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# Do Workforce and Organizational Practices Explain the Manufacturing Technology Implementation Advantage of Small Defense Contractors over Non-Defense Establishments?

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## ABSTRACT

This paper explores whether defense contractors' manufacturing technology advantages over purely commercial firms might be associated with differences in their workforce and organizational practices. I use unique original data collected specifically to test workforce and organizational complementarities in implementation of advanced manufacturing technology in small manufacturers. I find that defense contractors 1) have higher and deeper rates of technology use; 2) have greater success achieving manufacturing goals; 3) are more likely practitioners across a diverse spectrum of advanced workforce and organizational practices. Then, 4) econometrically, I find the defense contractors' technology advantages positively associated with those differences in organizational and workforce practices.

## INTRODUCTION

Remarkably, almost no empirical studies directly compare defense and commercial organizational, manufacturing or workforce practices. Those few that do uniformly find a higher rate of adoption of advanced manufacturing technologies among manufacturers that do some defense contracting or subcontracting than among those with purely commercial customers. This gap is particularly pronounced for small manufacturers.

What might explain the advantage? A growing literature, covering a wide range of industrial sectors, is uncovering complementary relationships between success in implementing new technologies and both workforce development practices and other organizational strategies. Based on this literature, I hypothesize that defense contractors' manufacturing technology advantages might be associated with differences in their workforce and organizational practices.

I use a unique original data set on 125 small (<250 employees) manufacturing establishments, collected specifically to test workforce and organizational complementarities in the implementation of advanced manufacturing technologies. I am able to test:

1. Whether or not small manufacturing establishments that do some defense contracting differ in their implementation of several advanced manufacturing technologies compared to similar establishments in the same industries with strictly commercial customers. I find significantly higher (and deeper) rates use by defense contractors, confirming earlier research from unrelated data.
2. Whether, among small establishments that have adopted those technologies, defense-contracting establishments differ in the degree of success in meeting the goals of manufacturing technology implementation, measured along several dimensions. I find significantly greater success among defense contractors. I believe this finding is unique in the literature.
3. Whether these small defense establishments differ from otherwise similar strictly commercial establishments in a number of workforce and organizational practices previously found in the literature to be positively associated with technology implementation. I find a remarkably consistent pattern across a diverse spectrum of workforce and organizational practices that defense contractors are more likely practitioners.
4. Econometrically, whether the defense contractor advantages confirmed in steps 1 and 2 are associated with those differences in organizational and workforce practices in step 3. Though unable to test for causality, I find strong evidence that they are positively associated.

This suggests the need for further research into the underlying question: what is it about the defense-contracting environment that fosters advanced approaches to workforce development and organization? What role has government played in creating that environment? The policy lessons from such future research might lead to improving significantly the competitiveness of the large numbers of small U.S. manufacturers.

## BACKGROUND

The potential intersection of two streams of literature motivates the analysis here. The first is a series of empirical findings about defense-contracting small firms' apparent advantages over their strictly commercial counterparts in manufacturing and in technology implementation. The second deals with the complementarities between new technology implementation and managerial, organizational and workforce practices. I briefly address each in turn below.

Why study small defense firms? To begin with, small firms are important in U.S. manufacturing, representing fully 42% of manufacturing employment (US Census, 2001). Similarly, defense contracting makes up a significant fraction of all US manufacturing. The US Department of Defense FY 2005 budget for procurement and R&D, which largely goes to manufacturing firms, was $147 billion. Moreover, small firms accounted for 21.4% of defense prime contracts to US firms in FY2003 (DOD, 2003). Small firms are even more important in the subcontracting base, consistently accounting for about 40% of the value of defense subcontracts since 1995 (NASCAM, 2003).

Defense contracting is spread remarkably broadly through US manufacturing. A US Census of Manufacturers survey in 1988 found very nearly half (49.7%) of all establishments in the manufacturing SIC sectors 34-38 were either defense prime or subcontractors (Bureau of the Census, 1989). Several years later, Kelley and Watkins (1995) found a similar 48.8% prime or subcontracting rate among establishments in 21 (SIC 3-digit) machining intensive durable goods (MDG) industries, amounting to approximately 40,000 manufacturing establishments involved in defense contracting nationwide in these industries alone, which do not include electronics or chemical industries. More recent data from Oden, Wolf-Powers, Markusen (2000) indicate that despite the defense downsizing and consolidation among the top-tier prime contractors in 1990s there was no major reduction in the number of supplier establishments among lower/smaller tiers of the DOD supply chain.

**Advantages to Small Firms in Defense Contracting** Special military performance and technical requirements, contracting and accounting procedures and government oversight have led many knowledgeable observers to agree with the conventional wisdom that defense contractors are inefficient, technically backward and isolated from commercial practice, a mantra repeated for decades since Eisenhower first referred in 1961 to the "military-industrial complex" (Peck & Scherer, 1962, Melman, 1974, Alic et al., 1992, Gansler, 1989, 1995, Markusen & Costigan, 1999). Recently, the National Coalition for Advanced Manufacturing (NACFAM, 2002) suggested that "Outdated and aging manufacturing systems and processes are present in the production processes of major weapons systems", and that small firms "frequently lack the necessary technical knowledge, staff, and resources to take advantage of new techniques and technology." Similarly, according to the National Research Council (2002): "Many individual examples of [Integrated Commercial and Military Manufacturing] potential have been demonstrated, but they remain the exception rather than the rule," and that "the commercial sector leads the military industrial sector in developing and adopting new technology." Even the DOD itself (DOD, 2003) believes that "Traditional defense suppliers, often shielded from the forces of competition based on price and speed to market, do not always have efficient practices and processes compared to the world's leading commercial firms."

Yet despite these claims, remarkably, almost no empirical studies directly compare defense and commercial organizational, manufacturing or workforce practices. Most claims have been based on looking at the defense contractors in isolation, compared only to some conceptual idealized "commercial firm." Those few studies that do use real comparative data uniformly find integration rather than isolation of commercial and military manufacturing in the smaller supplier tiers (Kelley & Watkins, 1992, 1995, 1998, Oden, Wolf-Powers and Markusen, 2000, Stowsky, 2004). This is a non-trivial refutation of the received wisdom: in the 1990s subcontracts alone accounted for 41% of all defense-related sales, and strictly lower-tier suppliers accounted for well more than half (54%) of the value of shipments to defense prime contractors (Kelley & Watkins, 1995). Even before the defense drawdown during the 1990s the typical defense contracting establishment was not particularly dependent on DOD, with median defense share of sales in 1990 only 15%, and only 21.4% of prime contractors with more than half their sales going to DOD (Kelly & Watkins, 1995). If anything, the integration within smaller firms has increased more recently. Oden, Wolf-Powers, Markusen (2000) found that while the large-scale consolidation of major primes during 1990s did increase their isolation, it conversely increased the integration of military and commercial manufacturing (i.e dual-use) among smaller defense contractors. Echoing these dual-use findings, Stowsky (2004) reports that defense technologies increasingly have commercial roots, and believes shared approaches have been more successful for DOD innovation than shielded ones.

Looking specifically at technology use, the few comparative studies also find a higher rate of adoption of advanced manufacturing technologies among manufacturers that do some defense contracting or subcontracting than among those with purely commercial customers. Kelley and Watkins, (1998) investigated the use of six different advanced manufacturing technologies, and found the gap particularly pronounced for small manufacturers, and the defense advantage holds even among those that do the vast majority of their business in commercial markets (Kelley & Watkins 1995, 1998). Differences in manufacturing scale, precision or industrial sector and other widely held assumptions about defense contracting turn out neither to be true, nor to explain the technical advantages of defense contractors (Watkins & Kelley, 2001).

**Technology Implementation and Complementary Organization and Workforce Practices** If differences in precision or manufacturing scale do not explain the technology implementation advantages of small defense contracting firms over commercial, what might? A rapidly growing literature, covering a wide range of industrial sectors, is uncovering complementary relationships between success in implementing new technologies and both workforce development practices and other organizational strategies (e.g. Gallardo, 2003; Bresnahan, Brynjolfsson & Hitt, 2002; Murnane, Levy & Autor, 1999; Kelley, 1994). In particular, the use of information technology (IT) in manufacturing is well understood to improve productivity, quality and flexibility (Piore & Sabel, 1984, Milgrom &

Roberts, 1990, Kelley, 1994, Brynjolfsson & Hitt, 1996, 2000, Siegel, 1995, Mukhopadhyay, Rajiv & Srinivasan, 1997, Jorgenson, 2001). However, the effectivness of IT implementation is dependent on a host of complementary organizational and manufacturing process changes and workforce skill sets. In terms of organizational and process issues, Milgrom and Roberts (1990) discuss the importance of implementing IT as part of an interdependent system of smaller batches, more frequent product design/redesign, more communication, less vertical governance and the joint implementation of multiple IT applications. Brynjolfsson & Hitt (2000) found empirical evidence that the value of computers in manufacturing depends on new processes, procedures and organizational structures, and computers enable productivity enhancing organizational investments. For workforce skills, Berman, Bound & Griliches (1994) find that skilled labor demand increases with IT investments. Similarly, Doms, Dunne & Troske, (1997) show factory automation adoption correlated at the plant level with more educated workers, more professional and managerial workers, higher-skilled craft workers, but this was true *both* pre-and post- adoption. Modeling workforce and organizational issues simultaneously, Bresnahan (1999) found falling IT costs and implementation coincident with a cluster of changes in both workplace organization and higher labor skills. Bresnahan, Brynjolfsson & Hitt (2002) found both, that IT, workplace reorganization (decentralized decisions, team building, employee involvement in decision making,) and higher labor skills (training & education) are all complementary.

This line of literature, when combined with empirical evidence of the technology adoption advantages of small defense contractors compared with their strictly commercial counterparts leads to the following:

> ***Hypothesis:*** *Defense contractors' manufacturing technology implementation advantages are associated with more advanced workforce and organizational practices.*

To address the hypothesis the analysis in the rest of the paper addresses the following four major research questions:

1. Do small manufacturing establishments that do some defense contracting differ in their implementation of several advanced manufacturing technologies compared to similar establishments in the same industries with strictly commercial customers?
2. Do small defense-contracting establishments differ in the degree of success in meeting the goals of advanced manufacturing technology implementation?
3. Do small defense-contracting establishments differ from otherwise similar strictly commercial establishments workforce and organizational practices previously found in the literature to be positively associated with technology implementation?
4. Econometrically, are the defense contractor advantages we confirm in questions 1 and 2 associated with those differences in organizational and workforce practices?

## METHODOLOGY & DESCRIPTIVE STATISTICS

The analysis here uses a unique data set from a 2003 telephone survey of a random sample of 125 small manufacturing establishments in southeastern Pennsylvania by Gallardo L. (2003). The purpose of this survey was to study complementarities among human resource management and organizational practices in the implementation of advanced manufacturing technologies. Gallardo L. (2003) has a detailed discussion of the methodology.

The target population included establishments with fewer than 250 employees in nine 2-digit SIC manufacturing industries likely to implement computer-aided design and manufacturing (CAD/CAM) technologies: 25-Furniture & Fixtures; 30-Rubber & Misc. Plastic Products; 33-Primary Metal Industries; 34-Fabricated Metal Products, except Machinery & Transportation; 35-Industrial & Commercial Machinery & Computer Equipment; 36-Electronic & Other Electrical Equipment & Components, except Computer Equipment; 37-Transportation Equipment; 38-Measuring, Analyzing & Controlling Instruments, Photographic, Medical & Optical Goods, Watches & Clocks; 39-Misc. Manufacturing Industries.

The population included all known manufacturing establishments with fewer than 250 employees in these industries in the greater Philadelphia and the Lehigh Valley (Bucks, Chester, Delaware, Lehigh, Montgomery, Northampton and Philadelphia counties). This population was identified through what we believe are the most comprehensive lists available in the region: the Delaware Valley Industrial Resource Center (DVIRC) establishment database for Philadelphia and neighboring counties; Lehigh University's Manufacturing Resource Center establishment database for the Allentown-Bethlehem-Easton region; and Dun & Bradstreet's establishment universe for the region.

From this population, 711 randomly selected establishments sere sent an introductory letter, and contacted by phone to request participation in the study. Of those, 513 (72.2%) were established as good contact addresses and working telephone numbers. From these 513 good contacts, 130 establishments completed telephone surveys, a response rate of 25.3%. Five of these were later eliminated because either the survey was incomplete or the establishment had more than 250 employees, resulting in a final sample size of 125. This region appears more heavily defense dependent than the nationwide average, as 75 (60%) of the establishments report some defense prime- or subcontracts.

The individuals responding to the telephone survey were the owner, president, operations manager or someone in an equivalent function. Questions probed six principal areas: 1) establishment profile, including employment, turnover and type of operations; 2) the sources of knowledge used by the establishment and employees; 3) design and manufacturing technologies used; 4) management's operational goals and extent of the accomplishment of those goals; 5) workforce training investment and methods; 6) other HRM and organizational practices.

Table 1 shows several descriptive statistics on the sample establishments, divided by whether or not the establishment reported that they do either defense prime or subcontracting. Consistent with earlier studies with different data (Kelly & Watkins, 1992, 1995, 1998, Watkins & Kelley, 2001), overall there is little statistical evidence that defense and commercial establishments differ in business age, scale, manufacturing intensity or product diversity. We see that these establishments average about 36 years old. The median establishment employs 33 employees, that these are manufacturing intensive organizations with about two-thirds of employees in production-related jobs. As Figure 1 shows, there is also no significant difference in the distribution of these employees across the types of jobs.

Two-thirds (65.6%) of these establishments do some of their own design work, typically one of the key uses of computer-aided technologies, and the number of different products they produce annually is quite high, numbering in the hundreds and sometimes several thousands. This indicates that many of these establishments would be characterized as manufacturing job-shops, producing output to order. This product diversity also suggests the need for flexibility in manufacturing processes, another key advantage of computer use. The only statistically significant difference (at p<.10) in general establishment characteristics between defense contracting and purely commercial establishments is in the physical space (in square feet) used for manufacturing, where defense contractors are roughly one-third smaller.

## COMPARING MANUFACTURING TECHNOLOGIES

To begin exploring the main research questions, Table 2 compares the rate of implementation by defense contracting and purely commercial establishments of six different computer-aided manufacturing technologies. Again consistent with earlier findings, the defense contractors are statistically significantly more likely to use four of the six than establishments without defense contracts. The gap is particularly large for quality assurance, with 81% of defense contracting establishments using computer-aided technologies, compared with only 56% of their purely commercial counterparts. This particular emphasis on quality assurance is consistent with the same finding from many years earlier (Kelley and Watkins, 1998). On the other hand, commercial establishments appear to have closed the gap in using computer-aided technologies in part design and process planning, now the two most ubiquitous IT applications. Of note, 124 of 125 establishments report using computers for at least one application.

The defense contracting advantage seems to be in the yes/no adoption decision, rather than depth or intensity of application. The survey asked respondents to report the degree to which they used each technology on a 1 (never), to 3(sometimes), to 5 (always) scale. Among those who report using the advanced manufacturing technologies at all, Figures 2 and 3 show no apparent difference in the intensity with which defense contracting and strictly commercial establishments apply them. Isolating among users, there is no statistically significant difference in implementation intensity for any of the six technologies (chi2>.33 for all six and chi2>0.74 for all but quality and materials handling). That said, as we see in the next section, defense contracts do report more success in implementing those technologies.

## COMPARING SUCCESS IN IMPLEMENTING ADVANCED MANUFACTURING TECHNOLOGIES

The survey explored technology implementation further, by inquiring about the importance of various goals managers may have in their manufacturing operations, and then asking how successful they had been in achieving those goals. As the multiple-axis radar diagram in Figure 4 shows, for 12 of the 13 different manufacturing operational goals covered in the survey, there is no significant difference in the reported level of importance (1 not important to 5 extremely important) between defense contractors and strictly commercial establishments. The single difference is that better managerial control was more a important goal (p<.05) for managers in strictly commercial establishment than in those that did some defense contracting. This rate of one difference out of 13 metrics (p=.077) is roughly consistent with the probability expected by statistical sampling chance even if there were no difference. So defense contractors appear to have essentially similar overall manufacturing goals.

This close matching of operational goals notwithstanding, defense contractors report substantially better success in achieving those goals. Figure 5 shows the level of reported success (1 not achieved to 5 fully achieved) for the same 13 operational goals. As the radar diagram shows with the darker line nearly exclusively external to the lighter line, defense contractors' responses have higher means for all but one goal, and seven are statistically significantly higher (p<.10). These seven include better average achievement in: reducing lead times, increasing productivity, reducing product costs, reducing direct labor, improving design and manufacturing integration, increasing process flexibility, and improving management control.

For modeling tractability in the econometric section of the paper below, I combine these 13 operational metrics into a single "Success" metric. Table 3 summarizes the components of that combined metric. First, I calculate a single sum of the level of importance of all 13 goals. Since these are 1 to 5 scales, the minimum possible score is 13 and the maximum is 65. Consistent with the individual goals metrics, there is no statistical difference between the mean sum of importance of goals among defense contracting (50.5) and commercial (51.0) establishments. For comparison purposes, a similar sum of the 13 achievement metrics shows a statistically (p<05) higher achievement mean for defense contractors (43.7) than non-defense contracting establishments (40.1). This gap represents nearly half (0.46) the overall standard deviation (3.6/7.86).

Next, to normalize for goal achievement relative to goal importance, the "Success" metric takes the summed product of each individual achievement metric multiplied by the importance metric, and normalizes that sum by dividing by the sum of the importance metrics from the first step. The result is a measure with a theoretical minimum of 1 and a maximum of 5. The actual minimum is 1.52 and maximum 4.89. Again, as measured in this composite, defense contractors show significantly (p<.05) higher achievement relative to importance (3.48) than strictly commercial establishments (3.24).

Even if statistically significant, how important is this difference in implementation success? A small manufacturer that could improve as much would jump 20 percentile points in ranking. Specifically, moving from 3.24 to 3.48 would move an individual establishment from the 41st to the 61st percentile in the distribution of overall success scores.

So with respect to Question 2, I conclude that among small manufacturing establishments that have adopted these advanced manufacturing technologies, those with at least some defense-contracts report a higher degree of success in meeting the goals of manufacturing technology implementation, measured along several dimensions. I believe this finding is unique in the literature.

## WORKFORCE & ORGANIZATION PRACTICES

In addition to exploring manufacturing technology issues, the survey asked about various workforce development and other organizational practices that earlier literature identified as associated with successful technology implementation. One important managerial choice variable that might help explain why defense contractors are more likely to chose computer-aided technologies is how they organize their workflow. The flexibility advantages of using computers in manufacturing are well rehearsed in the literature (e.g. Kaplinksy 1987, Ayres et al., 1992, Kelley, 1994). On computerized machine tools, the tool positions, cutting speeds and feed rates are controlled by a programmable sequence, often alterable at the machines. This permits far more flexible and/or complex machining control than on tools requiring human operators to change these.

This flexibility advantage appears correlated to the process choices made by managers in defense contractors, specifically the manufacturing lot sizes used. Mid-range lot sizes, 10-500 pieces, are where the flexibility advantages are most important. These lot sizes require neither unique, one-off setups, nor are they large enough to take advantage of the mass-manufacturing scales useful for fixed equipment. Defense contracting establishments organize a statistically significantly (p<.05) higher fraction (42.6% vs. 28.9) of their manufacturing in these mid-range lot sizes. This finding is consistent with Watkins and Kelley (2001), who using unrelated data found that although output volumes were not statistically different at the mean, strictly commercial manufactures were more likely to do both the very largest volume mass-manufacturing scales (among the very few plants that did above 100,000 units per year) and the very smallest (under 10 units). A general comment before proceeding, however, is to note the large fraction of overlap of the distributions. Rather than vastly different manufacturing worlds, the differences indicate more subtle differences at the margins. The bulk of machining jobs are similar by these metrics.

Moving now to workforce choices, again subtle differences begin to emerge. Defense contracting establishments hire a largely similarly educated workforce than their strictly commercial counterparts, except at the bottom of the educational scale. The workforce proportions of high school, technical school, college and graduate degree employees are not statistically different. However, defense contracting establishments are much less likely to hire those without high school degrees (2.9% of the workforce vs. 8.2%, p<.01).

Once hired, employees in the two types of establishments receive somewhat different workforce development regimes as well. In Table 4, we see that on average the overall training budget is similar at slightly less than 4% of the establishments' total budgets, as are the numbers of workers receiving training annually. However, defense contractors focus that training differently, emphasizing more formal approaches structurally and more manufacturing-related content. Defense contractors spend a greater fraction of their training budget (61.0% vs 46.8%, p<.05) on off-the job training for existing (rather than new) workers, are more than twice as likely to rely on academic institutions (26.7% vs. 12.0%, p<.05) and are a third-again more likely to rely on formal in-house mentoring by peers or supervisors (69.3% vs. 52.0%, p<.05) as main training providers. By contrast, defense contractors are less than half as likely to rely on informal in house mentoring (16.0% vs. 36.0%, p<.01) as a main source. In terms of content, defense contractors' training also emphasizes more manufacturing-related or CAD/CAM skills as a fraction of the training budget (67.9% vs. 54.4%, p<.05) and are more likely to offer manufacturing foundations skills training (92.0% vs. 82.0%, p<.10). The tendency, though not statistically significant, is for purely commercial establishments to have more fundamental/basic training, perhaps reflecting their greater reliance on less-than-high-school-educated employees.

Beyond training, similar differences exist in the implementation of other modern workforce management practices, shown in Table 5. Uniformly, where statistical differences exist, defense contractors are more likely to use management approaches that the literature has found favorable for successful technology implementation. Defense contractors are statistically significantly more likely to offer some sort of incentive plan such as profit sharing, stock options or performance bonuses (90.7% vs 74%, p<.05). While there is no statistical difference in the likelihood to have collaborative decision-making by workers and managers or joint committees for planning or implementing new technologies, the frequency of these types of joint committee meetings is higher in defense contractors. Defense contractors also make financial information about manufacturing costs and profit levels more accessible to all employees. Note that on those five related variables where the differences are not significant, defense contractors are nonetheless again uniformly on the higher side of each metric on average.

In summary, Question 3 regarded whether small defense manufacturing establishments differ from otherwise similar strictly commercial establishments in a number of workforce and organizational practices previously been found in the literature to be positively associated with successful technology implementation. I find a remarkably consistent pattern across a diverse spectrum of workforce and organizational practices that defense contractors are more likely practitioners. Their workforces are slightly better educated, more formally trained, with training more focused on existing workers and on manufacturing technologies. Moreover, defense contractors are more likely to implement modern workforce incentive packages and work more closely with their workforces on technology planning and implementation. This leaves the fourth question, then, whether these differences in managerial choices help explain the manufacturing technology implementation advantages found in Questions 1 and 2.

## ECONOMETRIC MODELING

To address this fourth question, the analysis now turns to ordinary least squares (OLS) econometric modeling. The dependent variable is the normalized combined “Success” in achieving manufacturing goals metric discussed for Table 3 above. Table 6 shows a series of OLS regression results. One respondent did not have a complete answers to one of the regression variables, so the regression sample size is 124.

For comparison purposes the first model, shown in the first column of Table 7 following the variable names, simply uses a single independent variable, a dummy for whether or not the establishment reported any defense prime or subcontracts. The result repeats the finding in Table 3 above: defense contractors’ average 0.247 manufacturing-success-metric points higher than establishments without defense contracts. The remaining models sequentially add potential explanatory variables, to explore whether they are associated with that defense advantage.

Model 2 adds a set of establishment control variables: establishment size measured as total employment, scale of manufacturing operations measured in 100,000s square feet, the age of the establishment, and product variety measured as the number of different products manufactured in the establishment. The scale variables appear because size is quite repeatedly found in the literature associated with manufacturing efficiency and technology implementation success. Size clearly has advantages. The establishment age variable controls for the equipment-life-cycle related likelihood that newer establishments are more likely to have been designed with and for the newer computerized technologies. The product variety variable aims to account for the flexibility needs of businesses with diverse products, and hence the increased importance to them of the flexible computerized manufacturing technologies studied here. As a group these variables do have explanatory power, increasing the R-squared significantly. However, as might be expected from the lack of differences in these descriptive types of organizational characteristics among defense and non-defense establishments, the variables do not explain the defense contracting advantage. The coefficient on the defense contractor dummy still shows a similar positive advantage (0.289) for manufacturing success.

Model 3 adds further control variables, in this case a set of 2-digit SIC industry dummies, to account for possible sectoral differences. Again this set of industry control variables is statistically significant as a group, increasing the explanatory power slightly. However, the defense advantage remains stable (0.264).

With the full-control Model 3 as the base, then, Models 4 though 8 sequentially add different sets of managerial choice variables. The bottom of Table 7 now includes a row of p-values and significance levels for statistical F-tests on adding these sets of variables, comparing each Model to Model 3. Model 4 includes three variables to capture manufacturing operational choices. The first is the scope of computer use, measured as the sum of the 1-to-5 scale intensity-of-use variables across six computer applications. The second is a dummy for whether or not the establishment does its own design work, indicating a level of integration and sophistication associated n the literature with manufacturing performance. The third variable in this set measures the percentage of the establishment’s output made in 10-500 unit lot sizes, those mid-range lot size where the advantages of flexible manufacturing technologies are often most valuable. As a group the set adds statistically significant explanatory power compared to Model 3 (F-test p=.063), primarily through the positive influence on success of the scope of computer use (p<.05). The magnitude of the coefficient on the defense dummy falls about 16%, to 0.222 from 0.264 without these operational choice variables, indicating an positive association between the defense manufacturing success advantage and these operational choices, controlling for firm and industry effects.

Model 5, instead, adds a set of three workforce skills related variables to the controls from Model 3. The first is the percent of the establishment's workforce with less than a high school education. The second is the percent that completed a four-year college. The third attempts to capture the extent to which the workforce might be otherwise high skilled by measuring the establishment's percent of employees who are non-managerial professionals. As expected, a high rate of non-high school graduates is associated with statistically significantly lower success rates(p<.05). The other two variables are statistically insignificant, as is the p-value (0.137) on the F-test comparing Model 5 to the full control Model 3. Compared to Model 3, however, the addition of these workforce skills variables reduces the coefficient on the defense dummy to 0.204, reducing its magnitude by nearly one-quarter, indicating a positive association between workforce skills and the defense manufacturing success advantage, controlling for firm and industry effects.

Model 6, similarly, adds group of four workforce training choice variables to the Model 3 controls. One is worker training budget as a percent of the establishment's overall budget. In this model, higher relative training budgets are associated with statistically significantly greater success rates (p<.05). The second and third variables in this set attempt to capture differences among how those training budgets are allocated. The second is the percent of the training budget that goes towards off-the job training for existing workers. The third is the percent of the training budget allocated towards manufacturing foundation skills or CAD/CAM skills. Neither turns out to be significant in any of the models. The fourth variable is constructed from four yes/no questions about different types of training and whether formal-in-house training was a main source of each type of training, so the maximum score on this variable was 4 and the minimum was zero. A greater extent of formal in-house mentoring is associated with a statistically significantly greater manufacturing success (p<.10). As a group these four variables significantly improve the explanatory power compared to Model 3 (F-test p=.058). Moreover, the coefficient on the defense contracting dummy contracts 17% compared to Model 3 to 0.219, again indicating that the defense advantage in achieving manufacturing goals appears correlated with differences in workforce training practices.

Model 7 adds a single variable to Model 3 in order to examine the potential explanatory power of whether or not the establishment makes incentive plans available to workers. This variable is not significant in any of the models, and has almost no effect on the defense coefficient or R-squared.

Model 8 adds a group of three variables intended to characterize different approaches to shared decision-making and information sharing. As an isolated group, this set had the largest effect on both the model's explanatory power and the defense coefficient of any of the five variable groups on their own. The defense coefficient shrinks more than 30%, to 0.184, with the inclusion of these decision making variables compared to Model 3, indicating a relatively strong association between higher defense manufacturing success and greater degree of joint decision making and information sharing.

The first variable in this set is a 1-5 scale variable concerning the extent of worker autonomy in deciding the pace of work, with 1 meaning work pace set exclusively by managers and 5 indicating exclusively by workers. Somewhat surprisingly, given earlier findings to the contrary in the literature, greater worker autonomy is associated with lower reported success in achieving operational goals in manufacturing. I speculate, in retrospect, that the construction of this variable does not allow it to fully capture the importance of collaborative decision making, which would score a 3, unfortunately in the middle rather than end of the scale. The second variable performs more as expected. The constructed 0-to-15 scale variable combines the frequency of three types joint meetings between blue collar workers and management: for implementing new technologies, for planning for new technologies, and for other production-related issues. Each type of meeting was scored zero if such joint committees did not exist at all, 1 rarely and 5 if they met constantly. The metric adds the individual scores for the three meeting types. Those of us who dislike committee meetings will be distressed to learn that more frequent joint meetings on new technologies and production issues lead to greater reported success in achieving manufacturing goals. The third variable in this set, and last overall, is a 1-5 scale metric on the level of accessibility to all workers of financial information on production costs and profit level (1 not accessible, 5 fully accessible). This variable had no discernable impact in either model in which it appears.

Moving on to Models 9 through 12, to the full control base case, Model 3, each adds additional sets from these five sets of variables. Model 9 includes both the operational choices variables and workforce skills variables. To these two groups, Model 10 adds workforce training, while Model 11 adds incentive plans, and Model 12 includes as well the joint decision making and information sharing variables. Thus, Model 12 is the most complete model, including the most and widest variety of variables. The intent of this additive process is primarily to illustrate how adding each additional group of variables influences the coefficient on the defense contracting dummy. It steadily falls from 0.264 in the full control Model 3, to 0.222 in Model 4 with only the first set of operational choice variables, to 0.157 in Model 9 with two sets of managerial choice variables, to 0.131 with all five sets. More than half of the magnitude of the defense effect is accounted for by including these workforce and organizational practices, and the defense coefficient falls to statistical insignificance. Simultaneously, the explanatory power of the model more than doubles, with the the R-squared increasing from 0.198 to 0.410.

To present a more succinct model, the last, Model 13, began with Model 12 and removed the most insignificant variables in a stepwise fashion leaving only the defense dummy and any other variable significant in one or two-tailed t-tests (at p=.10 one tailed or p=.20 two-tailed). This stepwise process removed nine variables, none of which had been statistically significant in any previous model. The defense coefficient now falls even further, to 0.119, 55% smaller than in Model 3. The R-squared remains nearly 40%, twice the explanatory power of the firm and industry control variables alone, and the adjusted R-squared increases above 30%.

## CONCLUSIONS

I conclude that the defense contractor manufacturing technology implementation advantages confirmed in Questions 1 and 2 are associated with the differences in organizational and workforce practices identified in Question 3. Though unable to test for causality, and though every variable is not independently helpful, the modeling indicates strong evidence that, overall, the greater extent and breadth of advanced workforce management and organizational practices among defense contractors, coupled with the their more intensive use of advanced computerized manufacturing technologies, are positively associated with their higher reported operational success in manufacturing.

As a sign of the robustness of the overall findings, note in particular the stability of the coefficients on the variables to the specification changes through including and excluding various variables. Even a casual perusal of the coefficients will show that only the defense contracting coefficient shows as substantial changes in its size. Most remain quite stable through the addition or subtraction of other variables, with only the worker training budget variable, the non-managerial professional and the joint meeting frequency variable changing more than marginally.

This suggests the need for further research into the underlying question: what is it about the defense-contracting environment that fosters advanced approaches to workforce development and organization? What role, if any, has government played in creating that environment? The policy lessons from such future research might lead to significantly improving the competitiveness of the large numbers of small U.S. manufacturers.

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## REFERENCES

Available upon request from the author.

**Figure 1. Distribution of Workforce by Job Category in Defense Contracting and Purely Commercial Small Manufacturing Establishments**

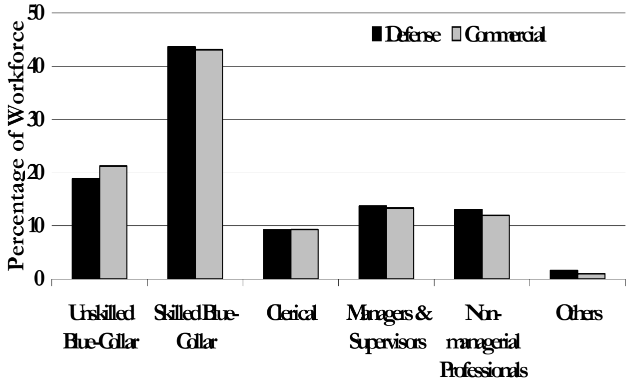

**Figure 2. Level of Use of Computers in Exchanging Data with Suppliers or Customers (Excluding Never Use)**

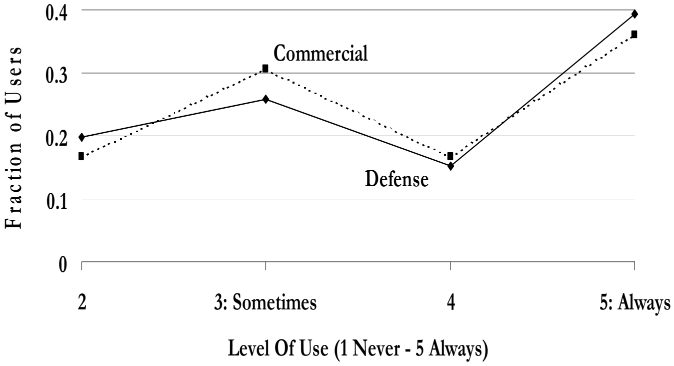

**Figure 3. Level of Use of Computers in Materials or Parts Planning (Excluding Never Use)**

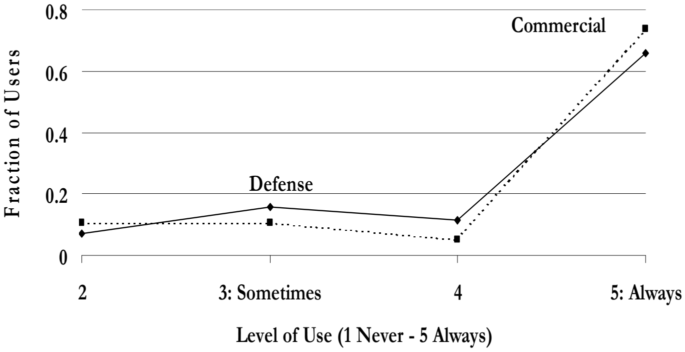

**Figure 4. Manufacturing Operational Goals (1-5 Scale: 1 Not Important to 5 Extremely Important)**

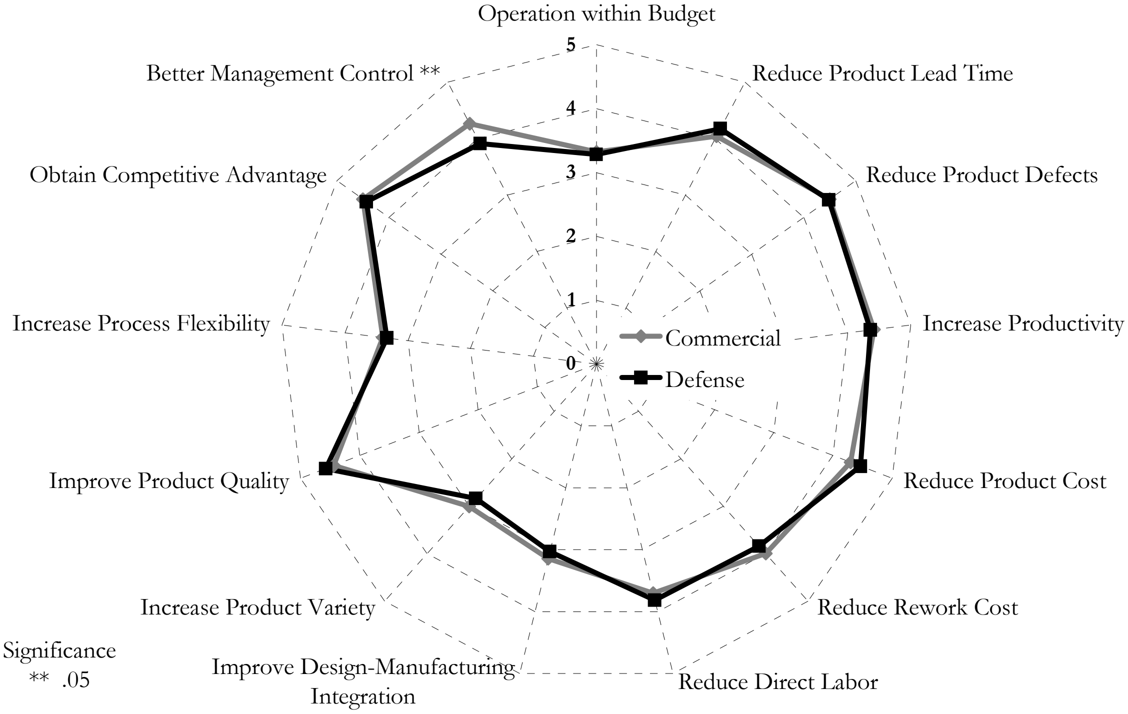

**Figure 5. Extent of Success in Achieving Manufacturing Operational Goals (1-5 Scale: 1 Not Achieved to 5 Fully Achieved)**

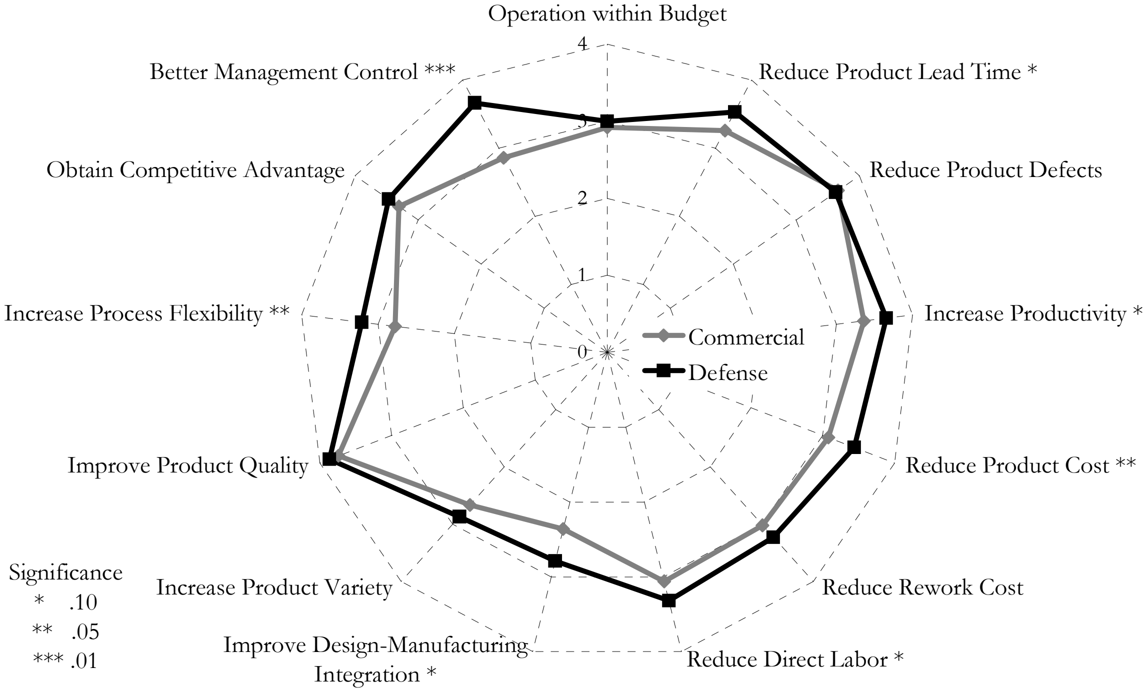

**Table 1. Descriptive Statistics on Organizational Characteristics of Defense Contracting & Purely Commercial Small Manufacturing Establishments**

| (Standard deviations in parentheses) | | Non-Defense Establishments (n=50) | | Establishments that Have Defense Contracts (n=75) | | p |
|---|---|---|---|---|---|---|
| Total Employment | Mean | 52.3 | (52.1) | 45.4 | (37.6) | 0.387 |
| | Median | 35 | | 32 | | 0.557 $^c$ |
| Employed in Production Jobs (% total) | | 68.4 | (19.5) | 65.3 | (23.8) | 0.446 |
| Sq. Ft. (1000s) for Manufacturing | Mean | 45.4 | (52.7) | 31.2 | (35.3) | 0.074 * |
| | Median | 25.0 | | 22.0 | | 0.826 $^c$ |
| Age of Establishment (years) | | 37.3 | (31.2) | 35.1 | (25.2) | 0.662 |
| Designs Some of its Own Products (%) | | 74.0 | (44.3) | 60.0 | (49.3) | 0.108 |
| # of Different Products Produced | Mean | 672 | (1700) | 939 | (3640) | 0.628 |
| | Median | 73.5 | | 100 | | 0.713 $^c$ |

Note: Variable means unless indicated;; *=significant at .10. p=probability population parameters not different, heterogeneous variances assumed; t-tests on means, except: $^c$ non-parametric chi2 test on equality of medians.

**Table 2. Computer-Aided Manufacturing Technology Use in Defense Contracting and Purely Commercial Small Manufacturing Establishments, 2003**

| Fraction of Establishments Using Computer in | Non-Defense Establishments | Establishments that Have Defense Contracts | p |
|---|---|---|---|
| Parts or Product Design | 0.780 | 0.720 | 0.456 |
| Process Planning, Scheduling, or Monitoring | 0.840 | 0.907 | 0.265 |
| Quality Assurance | 0.560 | 0.813 | 0.002*** |
| Materials or Parts Planning | 0.760 | 0.933 | 0.005*** |
| Automation of Other Production Processes | 0.180 | 0.373 | 0.020** |
| Data Exchange with Suppliers or Customers | 0.720 | 0.880 | 0.024** |

Variable proportions; **=significant at .05; ***=significant at .01; standard deviations in parentheses; p=probability population proportions are not different, heterogeneous variances assumed.

**Table 3. Combined Metrics on Goals and Achievement of Goals**

| | Non-Defense Establishments | Establishments that Have Defense Contracts | p |
|---|---|---|---|
| Sum(Importance of Goals)<br>(13-65 scale) | 51.0<br>(8.56) | 50.5<br>(6.67) | 0.715 |
| Sum(Extent of Achievement of Goal)<br>(13-65 scale) | 40.1<br>(8.52) | 43.7<br>(7.08) | 0.011** |
| Success=Sum(Importance * Extent of Achievement)/Sum(Importance) (1-5 scale) | 3.24<br>(0.610) | 3.48<br>(0.532) | 0.021** |

Variable means; standard deviations in parentheses; **=significant at .05; p=probability population means are not different, heterogeneous variances assumed.

### Table 4. Workforce Training in Defense Contracting and Purely Commercial Small Manufacturing Establishments, 2003

| (Standard deviations in parentheses) | Non-Defense | | Have Defense Contracts | | p |
|---|---|---|---|---|---|
| % of Total Budget Invested in Worker Training | 3.60 | (4.61) | 3.82 | (4.52) | 0.776 |
| % of Training Budget for Off-the-job Training for Existing Workers | 46.8 | (37.7) | 61.0 | (33.0) | 0.028 ** |
| % of Training Budget for Manufacturing or CAD/CAM Skills | 54.4 | (40.5) | 67.9 | (29.1) | 0.032 ** |
| Offer Fundamental Skills Training (Basic Math, Basic English, Basic Computers) (Yes/No) | .420 | | .373 | | 0.604 |
| Offer Manufacturing Foundation Skills Training (Y/N) | .820 | | .920 | | 0.093 * |
| Offer CAD/CAM-Related Skills Training (Y/N) | .560 | | .667 | | 0.231 |
| Percentage of Training Budget for Fundamental Skills (%) | 12.2 | (26.2) | 10.2 | (20.1) | 0.628 |
| Number of Manufacturing Workers Receiving Training in 2002 | 29.8 | (36.3) | 28.4 | (29.1) | 0.808 |
| Number of Manufacturing Workers Receiving Fundamental Skills Training in 2002 | 6.98 | (17.1) | 3.31 | (7.87) | 0.107 |
| Formal In-house Training by Peers or Supervisors is a Main Training Provider (Y/N) | .520 | | .693 | | 0.050 ** |
| Informal In-house Mentoring is a Main Training Provider (Y/N) | .360 | | .160 | | 0.010 *** |
| Government Funded Agencies a Main Training Provider (Y/N) | .020 | | .053 | | 0.356 |
| Vendors or Distributors are a Main Training Provider (Y/N) | .200 | | .240 | | 0.607 |
| Business/Industry Associations a Main Training Provider (Y/N) | .300 | | .373 | | 0.402 |
| Local Academic Institutions are a Main Training Provider (Y/N) | .120 | | .267 | | 0.048 ** |

Variable means or proportions; *=significant at .10; **=significant at .05; ***=significant at .01; p=probability population parameters are not different, heterogeneous variances assumed.

### Table 5. Workforce Management Practices in Defense Contracting and Purely Commercial Small Manufacturing Establishments

| (Standard deviations in parentheses) | Non-Defense | | Have Defense Contracts | | p |
|---|---|---|---|---|---|
| Offer Incentive Plans (Profit Sharing, Stock Ownership or Performance Based Bonus) (Yes/No) | .740 | | .907 | | 0.012 ** |
| Collaborative Decision Making by Workers & Managers on Work Pace and Task Definition (Y/N) | .360 | | .493 | | 0.145 |
| Joint Management-Blue Collar Worker Committees (Y/N) | .520 | | .627 | | 0.239 |
| Frequency of Meetings of Management-Blue Collar Worker | | | | | |
| Joint Committees to Discuss Planning of New Technology (0 Never to 5 Constantly) | 0.92 | (1.23) | 1.40 | (1.45) | 0.057 * |
| Joint Committees to Discuss Implementing New Technology | 0.86 | (1.14) | 1.47 | (1.51) | 0.017 ** |
| Joint Committees to Discuss Other Production Related Issues | 2.30 | (2.31) | 2.77 | (2.26) | 0.258 |
| Accessibility to All Workers of Information on: | | | | | |
| Financial Status of Company (1 Not Accessible to 5 Fully Accessible) | 1.96 | (1.37) | 2.24 | (1.38) | 0.268 |
| Financial Information About Product Costs & Profit Levels | 2.02 | (1.06) | 2.68 | (1.35) | 0.004 *** |
| Production Related Information (Goals, Quality Levels, etc.) | 4.20 | (1.20) | 4.45 | (0.92) | 0.184 |
| Strategic Plans | 2.94 | (1.41) | 3.25 | (1.38) | 0.219 |

Variable means or proportions; standard deviations in parentheses; **=significant at .05; ***=significant at .01; p=probability population parameters are not different, heterogeneous variances assumed.

## Table 6 Regression Results

| Dependent: Success in Achieving Manufacturing Goals | | Model Number | | | | | | | | | | | | Stepwise Remove |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Independent Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Defense Contractor Dummy | 0.247 ** | 0.289 *** | 0.264 ** | 0.222 ** | 0.204 * | 0.219 ** | 0.265 ** | 0.184 * | 0.157 | 0.153 | 0.145 | 0.131 | 0.119 |
| | | 0.104 | 0.103 | 0.105 | 0.111 | 0.107 | 0.106 | 0.109 | 0.105 | 0.112 | 0.112 | 0.116 | 0.116 | 0.102 |
| Establishment Controls | Size (Total Employed) | | 0.0006 | 0.0004 | -0.0009 | 0.0006 | 0.0007 | 0.0004 | 3.5 e-5 | -0.0007 | -0.0004 | -0.0004 | -0.0008 | |
| | | | 0.0013 | 0.0014 | 0.0014 | 0.0014 | 0.0014 | 0.0014 | 0.0013 | 0.0014 | 0.0014 | 0.0014 | 0.0014 | |
| | Scale of Manufacturing Operations (100,000 sq. ft.) | | 0.339 ** | 0.326 ** | 0.341 ** | 0.355 ** | 0.295 * | 0.326 ** | 0.249 * | 0.375 ** | 0.330 ** | 0.332 ** | 0.258 * | 0.223 * |
| | | | 0.152 | 0.152 | 0.151 | 0.151 | 0.157 | 0.153 | 0.147 | 0.148 | 0.156 | 0.156 | 0.155 | 0.120 |
| | Manufacturing Intensity (Production Workers as % of Total) | | 0.097 | 0.122 | 0.128 | 0.092 | 0.107 | 0.123 | 0.251 | 0.0466 | 0.085 | 0.076 | 0.142 | |
| | | | 0.228 | 0.233 | 0.235 | 0.242 | 0.230 | 0.235 | 0.231 | 0.242 | 0.241 | 0.245 | 0.246 | |
| | Establishment Age (Years) | | -0.0046 ** | -0.0054 *** | -0.0053 *** | -0.0055 *** | -0.0047 ** | -0.0054 *** | -0.0057 *** | -0.0056 *** | -0.0049 ** | -0.0048 ** | -0.0052 *** | -0.0052 *** |
| | | | -0.002 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0019 | 0.0020 | 0.0020 | 0.0020 | 0.0019 | 0.0018 |
| | Product Variety (# of Different Products) | | 1.15 e-5 | 8.86 e-6 | 5.80 e-6 | 7.83 e-6 | 1.53 e-5 | 8.89 e-6 | 9.19 e-6 | 3.99 e-6 | 9.16 e-6 | 8.95 e-6 | 6.81 e-6 | |
| | | | 1.66 e-5 | 1.67 e-5 | 1.66 e-5 | 1.66 e-5 | 1.66 e-5 | 1.68 e-5 | 1.61 e-5 | 1.63 e-5 | 1.63 e-5 | 1.64 e-5 | 1.60 e-5 | |
| Industry | 2-Digit Industry Dummies | no | no | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** | yes *** |
| Operational Choices | Scope of Computer Use | | | | 0.0262 ** | | | | | 0.0294 *** | 0.0251 ** | 0.0252 ** | 0.0233 ** | 0.0234 ** |
| | | | | | 0.0109 | | | | | 0.0111 | 0.0112 | 0.0113 | 0.0112 | 0.0098 |
| | Design Own Products Dummy | | | | 0.066 | | | | | 0.109 | 0.166 | 0.164 | 0.200 | 0.177 |
| | | | | | 0.121 | | | | | 0.12 | 0.123 | 0.124 | 0.122 | 0.114 |
| | Products Made in Middle Lot Sizes 10-500 (%) | | | | -0.0004 | | | | | 0.0001 | -0.0002 | 0.0002 | -0.0005 | |
| | | | | | 0.0014 | | | | | 0.0014 | 0.0014 | 0.0014 | 0.0014 | |
| Workforce Skills Choices | % Workers with Less than High School Education | | | | | -0.0113 ** | | | | -0.0119 ** | -0.0102 ** | -0.0102 ** | -0.0093 ** | -0.0094 ** |
| | | | | | | 0.0048 | | | | 0.0045 | 0.0047 | 0.0048 | 0.0046 | 0.0044 |
| | % Workers Completed 4-Year College | | | | | -0.0008 | | | | -0.0012 | -0.0034 | -0.0036 | -0.0035 | |
| | | | | | | 0.0046 | | | | 0.0045 | 0.0048 | 0.0048 | 0.0047 | |
| | % Non-Managerial Professionals | | | | | -0.0030 | | | | -0.0078 | -0.0052 | -0.0053 | -0.0053 | -0.0089 ** |
| | | | | | | 0.0053 | | | | 0.0054 | 0.0057 | 0.0057 | 0.0057 | 0.00441 |
| Workforce Training Choices | Worker Training % of Total Budget | | | | | | 0.0255 ** | | | | 0.0227 * | 0.0228 * | 0.0191 | 0.0162 |
| | | | | | | | 0.0120 | | | | 0.0129 | 0.013 | 0.0128 | 0.0108 |
| | % of Training Budget Invested in Off-Job Training for Existing Workers | | | | | | 0.0005 | | | | 0.0001 | 0.0001 | -0.0003 | |
| | | | | | | | 0.0015 | | | | 0.0015 | 0.0015 | 0.0015 | |
| | % of Training Budget for Manufacturing Foundation Skills or CAD/CAM Skills | | | | | | 0.0011 | | | | 0.0008 | 0.0008 | 0.0003 | |
| | | | | | | | 0.0016 | | | | 0.0015 | 0.0016 | 0.0015 | |
| | Extent of Formal In-House Training as Main Training Provider | | | | | | 0.0833 * | | | | 0.0824 * | 0.0813 * | 0.0827 * | 0.0830 * |
| | | | | | | | 0.0451 | | | | 0.0461 | 0.0465 | 0.0453 | 0.0420 |
| Incentives | Offer Incentive Plans Dummy | | | | | | | -0.005 | | | | 0.035 | 0.015 | |
| | | | | | | | | 0.143 | | | | 0.140 | 0.137 | |
| Decision Making Processes & Info Sharing | Degree of Worker Autonomy Deciding Work Pace | | | | | | | | -0.0822 * | | | | -0.108 ** | -0.107 ** |
| | | | | | | | | | 0.0481 | | | | 0.048 | 0.045 |
| | Frequency of Joint Blue Collar-Management Committee Meetings | | | | | | | | 0.0371 *** | | | | 0.0252 ** | 0.0233 ** |
| | | | | | | | | | 0.0112 | | | | 0.0114 | 0.106 |
| | Accessibility of Financial Info on Product Costs & Profit Levels | | | | | | | | 0.008 | | | | -0.008 | |
| | | | | | | | | | 0.040 | | | | 0.040 | |
| | Constant | 3.23 *** | 3.15 *** | 2.48 *** | 2.05 *** | 2.54 *** | 2.23 *** | 2.48 *** | 2.61 *** | 2.10 *** | 1.90 *** | 1.87 *** | 2.29 *** | 2.389 *** |
| | | 0.08 | 0.19 | 0.33 | 0.37 | 0.34 | 0.34 | 0.35 | 0.37 | 0.37 | 0.37 | 0.39 | 0.42 | 0.324 |
| | $R^2$ | 0.044 | 0.135 | 0.198 | 0.25 | 0.238 | 0.263 | 0.198 | 0.286 | 0.302 | 0.352 | 0.352 | 0.410 | 0.399 |
| | Adjusted-$R^2$ | 0.037 | 0.091 | 0.111 | 0.146 | 0.132 | 0.153 | 0.103 | 0.186 | 0.183 | 0.210 | 0.203 | 0.252 | 0.303 |
| | p for F-test on added variables (vs. model 3) | | | | 0.063 * | 0.137 | 0.058 * | 0.971 | 0.006 *** | 0.021 ** | 0.014 ** | 0.022 ** | 0.005 *** | |
| | RMSE | 0.566 | 0.550 | 0.544 | 0.533 | 0.538 | 0.531 | 0.546 | 0.520 | 0.521 | 0.513 | 0.515 | 0.499 | 0.482 |
| | n | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 |

Notes: Standard errors in parentheses; *significant at 0.1 level; **significant at 0.05; ***significant at 0.01.