figures (typically for whole industries) that we hear about now.[16] It was very big relative to average performance in other industries of the day. There is

[14]See in particular his Tables A-XIX, D-III, and D-IV.

[15]It would of course be better to subject Ford's performance to whatever economy-wide influences affected all firms in the 1914-1919 period. But the thought experiment of imagining a decadal Ford calculation with the true number for 1909-1914 and the Transportation Equipment or even Durable Goods number for the remainder will confirm the point that Ford was a genuine outlier.

[16]I am not aware of any publications examining intra-industry distributions of such measures. Presumably they can be calculated and studied using the Longitudinal Establishment Database of the Center for Economic Studies of the Bureau of the Census, though individual firm identities in that database are masked.

every reason to suspect that it was big relative to those of other firms in the automobile industry in its own day. The manuscript returns to the Census of Manufactures covering 1919 have not survived, so no exercises of the form of Bresnahan and Raff [2] can be performed. But crude indicative calculations can be performed on the published Census numbers indicating that the typical Ford plant in that year looked very different from the typical plant in the rest of the industry in terms of output-, capital-, and many other Census measures per head.[17] The strikes that threatened to cripple the industry late in the measurement period seem to have been strikes of craft workers.[18] Even a decade later, the Big Three plants appear in the statistics very different from the great bulk of the industry; and in the six years that followed they seem to have acted differently [1, 2]. The smaller plants appear to have been less capital-intensive and more skill-intensive. They seem to have been markedly less productive. The big diffusion of technique, despite the conspicuousness of Ford's innovations and the riches he reaped from them, did not come until significantly later.

Conclusions

This paper has three positive findings. These are that 1) the bulk of the growth in total factor productivity preceded rather than followed the introduction of the moving assembly line, 2) this growth came in bursts, i.e., that mass production was not One Big Thing, and, on the other hand, 3) mass production was One Very Big Thing. The paper also offers an indication that 4) mass production was One Very Local Thing for a very long time. The first three of these points deserve investigation with higher-frequency data drawing on non-quantitative sources to characterize the nature and timing of the technological and organizational change. Micro comparisons to firms implementing different programs of change should also be interesting under all four heads. Investigations of both these sorts are currently under way.

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[17]The main reason for being cautious about these numbers concerns the non-uniformity of Ford capital investment across the company's plants. But the union of all these facilities was the real operating system. A reasonably reliable Ford-versus-Typical-Firm-in-the-Rest-of-the-Industry comparison could in principle be constructed. I hope to include one in [8].

[18]See, e.g., "Government Analysis of Labor: Detroit Situation Reaches Acute Stage," *Automotive Industries* 38 (April 25, 1918), 841, and "Detroit Union Workers Demand 44 Hour Week" *Automotive Industries* 40 (May 1, 1919), 972.

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