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Lean Manufacturing and its Impact on Production Wages and Employment

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Abstract. The study is an initial assessment of linkages which may exist between measures of lean manufacturing, as measured by value added, and employee wages. The results confirm a positive correlation between lean (or value-added) manufacturing and increased worker wages. Subsequent research will examine causation and direction of influence.

Keywords: Lean manufacturing, production wage, employment

1. Introduction

As manufacturing processes becomes increasingly complex and rapidly changing, there is a greater potential for workforce apprehension. This reluctance sometimes manifests itself in struggles to adopt new workplace processes. Workplace initiatives can be negatively misinterpreted as attempts to undermine the social contract between the employer and employees. Given the natural power disparity inherent in this relationship, employees may view further change as attempts to further mitigate their bargaining position. Within this context, the incentives for employees to resist the adoption of lean manufacturing become clear. These efforts can be viewed as steps to minimize their organizational importance and contribute to further decreases in manufacturing wages and employment opportunities. The lack of direct research to counteract this prevailing viewpoint only re-enforces its legitimacy.

This study is an initial step in understanding the impact of value adding (or lean) manufacturing on manufacturing employment and wages.

This research is aligned with existing and well established work in the area of efficiency wage hypothesis. Efficiency wage hypothesis (EWH) research examines the potential for wage premiums over market clearing wages to attract better talent to an organization and favorably impact productivity (Stiglitz 1976).

As EWH research focuses on the premium to lure better talent it is both a directional. The premiums lure better talent, thus the increased wage results in better performance. Additionally, as more firms adopt this approach, the pool of better talent diminishes thus reducing the impact. This research differs from the studies in EWH as it does not assess the performance impacts of wage premiums over market clearing. In contrast, this study uses statewide wage averages which are market clearing prices. Using state-wide averages, the study examines the directional link between productivity and market clearing wages, rather than a premium. Specifically, this study is the first step in understanding productivity's influence on market clearing wages. Additionally, this research maintains a singular focus on the manufacturing industry rather than the larger aggregate labor market.

2. Methodology

This study sources data from the U.S. Census Annual Survey of Manufacturing (ASM). It includes statewide data for fifty states and the District of Columbia beginning in 1998 through 2013 (U.S. Census Bureau, 2015). The manufacturing data includes total number of employees, total number of production employees, total wages for production employees, total production hours for production employees, value added by the company, and capital expenditures by the company. Calculated variables are added. The data is compiled into an unbalanced panel dataset and summary statistics for data are provided in Table 1. The methods used to determine the calculated variables are provided at the bottom of Table 1.

Table 1.

Table 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Total Employees	13,767	1,551.48	23,126.73	0	395,299
Production Employees	13,728	10,957.02	15,907.37	0	220,427
Total Wages for Production Employees	13,698	3.65E+08	6.20E+08	0	1.2E+10
Total Hours for Production Employees	13,748	2.09E+07	3.20E+07	0	4.82E+08
Production Employees Wages per Hour (1)	13,587	17.27	5.30	0	50.35
Wage per Production Employee (2)	13,569	31993.21	13825.79	0	114817.10
Value Added	13,428	2.32E+09	4.37E+09	0	8.06E+10
Value Added per Production Hour (3)	13,310	118.00	141.21	0	2,679.85
Capital Expenditures	12,313	1.54E+08	3.35E+08	0	6.83E+09
Capital Expenditures per Production Employees (4)	12,168	14,811.97	31,205.54	0	1,279,897
Ratio of Total Employees to Production Employees (5)	13620	1.43	0.30	0	7.95

(1) Calculated as: Total Wages for Production Employees / Total Hours for Production Employees
(2) Calculated as: Total Wages for Production Employees / Production Employees
(3) Calculated as: Value Added / Total Hours for Production Employees
(4) Calculated as: Capital Expenditures / Production Employees
(5) Calculated as: Total Employees / Production Employees

The empirical design chosen is an ordinary least squares (OLS) model. Yearly binaries are created to account for yearly influence such as the general economic climate and inflation. State binaries are created to account for state specific influences and variation in cost of living. Industry binaries are created which designate the type of manufacturing, as differing wage scales within specific segments of manufacturing exist. The manufacturing designations are based on 3 digit NAISCS code. The study assumes that different types of manufacturing require differing levels of employee skill endowments, and that the more skills required, the higher the wage (Snell & Dean 1992. Different skill requirements for different categories of manufacturing therefore lead to different wage structures across industries.

The second goal is to establish that link within all manufacturing categories. Even within a low value added manufacturing category, the increases in efficiency achieved by the adoption of lean manufacturing practices may have wage and employment implications which can be assessed by including a control for the potential industry classification bias. The industry binary variable should help accommodate these differences and help provide unbiased results by validating a link between a marginal increases in value and marginal increases in wages, across all manufacturing.

The model is run on four variables. The first two independent variables in the study are the number of production employees and total hours for production employees. This will determine the influence of the explanatory variables on production employment. The next two are production employees' wages per hour wage per production employee (annual). These independent variables will help determine the influence of explanatory variables on these measures of wages.

As the study is attempting to determine the impact of lean manufacturing on production line employee wages and employment, a measure of lean must be derived. Lean management "refers to an approach to management that focuses on reducing or eliminating waste in all facets of the system" (APICS). Given the measurable provided in the dataset, the study will use value added per production employee hour as a proxy for lean. As a manufacturer becomes lean, it should increase the value added it provides per production employee per hour. Gross value added per employee has been used in prior studies, such as by Kochan, Landsbury, et al (1997). The variable, value added per production employee, is used as explanatory in this study.

Investment is also a possible explanatory variable. In particular capital investment can influence the level of value added in the manufacturing process. Capital investment can be a potential influence on the independent variables. Finally, the ratio or total to production employees is added as an explanatory variable. This variable will help ascertain the influence, if any, of differing employee structures.

The non-binary data is transformed to natural log form. This is done to help account for exponential effects. Secondly, and more importantly, is to aid in the interpretation of the data. As both the independent and explanatory variables of note are in natural log form, the magnitudes of the result coefficients will be elasticities.

In an effort to better understand the directionality of influence, Durbin-Watson test is conducted which finds evidence of autocorrelation. Increases in value added per employee hour (or becoming lean) have a lingering effect on wages. The impact is not only felt in the current period, but the influence carries into future periods. This effect provides some evidence for directionality of influence and causality. The value added influence precedes wage and employment change. An autogressive term is added to model in order to accommodate this influence, and is represented by a one year lagged value added per production employee term.

3. Results

The results establish a strong correlation between value added and wage variation. Increases in worker productivity yield higher wages for workers. The results of the non-binary variables are provided in Table 2.

Table 2.

Table 2: OLS Results (Non-Binary Variables)	1			2			3			4		
	Production Employees			Total Hours For Production Employees			Production Employees Wages Per Hour			Wage Per Production Employee		
Adjusted R-Square	0.747			0.919			0.850			0.996		
	Coeff	Std Err.		Coeff	Std Err.		Coeff	Std Err.		Coeff	Std Err.	
Value Added Per Production Employee	0.161	0.031	***	0.131	0.031	***	0.139	0.006	***	0.109	0.006	***
Value Added Per Production Employee Lagged (one year)	0.320	0.031	***	0.334	0.031	***	0.051	0.006	***	0.064	0.006	***
Capital Expenditures per Production Employees	0.250	0.012	***	0.270	0.012	***	0.055	0.002	***	0.075	0.002	***
Ratio of Total Employees to Production Employees	-0.641	0.059	***	-0.590	0.059	***	-0.080	0.011	***	-0.029	0.011	***
*** 1% level of significance												

The value added and its lagged variable are both highly significant and positive in all four models. Value added is positively correlated with more production employees, more total hours for production employees, higher production employee's wages per hours, and higher total wage per production employee. Increasing the value added per employee is correlated with increasing levels of production employment and higher production wages. Value added also has a lingering effect as indicated by the lagged variable. This is important as it indicates directionality, as it supports the theory that value added leads to higher salaries (and not the reverse) while also suggesting causation. However, this study lacks the explanatory variables necessary to claim a causal link, so the focus is correlation. The results do provide the basis of further research to substantiate the current findings and further develop the case for causality.

The capital expenditure per production employee variable is highly significant and positive in all four models. Capital expenditures and process automation is positively correlated with more production employees, more total hours for production employees, higher production employee's wages per hours, and higher total wage per production employee. Efforts in lean manufacturing are often coupled with capital expenditures. These capital expenditures, rather than diminishing the need for workers, are correlated with increasing levels of production employment and higher production wages.

The ratio of total employees to production employees is highly significant and negative in all four models. Manufacturing companies which are increasingly top heavy are correlated with less production employees, less total hours for production employees, lower production employee's wages per hours, and lower total wage per production employee.

The results suggest a positive link between value added enhancement activities and worker welfare. However, the results are not uniformly positive. As the non-binary variables are transformed into natural log form, the coefficients are elasticities. From this analysis it can be inferred that although increasing value add will result in increased employment and wages, the increases in employment and wages are less than proportional. A 1% increase in value added only results in a 0.16% increase in production employment, a 0.13% increase in total hours for production employees, a 0.14% increase in production employee's wages per hour, and 0.11% increase in total production employee wages. This indicates that only a small portion of the benefits of value added enhancement activities are allocated to production employees.

The results generally suggest a positive relationship between lean manufacturing its financial impact on production employees. Value added enhancement is associated with higher levels of production employment and wages. However, the advances in employment and wage growth are less than proportional to the increase in value add.

The results suggest a strong bias to future increases in manufacturing are likely afforded those which can provide higher levels of value compared to competition. Lean manufacturing advocates can use this information to thwart possible negative perceptions of lean efforts. This knowledge is also important in both State planning and educational strategy. Economic development should focus on brining high value add manufacturing to the state if they wish long term increases in wage and employment growth. A state with only low skill manufacturing will more likely languish with slow wage growth and lower rates of employment growth. If a State wishes to bring in higher value added they will also need a workforce with the skills desired of value added (or advanced) manufacturers. Having adequate educational services to provide for this demand is important. Full results are provided in Table 3.

Table 3.

Table 3: OLS Results	1		2		3		4	
Full Results	Production Employees		Total Hours For Production Employees		Production Employees Wages Per Hour		Wage Per Production Employee	
Adjusted R-Square	0.747		0.919		0.850		0.996	
	Coeff	Std Err.	Coeff	Std Err.	Coeff	Std Err.	Coeff	Std Err.
Value Added Per Production Employee	0.161	0.031 ***	0.131	0.031 ***	0.139	0.006 ***	0.109	0.006 ***
Value Added Per Production Employee Lagged (one year)	0.320	0.031 ***	0.334	0.031 ***	0.051	0.006 ***	0.064	0.006 ***
Capital Expenditures per Production Employees	0.250	0.012 ***	0.270	0.012 ***	0.055	0.002 ***	0.075	0.002 ***
Ratio of Total Employees to Production Employees	-0.641	0.059 ***	-0.590	0.059 ***	-0.080	0.011 ***	-0.029	0.011 ***
NAISCS 311	1.337	0.036 ***	1.372	0.036 ***	-0.131	0.007 ***	-0.095	0.007 ***
NAISCS 312	-1.808	0.042 ***	-1.787	0.042 ***	-0.050	0.008 ***	-0.029	0.008 ***
NAISCS 313	-0.200	0.048 ***	-0.159	0.048 ***	0.005	0.009	0.047	0.009 ***
NAISCS 314	-0.316	0.044 ***	-0.318	0.045 ***	-0.112	0.008 ***	-0.114	0.008 ***
NAISCS 315	0.247	0.048 ***	0.222	0.050 ***	-0.191	0.009 ***	-0.215	0.009 ***
NAISCS 321	0.818	0.039 ***	0.850	0.040 ***	0.019	0.007 ***	0.051	0.007 ***
NAISCS 322	0.036	0.039	0.111	0.039 ***	0.164	0.007 ***	0.239	0.007 ***
NAISCS 323	0.726	0.036 ***	0.715	0.037 ***	0.148	0.007 ***	0.137	0.007 ***
NAISCS 324	-2.374	0.050 ***	-2.288	0.051 ***	0.151	0.009 ***	0.237	0.009 ***
NAISCS 325	-0.281	0.037 ***	-0.249	0.038 ***	0.086	0.007 ***	0.117	0.007 ***
NAISCS 326	0.914	0.038 ***	0.954	0.038 ***	0.018	0.007 ***	0.058	0.007 ***
NAISCS 327	0.216	0.037 ***	0.275	0.038 ***	0.092	0.007 ***	0.152	0.007 ***
NAISCS 331	0.038	0.039	0.119	0.040 ***	0.210	0.007 ***	0.291	0.007 ***
NAISCS 332	1.525	0.035 ***	1.566	0.036 ***	0.130	0.006 ***	0.170	0.007 ***
NAISCS 333	0.962	0.033 ***	0.990	0.034 ***	0.131	0.006 ***	0.160	0.006 ***
NAISCS 334	omitted		omitted		omitted		omitted	
NAISCS 335	0.119	0.036	0.139	0.036 ***	0.057	0.006 ***	0.077	0.007 ***
NAISCS 336	1.127	0.035 ***	1.147	0.036 ***	0.288	0.006 ***	0.307	0.007 ***
NAISCS 337	0.741	0.039 ***	0.764	0.039 ***	0.275	0.007 ***	0.050	0.007 ***
NAISCS 339	0.560	0.034 ***	0.564	0.034 ***	-0.043	0.006 ***	-0.039	0.006 ***
Year 1998	omitted		omitted		omitted		omitted	
Year 1999	-1.001	0.090 ***	5.782	0.091 ***	-0.627	0.016 ***	6.156	0.017 ***
Year 2000	-1.026	0.090 ***	5.748	0.091 ***	-0.603	0.016 ***	6.172	0.017 ***
Year 2001	-1.068	0.089 ***	5.701	0.090 ***	-0.585	0.016 ***	6.184	0.017 ***
Year 2002	-1.138	0.089 ***	5.631	0.090 ***	-0.578	0.016 ***	6.241	0.017 ***
Year 2003	-1.202	0.087 ***	5.598	0.088 ***	-0.524	0.016 ***	6.276	0.016 ***
Year 2004	-1.274	0.088 ***	5.537	0.089 ***	-0.499	0.016 ***	6.311	0.017 ***
Year 2005	-1.382	0.088 ***	5.429	0.089 ***	-0.493	0.016 ***	6.318	0.017 ***
Year 2006	-1.450	0.088 ***	5.354	0.089 ***	-0.479	0.016 ***	6.324	0.017 ***
Year 2007	-1.464	0.089 ***	5.319	0.090 ***	-0.476	0.016 ***	6.307	0.017 ***
Year 2008	-1.487	0.089 ***	5.293	0.090 ***	-0.443	0.016 ***	6.337	0.017 ***
Year 2009	-1.618	0.087 ***	5.142	0.088 ***	-0.407	0.016 ***	6.352	0.016 ***
Year 2010	-1.690	0.087 ***	5.088	0.089 ***	-0.392	0.016 ***	6.386	0.017 ***
Year 2011	-1.756	0.089 ***	5.019	0.090 ***	-0.391	0.016 ***	6.384	0.017 ***
Year 2012	omitted		omitted		omitted		omitted	
Year 2013	omitted		omitted		omitted		omitted	
Alabama	2.891	0.419 ***	3.004	0.425 ***	-0.061	0.027	-0.113	0.028 ***
Alaska	1.736	0.441 ***	1.900	0.447 ***	omitted		omitted	
Arizona	2.064	0.419 ***	2.158	0.425 ***	-0.090	0.027 ***	-0.160	0.028 ***
Arkansas	2.434	0.419 ***	2.539	0.425 ***	-0.085	0.027 ***	-0.145	0.028 ***
California	4.211	0.419 ***	4.309	0.424 ***	-0.048	0.027	-0.114	0.028 ***
Colorado	2.028	0.419 ***	2.127	0.425 ***	0.005	0.027	-0.061	0.028
Connecticut	2.129	0.419 ***	2.234	0.425 ***	0.046	0.027	-0.014	0.028
Delaware	0.857	0.422	0.963	0.427	0.034	0.028	-0.024	0.030
Washington D.C.	omitted		omitted		0.275	0.079 ***	0.110	0.083
Florida	2.989	0.419 ***	3.092	0.422 ***	-0.102	0.027 ***	-0.163	0.028 ***
Georgia	3.208	0.419 ***	3.329	0.424 ***	-0.072	0.027 ***	-0.115	0.028 ***
Hawaii	1.000	0.429	1.061	0.434	0.024	0.031	-0.079	0.033
Idaho	1.224	0.421 ***	1.318	0.426 ***	-0.289	0.028	-0.100	0.029 ***
Illinois	3.384	0.419 ***	3.503	0.424 ***	-0.031	0.027	-0.077	0.028 ***
Indiana	3.255	0.419 ***	3.364	0.425 ***	-0.006	0.027	-0.619	0.028
Iowa	2.391	0.419 ***	2.487	0.425 ***	-0.040	0.027	-0.109	0.028 ***
Kansas	2.189	0.419 ***	2.289	0.425 ***	-0.025	0.027	-0.089	0.028 ***
Kentucky	2.714	0.420 ***	2.812	0.425 ***	-0.048	0.027	-0.114	0.028 ***
Louisiana	2.071	0.420 ***	2.187	0.425 ***	0.000	0.027	-0.047	0.028
Maine	1.423	0.420 ***	1.506	0.425 ***	0.013	0.027	-0.068	0.028
Maryland	1.959	0.419 ***	2.054	0.425 ***	0.017	0.027	-0.053	0.028
Massachuetts	2.608	0.419 ***	2.718	0.424 ***	0.032	0.027	-0.023	0.028
Michigan	3.227	0.419 ***	3.338	0.425 ***	0.033	0.027	-0.020	0.028
Minnesota	2.798	0.419 ***	2.887	0.424 ***	0.010	0.027	-0.067	0.028
Mississippi	2.398	0.420 ***	2.510	0.425 ***	-0.107	0.027 ***	-0.160	0.028 ***
Missouri	2.796	0.419 ***	2.883	0.424 ***	-0.051	0.027	-0.129	0.028 ***
Montana	0.564	0.423	0.625	0.428	0.045	0.029	-0.059	0.030
Nebraska	1.684	0.420 ***	1.800	0.425 ***	-0.067	0.027 ***	-0.116	0.028 ***
Nevada	0.997	0.420 ***	1.108	0.425 ***	-0.046	0.027	-0.100	0.029 ***
New Hampshire	1.549	0.420 ***	1.646	0.424 ***	0.008	0.027	-0.059	0.028
New Jersey	2.825	0.419 ***	2.940	0.424 ***	0.022	0.027	-0.027	0.028
New Mexico	0.869	0.422	0.961	0.428	-0.061	0.283 ***	-0.133	0.030 ***
New York	3.402	0.419 ***	3.493	0.424 ***	-0.011	0.267	-0.085	0.0280 ***
North Carolina	3.484	0.419 ***	3.587	0.424 ***	-0.074	0.027 ***	-0.136	0.028 ***
North Dakota	0.684	0.423	0.767	0.428	-0.084	0.0283 ***	-0.166	0.028 ***
Ohio	3.464	0.423 ***	3.570	0.424 ***	-0.004	0.027	-0.061	0.028
Oklahoma	2.073	0.419 ***	2.184	0.425 ***	-0.080	0.027 ***	-0.134	0.028 ***
Oregon	2.211	0.419 ***	2.287	0.425 ***	0.005	0.027	-0.083	0.028 ***
Pennsylvania	3.588	0.419 ***	3.690	0.424 ***	-0.010	0.027	-0.073	0.028 ***
Rhode Island	1.309	0.419 ***	1.421	0.425 ***	-0.024	0.027	-0.076	0.029 ***
South Carolina	2.712	0.419 ***	2.824	0.425 ***	-0.053	0.027	-0.106	0.028 ***
South Dakota	1.142	0.419 ***	1.246	0.426 ***	-0.103	0.027 ***	-0.163	0.029 ***
Tennessee	2.996	0.421 ***	3.098	0.424 ***	-0.078	0.027 ***	-0.140	0.028 ***
Texas	3.675	0.419 ***	3.790	0.424 ***	-0.078	0.027 ***	-0.128	0.028 ***
Utah	1.786	0.419 ***	1.878	0.425 ***	-0.055	0.027	-0.127	0.028 ***
Vermont	0.934	0.421	1.030	0.426	0.015	0.028	-0.053	0.029
Virginia	2.862	0.419 ***	2.977	0.424 ***	-0.030	0.027	-0.080	0.028 ***
Washington	2.499	0.419 ***	2.579	0.424 ***	0.030	0.027	-0.054	0.028
West Virginia	1.533	0.420 ***	1.622	0.426 ***	-0.010	0.027	-0.086	0.029 ***
Wisconsin	3.110	0.419 ***	3.201	0.424 ***	0.005	0.027	-0.069	0.028
Wyoming	0.455	0.429	0.597	0.425 ***	0.069	0.032	0.048	0.033
Constant	2.989		3.551		1.947		2.672	

*** 1% level of significance

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