

# Musculoskeletal Disorders and Productivity\*

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## I. Introduction

In the economic analysis of its proposed ergonomics rule, the Occupational Safety and Health Administration (OSHA) references case studies and academic journal reports linking productivity gains with workplace changes designed to reduce or eliminate workplace ergonomic risk factors. (Physical stress on the body is associated with repetitive motion, forceful exertion, vibration, and awkward posture. Left uncorrected these risk factors can result in injury or disorder to muscles, tendons, ligaments, joints, cartilage, and spinal discs.) The weight of the evidence evaluated by OSHA and presented in its "Preliminary Economic Analysis and Initial Regulatory Flexibility Analysis for the Occupational Safety and Health Administration's Proposed Ergonomics Program Standard," November 1999, leads the Agency to conclude that efforts made to reduce musculoskeletal disorders (MSD) in the workplace often result in workplace productivity improvement. This conclusion is important and supports OSHA's belief that the cost of workplace reforms made to address and reduce MSDs in the workplace will be compensated by productivity gains. Productivity improvement is realized by workers being more efficient and working without the danger of physically breaking down because of awkward or repetitive motion or violent impacts on the body. We analyze the relationship between industry MSD and productivity changes during the 1990s and find support for such an association.

## II. Research Approach

To evaluate the empirical evidence concerning the relationship between ergonomic interventions and productivity, national-level data by industry were compiled.<sup>1</sup> These data were used to test hypotheses and investigate associations regarding MSD rates, changes in MSD rates, the implementation of ergonomic controls, and changes in productivity. Data analyses included correlations between variables with tests for statistical significance, across all industries and within certain subsets of industries. In addition, specific industry groups were identified based on values of particular variables to determine whether any unique characteristics would be observed. The approach and the findings of this research follow from and are presented in the context of the theoretical expectations and the conventional perceptions about the nature of the relationships between these variables.

### III. *Theory and Expectations*

Traditionally, labor productivity has been viewed as a measure of technological and organizational efficiency: how many person-hours per unit of output. Empirical data on productivity changes in individual industries reflect changes over time, including technological change, use of contract labor, contracting out production, and purchase of pre-assembled components. A recent report (Oliner and Sichel, 2000) identified technology as the prime mover behind productivity change in the U.S. economy in the late 1990s.

As societal welfare increases, one would expect increasing average employee compensation, increasing average productivity, and lower average MSD rates. These trends should be mutually reinforcing, as supported by conventional theory and the effects of technological changes (increasing ratio of capital to labor). Trends in manufacturing are usually cited as the most visible examples. But broader industry measures offer additional confirmation. BLS labor productivity data for the nonfarm business sector report output per hour of all persons increased by 7.3 percent from 1992–1997 and by 16.1 percent from 1987 to 1997. BLS data on MSDs rates for all industries declined from 102.50 to 66.77, a reduction of 35 percent, between 1992 and 1998. We expected a negative correlation between MSD levels and percent changes in recent years and productivity increases.

Current reductions in MSD rates appear to result from many causes that cut across industry sectors: increased awareness of total costs associated with injuries; ability to control risks and costs has spurred risk reduction efforts generally; unforeseen/inadvertent increases in MSD risks caused by production process changes in the past have since become apparent and are being addressed; across all types of ongoing production process changes, increasing attention is being paid to ergonomic considerations as an integral part of process design.

In manufacturing, as labor is displaced from dangerous jobs, the incidence of MSD's should decline. In reality, though, all jobs are not made less dangerous as a result of process change. Process changes made to improve productivity may simultaneously lower MSD rates but not necessarily. Industries with different MSD rate/productivity trends in recent years were identified in this study. Some analyses of the economic characteristic of industries with particular MSD/productivity profiles was attempted. The analyses did not probe intrinsic industry process characteristics or profit incentives/constraints; the evaluation was guided and limited by the availability of relevant national industry data. This restricted the focus to industry-level revenue, employment, payroll, productivity, and MSD rate levels and changes.

Service industries have emerged as this economy's employment "driver" accounting for the lion's share of employment growth over the past half century. Importantly a large number of service sector industries have reported relatively high MSD incident rates. A research interest was to compare and contrast findings between manufacturing and non-manufacturing industries in order to identify differences. While high productivity in manufacturing could be achieved through mechanization and a lowering of MSD rates, it was not clear that this was an option (process change) available to most service industries. In services, higher productivity absent the option to mechanize oper-

ations in some nonmanufacturing services, could be achieved at the expense of working employees harder, resulting in higher MSD rates.

While new technology generally has enabled many occupational risks to be eliminated or reduced, new technology may introduce new risks, some of which may not be immediately apparent. In recent years there has been growing apprehension over the potential adverse effects of new technology. One dimension of the threat is manifest in growing MSD problems among those who spend many hours at computer stations.

### III. *The Data*<sup>2</sup>

The database assembled for the analyses consisted of the most recent relevant data available by industry. The database includes all 3- and 4-digit industries from 2000 to 8999 (classified by SIC code) for which the following data elements were available:

- revenues, employment, and payroll for 1992 and 1997 for 438 industries (source: U.S. Department of Commerce, Bureau of the Census);
- rate of MSDs for 1992 and 1998 for 438 industries (source: U.S. Department of Labor, Bureau of Labor Statistics).
- productivity index, output per hour in 1997 (1987=100), available for 319 industries (source: U.S. Department of Labor, Bureau of Labor Statistics);
- average hourly earnings for production/nonsupervisory workers in 1999, available for 305 industries (source: Bureau of Labor Statistics).
- ergonomic engineering control implementation rates, available for 178 of 179 industry groups studied (source: U.S. Department of Labor, Occupational Safety and Health Administration);

The BLS rate data on MSDs are all "lost-worktime" injuries, with or without restricted work activity. In 1998 nearly 593,000 MSD cases were reported, accounting for about one-third of all injuries and illnesses involving recuperation away from work. MSD rates are comparable to other BLS injury/illness rate data. Basically, these represent numbers of cases per 10,000 full-time equivalent employees.<sup>3</sup>

#### *Descriptive Statistics*

	Mean	Standard Deviation	Number	3-Digit N=178	4-Digit N=259
Revenue Change (1992–1997)	34.75	26.88	438	35.07	34.53
Payroll Change (1992–1997)	25.85	24.25	438	28.49	24.03
Employment Change (1992–1997)	7.82	20.49	438	9.87	6.40
Hourly Earnings (1999)	\$13.43	\$3.14	305	\$13.43	\$13.43
Productivity Index (1987=100)	123.74	38.13	319	128.43	121.02
Engineering Controls (% 1993)	48.91	21.66	178	48.91	NA
1998 MSD Rate	83.62	46.65	438	73.15	90.86
1992–1998 MSD Rate Change	-33.52	27.04	438	-31.05	-35.23

#### IV. *Data Analysis and Findings*

*Overview.* Across all industries for which data were available, no significant correlation was found between changes in productivity and changes in MSD rates. The lack of a statistically significant correlation implies that both changes in productivity and changes in MSD rates can occur for a variety of different reasons and from independent sources of change. The lack of a correlation also shows that achieving reductions in MSDs does not reduce the potential for increasing productivity. The data do not reject the hypothesis that production process changes implemented specifically to reduce MSD rates also tend to increase productivity. Rather, the data indicate that achieving large increases in productivity do not necessarily require large reductions in MSDs. This finding was not surprising given the diverse sources of productivity change.

In general, employees in industries with low MSD rates in 1998 received above average hourly earnings and had greater than average productivity gains; conversely, employees in industries with high MSD rates had below average hourly earnings and recorded low productivity gains. (Low hourly earnings were also found in several high-productivity manufacturing industries.)

For 319 industries (combined 3- and 4-digit industry levels), a statistically significant negative correlation of  $-0.119$  at the five percent level, was found between the BLS Productivity Index in 1997 (1987= 100), and an industry's 1998 MSD rate. For these industries a positive productivity index change was inversely related to 1998 MSD rates; a productivity increase was related to a relatively low MSD rate. For manufacturing industries (4-digit level) a negative correlation was found between 1997 productivity indices and changes in MSD rates over the 1992–1998 period. The larger the MSD rate reduction the larger the productivity gain recorded in 1997 among low-productivity industries.

An interesting finding emerged from analyses of 178 industry groups (3-digit level) for which OSHA had data on ergonomic engineering control implementation rates. Industries with low MSD levels (1998) and large 1992–1998 rate reductions were found to have below average engineering control implementation rates. Conversely, industries with above average rates for implementing engineering controls to address ergonomic hazards continued to experience relatively high MSD levels. Industries in this group will require continued resourcefulness and interventions to address less tractable MSD problems. Across all industry groups the percent of employees in each industry for whom ergonomic controls have been implemented was significantly correlated with the 1998 rate of MSDs for the industry. This implies that the industries that have taken steps to address ergonomic risks among their workers tend to be those in which ergonomic risk factors have been and continue to be more prevalent.

Based on the industry-level MSD data analyzed no specific new technology threat was identified and no correlation was identified that would support the contention that low productivity was associated with reductions in MSD cases. Analysis of industry data does not support the hypothesis that MSD rate reductions have contributed in a systematic way to poor productivity. Significantly, a strong negative correlation between

larger (negative) MSD rate changes and productivity increases was found in industries with low productivity growth (-.424 at the one percent level).

*Industries with Low MSD Rates 1992 and 1998 — Tables 1 and 2.* Across industry groups at the 3-digit SIC level, the lowest MSD rate in 1992 was recorded in Accounting, Auditing and Bookkeeping (872) with a 8.97 rate. An additional 30 industry groups had rates below 50 (from a low of 15.70 for Commercial Banks (602) to a rate of 49.08 for Radio, Television and Computer Stores (573)). Among the 31 industries with rates below 50, 21 were in nonmanufacturing and ten in manufacturing.

By 1998 Accounting, Auditing and Bookkeeping once again led all industry groups with a low MSD rate of 4.86, followed by Computer and Data Processing Services (737) with a rate of 7.87. Among the top 30 industry groups with the lowest MSD rates, 19 were in nonmanufacturing and 11 in manufacturing.

Among the top 50 low-rate industry groups in 1998 (MSD rate below 43) all but three had achieved a reduction in their MSD rates over 1992 levels. In 18 cases the reductions were above 50 percent.

Among manufacturing industries at the more disaggregated 4-digit level, the lowest recorded MSD rate in 1992 was achieved in Organic Fiber, Noncellulosic (2824) with a rate of 22.59. The only other manufacturing industry with a rate below 30 was Yarn Spinning Mills (2281) with 26.12. Overall, 30 manufacturing industries recorded rates below 70 in 1992; the top 50 industries were under 100.

By 1998 Space Propulsion Units and Parts (3764) occupied first place in manufacturing with a low rate of 13.59, followed by Nonwoven Fabrics (2297) at 13.86 and Organic Fibers Noncellulosic with a 15.95 rate. The top 32 manufacturing industries had rates below 40. Among the top 50 manufacturing industries in 1998 (rates below 52) each had succeeded in reducing MSD rates below 1992 levels; 30 of 50 had reductions of 50 percent or more; eight industries had reduced rates by over 70 percent (led by Nonwoven Fabrics with -87.75)

In 1998, low MSD industries had above average employee hourly earnings; for 3-digit industry groups \$14.81 and for 4-digit industries \$14.00 compared with the all-industry average of \$13.43, and above average productivity indices; 147.3 for the 3-digit groups and 142.6 for the 4-digit industries compared with the 123.74 all-industry average.

*Industries with Large MSD Rate Reductions 1992–1998 — Table 3.* Across all 3-digit industry groups regardless of their 1998 MSD rate levels, 50 of 178 industries succeeded in reducing 1998 rates over 1992 rates by 45 percent or more. Reductions above 70 percent were found in Retail Stores, NEC (599) with -77.13, Mailing, Reproduction, Stenographic (733) with -74.49, Women's and Misses' Outerwear (233) with -73.61, Cut Stone and Stone Products (328) with -71.05, and Reupholstery and Furniture Repair (764) with -70.28. Among the top 50 industry groups with large MSD reductions, 30 were in manufacturing and 20 in nonmanufacturing. Within this high rate reduction group, only five industries had 1998 MSD levels above 100 (Wood Products, Trucking and Courier Services, Leather Tanning and Finishing, Structural Clay Products, and Wood Building and Mobile Homes).

Table 1. Industries with Low 1992 MSD Rates

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by 1992 MSD Rate											
8720	Accounting, Auditing & Bookkeeping	54,635,855	60.51	63.54	32.55	15.82		23	4.9	9.0	-45.8
6020	Commercial Banks	386,117,815	21.39	34.38	5.65	10.82	133.0	9	10.5	15.7	-33.2
7370	Computer & Data Processing Services	224,114,386	121.73	112.95	60.40	22.38		52	7.9	15.8	-50.1
7230	Beauty Shops	12,051,795	21.65	25.85	5.19	9.82	107.5	32	17.7	15.9	11.2
8710	Engineering & Architectural Services	108,622,515	37.90	32.90	13.22	20.19		23	16.5	17.1	-3.8
2210	Broadwoven Fabric Mills, Cotton	6,195,171	6.62	2.21	-16.94	11.05	130.9	53	10.1	17.4	-42.2
2910	Petroleum Refining	157,525,704	15.36	6.78	-12.54	24.41	149.2	43	17.9	25.6	-30.1
8070	Medical and Dental Laboratories	19,310,096	33.54	33.76	8.25			48	36.6	25.8	42.2
6330	Fire, Marine and Casualty Insurance	300,158,713	16.16	33.91	7.4	18.5		44	15.2	25.8	-41.0
4830	Radio and Television Broadcasting	40,425,210	43.20	41.46	12.61	18.38	101.1	10	13.3	28.1	-52.7
5620	Women's Clothing Stores	27,257,683	-12.99	-8.79	-27.74	8.87	145.8	7	15.4	28.3	-45.5
8010	Offices & Clinics of Medical Doctors	172,896,422	22.25	23.03	15.23	14.85		21	17.0	28.8	-41.1
5660	Shoe Stores	20,543,252	14.87	7.51	0.75	8.51	143.5	7	21.7	31.5	-31.2
8350	Child Day Care Services	8,401,972	59.43	65.07	37.16	8.29		56	22.6	33.4	-32.3
8730	Research and Testing Services	37,401,157	64.83	62.5	29.84	18.46		23	16.6	33.5	-50.4
4810	Telephone Communications	256,130,797	49.28	30.64	7.73	17.66	160.9	15	37.3	34.9	7.0
8740	Management and Public Relations	101,345,844	76.81	72.22	46.18	18.35		23	27.8	34.9	-20.4
2110	Cigarettes	29,252,787	-1.66	3.45	-16.25	24.59	147.2	69	85.4	35.8	138.6
4910	Electric Services	169,783,807	16.62	1.52	-15.53	21.71	150.5	10	30.9	40.2	-23.2
2820	Plastics Materials and Synthetics	63,639,476	30.68	4.21	-10.67	18.11	133.8	75	23.5	42.2	-44.3

4-Digit Industries Ranked by 1992 MSD Rate

2824	Organic Fibers, Noncellulosic	11,912,262	7.19	-7.17	-16.46	15.3	148.3	15.95	22.59	-29.39
2281	Yarn Spinning Mills	8,094,341	5.55	2.12	-15.71	10.43	153.4	21.26	26.12	-18.61
3764	Space Propulsion Units and Parts	3,239,033	-36.76	-28.03	-42.06			13.59	30.30	-55.15
3571	Electronic Computers	66,331,909	73.63	-11.68	-9.50	18.38		19.26	32.70	-41.10
2865	Cyclic Crudes and Intermediates	12,929,238	35.25	7.04	-10.33	20.52	147.9	27.73	33.07	-16.15
2841	Soap and Other Detergents	16,776,051	13.9	1.00	-11.51	18.65	130.1	19.37	40.40	-52.05
2296	Tire Cord and Fabrics	1,212,119	24.26	50.07	12.97			107.29	41.11	160.98
3761	Guided Missiles and Space Vehicles	14,791,466	-23.85	-31.94	-46.63		128	24.84	44.77	-44.52
2821	Plastics Materials and Resins	44,478,404	40.75	15.51	-0.68	20.59	129	27.62	44.77	-38.31
3661	Telephone and Telegraph Apparatus	39,673,619	93.44	49.56	21.15	14.66		30.06	45.64	-34.14
2834	Pharmaceutical Preparations	66,382,907	31.67	10.2	-8.49	17.09	99.8	37.38	46.43	-19.49
3674	Semiconductors and Related Devices	78,539,562	143.98	46.91	15.98	18.36		23.02	47.19	-51.22
2833	Medicinal and Botanicals	11,813,902	81.02	157.10	109.58			23.68	49.79	-52.44
2395	Pleating and Stitching	1,010,106	39.07	63.92	38.70			22.65	50.56	-54.75
3823	Process Control Instruments	7,890,923	21.96	12.95	-2.51	14.44	104.4	39.33	52.99	-25.78
3769	Space Vehicle Equipment, NEC	898,758	-54.23	-57.94	-62.24			53.20	54.27	-1.97
2731	Book Publishing	22,976,675	37.61	38.56	16.33	12.83	108.8	75.45	54.52	38.39
3845	Electromedical Equipment	10,567,566	47	52.51	17.44			29.30	56.08	-47.75
3675	Electronic Capacitors	2,482,163	56.97	27.79	5.78			26.61	58.05	-54.16
2282	Throwing and Winding Mills	4,333,710	56.54	50.85	24.58	10.54	157.3	53.44	59.82	-10.67

Table 2. Industries with Low 1998 MSD Rates

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
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2210	Broadwoven Fabric Mills, Cotton	6,195,171	6.62	2.21	-16.94	11.05	130.9	53	10.1	17.4	-42.2
6020	Commercial Banks	386,117,815	21.39	34.38	5.65	10.82	133.0	9	10.5	15.7	-33.2
4830	Radio and Television Broadcasting	40,425,210	43.20	41.46	12.61	18.38	101.1	10	13.3	28.1	-52.7
6330	Fire, Marine and Casualty Insurance	300,158,713	16.16	33.91	7.4	18.5		44	15.2	25.8	-41.0
5620	Women's Clothing Stores	27,257,683	-12.99	-8.79	-27.74	8.87	145.8	7	15.4	28.3	-45.5
8710	Engineering & Architectural Services	108,622,515	37.90	32.90	13.22	20.19		23	16.5	17.1	-3.8
8730	Research and Testing Services	37,401,157	64.83	62.50	29.84	18.46		23	16.6	33.5	-50.4
8010	Offices & Clinics of Medical Doctors	172,896,422	22.25	23.03	15.23	14.85		21	17.0	28.8	-41.1
7230	Beauty Shops	12,051,795	21.65	25.85	5.19	9.82	107.5	32	17.7	15.9	11.2
2910	Petroleum Refining	157,525,704	15.36	6.78	-12.54	24.41	149.2	43	17.9	25.6	-30.1
3810	Search and Navigation Equipment	32,497,776	-7.25	-9.15	-25.88	17.57	148.9	72	18.8	45.5	-58.7
5990	Retail Stores, NEC	44,034,282	64.06	50.53	30.85	9.96	147.3	9	21.7	94.7	-77.1
5660	Shoe Stores	20,543,252	14.87	7.51	0.75	8.51	143.5	7	21.7	31.5	-31.2
8350	Child Day Care Services	8,401,972	59.43	65.07	37.16	8.29		56	22.6	33.4	-32.3
2330	Women's and Misses' Outerwear	22,962,707	6.16	-2.41	-17.93	8.41	151.5	64	22.8	86.4	-73.6
2820	Plastics Materials and Synthetics	63,639,476	30.68	4.21	-10.67	18.11	133.8	75	23.5	42.2	-44.3
2740	Miscellaneous Publishing	16,507,914	51.34	52.65	20.77	13.02	114.5	47	24.7	47.1	-47.7
3760	Guided Missiles, Space Vehicles, Parts	18,929,257	-28.59	-33.62	-47.36	20.24	126.6	87	26.7	42.7	-37.4



4-Digit Industries Ranked by 1998 MSD Rate

3764	Space Propulsion Units and Parts	3,239,033	-36.76	-28.03	-42.06					13.59	30.30	-55.15
2297	Nonwoven Fabrics	3,759,985	24.11	18.77	1.8			100.9		13.86	113.17	-87.75
2824	Organic Fibers, Noncellulosic	11,912,262	7.19	-7.17	-16.46	15.3		148.3		15.95	22.59	-29.39
3571	Electronic Computers	66,331,909	73.63	-11.68	-9.50	18.38				19.26	32.70	-41.10
2841	Soap and Other Detergents	16,776,051	13.9	1.00	-11.51	18.65		130.1		19.37	40.40	-52.05
3829	Measuring & Controlling Devices, NEC	5,176,695	17.23	5.76	-8.35			122.8		20.60	76.71	-73.15
2281	Yarn Spinning Mills	8,094,541	5.55	2.12	-15.71	10.43		153.4		21.26	26.12	-18.61
2395	Pleating and Stitching	1,010,106	39.07	63.92	38.70					22.65	50.06	-54.75
3674	Semiconductors and Related Devices	78,539,562	143.98	46.91	15.98	18.36				23.02	47.19	-51.22
2833	Medicinal and Botanicals	11,813,902	81.02	157.10	109.58					23.68	49.79	-52.44
2257	Wet Knit Fabric Mills	4,890,995	-1.35	-3.35	-22.72	10.49				24.38	114.78	-78.76
2251	Women's Hosiery, Except Socks	1,541,302	-16.37	-17.71	-32.95	8.96		165		24.80	70.22	-64.68
3761	Guided Missiles and Space Vehicles	14,791,466	-23.85	-31.94	-46.63			128		24.84	44.77	-44.52
2339	Women's and Misses' Outerwear, NEC	9,522,284	20.56	16.74	-3.70	8.12				25.18	101.98	-75.31
3675	Electronic Capacitors	2,482,163	56.97	27.79	5.78					26.61	58.05	-54.16
3489	Ordnance and Accessories, NEC	1,750,485	28.31	-33.60	-36.87					27.45	61.69	-55.50
2821	Plastics Materials and Resins	44,478,404	40.75	15.51	-0.68	20.59		129		27.62	44.77	-38.31
2253	Knit Outerwear Mills	5,393,105	29.32	1.55	-17.21	9.46		202		27.63	98.11	-71.84
2865	Cyclic Crudes and Intermediates	12,929,238	35.25	7.04	-10.33	20.52		147.9		27.73	33.07	-16.15
3845	Electromedical Equipment	10,567,566	47	52.51	17.44					29.30	56.08	-47.75

Table 3. *Industries with Largest MDS Rate Reductions*

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by MSD Rate Reduction											
5990	Retail Stores, NEC	44,034,282	64.06	50.53	30.85	9.96	147.3	9	21.65	94.68	-77.13
7330	Mailing, Reproduction, Stenographics	22,229,670	59.39	53.67	32.01			17	28.24	110.69	-74.49
2330	Women's and Misses' Outerwear	22,962,707	6.16	-2.41	-17.93	8.41	151.5	64	22.81	86.42	-73.61
3280	Cut Stone and Stone Products	1,249,927	24.17	24.95	7.52			60	75.36	260.27	-71.05
7640	Reupholstery and Furniture Repair	1,193,414	21.73	24.93	5.02			10	29.98	100.89	-70.28
7360	Personnel Supply Services	91,043,505	138.56	144.56	85.70			17	40.68	119.21	-65.88
3110	Leather Tanning and Finishing	3,342,127	15.04	-0.92	-9.69	12.51		52	102.49	297.67	-65.57
2010	Meat Products	111,141,955	18.15	28.66	15.35	9.96	103.2	69	82.99	217.86	-61.91
2770	Greeting Cards	5,470,559	30.57	14.22	-3.87		92.2	47	38.35	97.54	-60.68
5230	Paint, Glass and Wallpaper Stores	7,738,469	24.8	25.38	2.76	10.8	143.8	42	50.38	127.01	-60.33
4730	Freight Transportation Arrangement	16,392,866	78.99	56.75	33.79	14.24		15	39.03	98.25	-60.27
5190	Misc. Nondurable Goods	244,016,844	32.2	32.75	12.15	10.97		42	52.01	130.23	-60.06
5120	Drugs, Proprietaries, and Sundries	203,147,771	57.11	56.39	20.44	18.99		36	35.10	85.79	-59.09
2840	Soap, Cleaners and Toilet Goods	57,507,318	34.13	16.71	3.37	14.87	130.4	75	34.52	83.69	-58.75
3810	Search and Navigation Equipment	32,497,776	-7.25	-9.15	-25.88	17.57	148.9	72	18.79	45.52	-58.72
3430	Plumbing & Heating, Except Electric	8,671,083	48.85	30.27	17.26	12.07	127.2	59	67.93	161.69	-57.99
3470	Metal Services, NEC	14,454,652	45.24	40.33	20.82	11.57	123.5	59	74.97	178.27	-57.95
2320	Men's and Boys' Furnishings	19,192,734	7.42	-11.37	-24.27	8.27	152.4	64	90.17	211.61	-57.39
2720	Periodicals	29,972,538	35.6	47.10	19.74	15.31	100.1	47	28.16	65.89	-57.26
7540	Automotive Services, Except Repair	9,792,476	61.94	68.71	42.91	8.62		52	33.67	77.93	-56.79

4-Digit Industries Ranked by MSD Rate Reduction

2297 Nonwoven Mills	3,759,985	24.11	18.77	1.80	100.9	13.86	113.17	-87.75
2257 Wefit Knit Fabric Mills	4,890,995	-1.35	-3.35	-22.72	10.49	24.38	114.78	-78.76
2015 Poultry Slaughtering and Processing	33,403,654	39.39	37.33	21.12	8.96	37.90	158.08	-76.02
2339 Women's and Misses' Outerwear, NEC	9,522,284	20.56	16.74	-3.70	8.12	25.18	101.98	-75.31
3088 Plastics Plumbing Fixtures	2,185,349	100.64	97.32	78.42		64.46	261.04	-75.31
3497 Metal Foil and Leaf	3,257,743	3.03	1.06	-13.19		40.96	160.31	-74.45
2677 Envelopes	3,640,243	29.27	19.48	4.83	12.96	60.72	227.41	-73.30
3829 Measuring & Controlling Devices, NEC	5,176,695	17.23	5.76	-8.35		20.60	76.71	-73.15
2392 House Furnishings, NEC	7,318,895	30.58	21.28	1.14	9.54	30.84	113.22	-72.76
3497 Metal Coating and Allied Services	8,475,247	59.09	46.55	27.15	11.75	52.32	190.68	-72.56
2253 Knit Outerwear Mills	5,393,105	29.32	1.55	-17.21	9.46	27.63	98.11	-71.84
2326 Men's and Boys' Work Clothing	1,928,453	28.28	-2.18	-14.85	8.12	105.53	372.15	-71.64
2337 Women's and Misses' Suits and Coats	3,945,440	-10.26	-18.54	-33.81	8.49	30.81	97.70	-68.46
2066 Chocolate and Cocoa Products	3,954,586	27.31	26.46	6.50		62.25	196.71	-68.35
2844 Toilet Preparations	25,369,339	36.18	24.75	11.04	12.96	36.78	112.59	-67.33
2042 Cereal Breakfast Foods	9,098,833	-6.55	-3.65	-10.57		46.41	140.31	-66.92
2675 Die-Cut Paper and Board	2,869,679	43.52	24.36	2.79	98.4	49.48	147.33	-66.42
2251 Women's Hosiery, Except Socks	1,541,302	-16.37	-17.71	-32.95	8.96	24.80	70.22	-64.68
3691 Storage Batteries	4,432,112	33.27	34.74	12.21	15.57	51.54	143.23	-64.02
2048 Prepared Feeds, NEC	19,185,447	33.79	12.57	-7.04	12.33	50.60	134.82	-62.47

Industries achieving the largest reductions in MSD rates presumably are more likely to have made changes specifically intended to reduce ergonomic risk factors. Among 3-digit industry groups with the largest reductions in MSDs (top quartile, with reductions of over 47 percent), greater reductions in MSD rates were significantly correlated with larger increases in productivity at the five percent level.

Among 50 manufacturing industries (4-digit level) with the largest rate reductions, only three industries had 1998 rates above 100 (Potato Chip and Similar Snacks (2096), Converted Paper Products (2679), and Men's and Boy's Work Clothing (2326)).

*Industries with High MSD Rates 1992 and 1998 — Tables 4 and 5.* In 1992, among industries at the 3-digit level, Nursing and Personal Care Facilities (805) recorded the highest MSD rate at 405.33. No other industry group exceeded 300. Eighteen industry groups recorded rates between 200-300 with Leather Tanning and Finishing (311) at 297.67 at the high end and Wood Buildings and Mobile Homes (245) with a rate just over 200, at the low end. Fourteen of the 18 industries were in manufacturing; high rate nonmanufacturing industry groups included Beer, Wine and Distilled Services (518), Trucking and Courier Services (421), Groceries and Related Products (514), and Sanitary Services (495).

In 1998 Nursing and Personal Care Facilities (805) remained at the head of the list with the highest MSD rate of 245.85, followed by Pottery and Related Products (326) with a rate of 228.87. These two industry groups were the only ones above 200; 18 industry groups recorded rates between 120 and 200; 14 in manufacturing and four in nonmanufacturing. Among the nonmanufacturing industries, Beer, Wine and Distilled Services and Groceries and Related Products remained in the high rate group now joined by Lumber and Other Building Products (521) and Hospitals (806). Most industry groups registered impressive rate reductions between 1992 and 1998.

In 1992 at the more discrete level of industry detail for manufacturing, three industries recorded MSD rates between 300 and 400 with the highest rate, 397.24, in Bottled and Canned Soft Drinks (2086); Men's and Boy's Work Clothing (2326) recorded 372.15 and Mattresses and Bed Springs (2515) had a rate just above 300. Thirty-two manufacturing industries had rates between 200-300 led by Meat Packing Plants (2011) at 291.96 down to Steel Investment Foundries (3324) with a rate of 201.43.

By 1998 only one manufacturing industry, Vitreous Plumbing Fixtures (3261), had an MSD rate above 300 (a 1998 rate of 372.65, up from 238.63 in 1992). Thirty-four industries had rates between 135-300 with the highest rate in this range (281.44, up from 169.33 in 1992) recorded in Pottery Products (3269).

The high MSD industries at both 3- and 4-digit industry levels were found to have below average productivity rates (121.14 for the 3-digit and 117.87 for 4-digit industries) compared with the all-industry average of 123.74 and below average employee hourly earnings (\$13.25 for industry groups and \$13.11 for manufacturing industries) compared to the \$13.43 average.

Separate data analyses were made for all 438 industries, 3- and 4-digit levels combined, focusing on the highest quartile, those with 1998 MSD rates above 108. Inter-

estingly 109 high-rate industries were above average in their implementation of ergonomic engineering controls with an average rate of 55.10 versus the all-industry average of 48.91. The average wage rate for the high MSD quartile was \$13.37, somewhat lower than the \$13.43 all-industry average. For the high-rate group, a positive relationship was found between control implementation and payroll per employee of .377 at the five percent level.

The 109 industries in the high rate group had an average productivity index of 119.6 compared with the all-industry average of 123.74. The productivity indices for the high MSD category were positively correlated with industry revenue changes (.353 at the one percent level). Some industries in this category would appear to be in a financial position to address their MSD problem.

Among 3-digit SICs with 1992 MSD rates in the top quartile (above 154), the percent of employees in the industry working with the benefit of ergonomic controls implemented was significantly correlated with changes in productivity at the five percent level. This finding seems to support the conclusion that in industries with more severe MSD risk factors, the implementation of ergonomic controls tends to be associated with improvements in productivity.

Among the industries in the quartile with the highest 1992 MSD rates, there was no statistically significant difference in the average change in productivity between those with the highest MSD rate reductions (1992–1998) and those with the lowest rate reductions.

*MSD Rates in Industries with High Productivity Increases — Table 6.* During 1987–1997 the highest recorded productivity gain among industries at the 3-digit level was achieved in Electronic Components and Accessories (367) with an index of 610.5. An additional three industry groups had indices above 200 (gains over 100 percent): Communication Equipment (366) with 221.0, Radio, Television, and Computer Stores (573) at 215.1, and Ophthalmic Goods (385) with 202.6. The top 30 industry groups had gains of 33 percent or more (indices equal to or above 133); the top 50 industry groups recorded gains of 23.5 percent and above.

Within the top 30 productivity gainers (index at 133.0 and above), four industry groups experienced higher MSD rates in 1998 over 1992 (the highest, Cigarettes (211), recorded a rate increase of 138.56; the next highest was Ophthalmic Goods with a 22.09 percent increase). Among the four industry groups with rate increases only one, Electric Distribution (361), recorded a 1998 rate above 100 (the rate increase was 2.73 and the 1998 level was 116.33).

Among the top 50 industry groups with large productivity gains (1997 index of 123.5 or above) only one additional industry group, Construction and Related Machinery (353), had an MSD 1992–1998 rate increase (14.38). Within the top 50 productivity gainers, nine industry groups had 1998 rates above 100 with the highest group, Nonferrous Foundries (336) at 185.0 (combined with a 131.8 productivity index).

While the average percent change in MSD rates between 1992 and 1998 for all industries was –33.53 the average rate for the 50 industries in the high productivity

Table 4. Industries with High 1992 MSD Rates

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by 1992 MSD Rate											
8050	Nursing and Personal Care Facilities	49,532,896	45.73	40.15	15.66	10.17		22	245.85	405.33	-39.35
3110	Leather Tanning and Finishing	3,342,127	15.04	-0.92	-9.69	12.51		52	102.49	297.67	-65.57
3280	Cut Stone and Stone Products	1,249,927	24.17	24.95	7.52			60	75.36	260.27	-71.05
2440	Wood Containers	4,332,491	47.26	45.21	23.69	9.23	106.6	57	122.20	255.52	-52.18
5180	Beer, Wine and Distilled Beverages	69,703,203	17.17	21.36	6.95	15.97		42	198.84	254.89	-21.99
3730	Ship and Boat Building and Repairing	17,015,123	11.59	0.16	-8.92	13.81	104.3	87	130.62	239.06	-45.36
3320	Iron and Steel Foundries	17,533,215	47.83	24.80	8.83	14.69	121.7	67	168.33	223.82	-24.79
2540	Partitions and Fixtures	10,637,959	61.66	59.51	36.77	11.83	121.4	65	150.17	220.92	-32.03
3260	Pottery and Related Products	3,721,465	32.12	22.22	8.45	12.01	116.1	60	228.87	219.11	4.45
2010	Meat Products	111,141,955	18.15	28.66	15.35	9.96	103.2	69	82.99	217.86	-61.91
3060	Fabricated Rubber Products, NEC	15,430,435	34.48	20.16	3.58	12.18	125.4	70	145.66	214.28	-32.02
2530	Public Building & Related Furniture	7,869,175	75.53	39.69	22.12	12.49	186.5	65	164.40	212.56	-22.66
2320	Men's and Boys' Furnishings	19,192,734	7.42	-11.37	-24.27	8.27	152.4	64	90.17	211.61	-57.39
3360	Nonferrous Foundries (Castings)	11,598,177	65.63	49.18	26.85	12.82	126.4	67	185.86	211.55	-12.14
4210	Trucking & Courier Services, Ex. Air	184,178,733	35.99	39.07	23.37	14.18		15	110.60	210.78	-47.53
5140	Groceries and Related Products	590,785,074	17.09	23.76	5.74	13.75		36	168.95	206.28	-18.10
2020	Dairy Products	59,020,541	11.95	12.32	-1.78	14.04	119.5	69	149.99	205.80	-27.12
4950	Sanitary Services	17,165,878	13.26	25.36	11.42	16.83		68	115.62	203.33	-43.14
2450	Wood Buildings and Mobile Homes	13,179,370	98.34	91.55	62.93	11.61	101.1	57	100.30	200.96	-50.09
3250	Structural Clay Products	3,515,593	23.04	11.07	-3.88	12.34	116.10	60	101.39	199.80	-49.25

4-Digit Industries Ranked by 1992 MSD Rate

2086	Bottled and Canned Soft Drinks	32,181,998	26.59	16.20	1.34	13.35	163.2	245.24	397.24	-38.26
2326	Men's and Boys' Work Clothing	1,928,453	28.28	-2.18	-14.85	8.12	164	105.53	372.15	-71.64
2515	Mattresses and Bedsprings	4,067,225	44.19	32.99	10.78	11.39	114	195.72	301.96	-35.18
2011	Meat Packing Plants	54,484,916	8.61	33.32	17.36	10.81	99	132.37	291.96	-54.66
2045	Prepared Flour Mixes and Doughs	5,047,752	30.58	14.53	-0.98		103.3	217.37	275.81	-21.19
2448	Wood Pallets and Skids	3,449,491	60.67	59.23	35.84		99.5	128.19	275.48	-53.47
2439	Structural Wood Members, NEC	5,085,234	100.32	84.09	55.92		121.4	139.77	265.95	-47.45
3061	Mechanical Rubber Goods	6,548,250	44.19	31.73	13.48		135.8	138.99	261.49	-46.85
3088	Plastics Plumbing Fixtures	2,185,349	100.64	97.32	78.42		176.50	64.46	261.04	-75.31
3731	Ship Building and Repairing	10,571,810	-0.27	-7.28	-17.64	15.22	108.20	133.29	254.17	-47.56
2679	Converted Paper Products, NEC	5,536,962	23.02	12.30	-3.97		143	107.49	250.25	-57.05
2096	Potato Chips and Similar Snacks	9,178,696	25.58	23.61	-3.77		150.5	109.34	249.20	-56.12
2325	Men's and Boys' Trousers and Slacks	7,363,905	12.97	-13.92	-25.41	8.44	135.1	131.62	245.18	-46.32
2013	Sausages and Other Prepared Meats	22,253,385	16.62	9.75	-0.60	11.17	104.5	120.21	239.00	-49.70
2026	Fluid Milk	22,223,852	1.36	4.45	-8.01	14.78	108.1	180.69	238.93	-24.38
3261	Vitreous Plumbing Fixtures	1,109,995	23.04	31.41	10.26			372.65	238.63	56.16
3321	Gray and Ductile Iron Foundries	11,911,623	53.19	26.73	8.98	15.32	127.5	174.27	234.68	-25.74
3365	Aluminum Foundries	3,937,406	100.97	74.60	49.22	12.27	172.8	237.77	231.23	2.83
2541	Wood Partitions and Fixtures	5,388,485	73	71.37	45.57			176.72	231.20	-23.56
3357	Nonferrous Wiredrawing & Insulation	19,116,555	46.56	36.66	15.15	14.11	127.1	94.35	230.26	-59.02

Table 5. Industries with High 1998 MSD Rates

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by 1998 MSD Rate											
8050	Nursing and Personal Care Facilities	49,532,896	45.73	40.15	15.66	10.17		22	245.85	405.33	-39.35
3260	Pottery and Related Products	3,721,465	32.12	22.22	8.45	12.01	116.1	60	228.87	219.11	4.45
5180	Beer, Wine and Distilled Beverages	69,703,203	17.17	21.36	6.95	15.97		42	198.84	254.89	-21.99
3360	Nonferrous Foundries (Castings)	11,598,177	65.63	49.18	26.85	12.82	126.4	67	185.86	211.55	-12.14
5140	Groceries and Related Products	590,785,074	17.09	23.76	5.74	13.75		36	168.95	206.28	-18.10
3320	Iron and Steel Foundries	17,533,215	47.83	24.80	8.83	14.69	121.7	67	168.33	223.82	-24.79
2530	Public Building & Related Furniture	7,869,175	75.53	39.69	22.12	12.49	186.5	65	164.40	212.56	-22.66
3210	Flat Glass	2,795,507	34.86	18.64	-2.24	18.3	107.6	60	154.32	80.27	92.25
3530	Construction and Related Machinery	47,935,156	76.28	42.69	21.09	14.12	131.8	62	152.02	132.91	14.38
2540	Partitions and Fixtures	10,637,959	61.66	59.51	36.77	11.83	121.4	65	150.17	220.92	-32.03
2020	Dairy Products	59,020,541	11.95	12.32	-1.78	14.04	119.5	69	149.99	205.80	-27.12
3060	Fabricated Rubber Products, NEC	15,430,435	34.48	20.16	3.58	12.18	125.4	70	145.66	214.28	-32.02
3140	Footwear, Except Rubber	3,421,771	-12.23	-14.21	-33.66	9.33	129.5	52	133.64	173.18	-22.83
3730	Ship and Boat Building and Repairing	17,015,123	11.59	0.16	-8.92	13.81	104.3	87	130.62	239.06	-45.36
2420	Sawmills and Planing Mills	32,750,181	40.59	24.91	6.01	11.41	117.50	57	128.92	166.48	-22.56
3460	Metal Forgings and Stampings	44,832,778	46.41	35.33	14.67	15.84	120.2	59	128.48	184.65	-30.42
5210	Lumber and Other Building Materials	103,414,057	51.41	47.66	35.57	11.3	122.2	42	126.74	196.02	-35.34
8060	Hospitals	40,146,379	29.16	31.54	19.49	15.96		22	126.49	175.88	-28.08
3440	Fabricated Structural Metal Products	65,206,295	45.3	36.19	18.24	12.95	110	59	126.40	172.39	-26.68
2440	Wood Containers	4,332,491	47.26	45.21	23.69	9.23	106.6	57	122.20	255.52	-52.18



4-Digit Industries Ranked by 1998 MSD Rate

3261 Vitreous Plumbing Fixtures	1,109,995	23.04	31.41	10.26	372.65	238.63	56.16
3269 Pottery Products, NEC	998,876	49.21	27.70	18.13	281.44	169.33	66.21
2086 Bottled and Canned Soft Drinks	32,181,998	26.59	16.20	1.34	13.35	397.24	-38.26
3365 Aluminum Foundries	3,937,406	100.97	74.60	49.22	12.27	231.23	2.83
2045 Prepared Flour Mixes and Doughs	5,047,752	30.58	14.53	-0.98	103.3	275.81	-21.19
3325 Steel Foundries, NEC	2,927,240	39.45	23.29	7.02	13.9	229.60	-6.79
3715 Truck Trailers	5,507,768	55.1	47.66	30.82	11.52	229.14	-8.14
2295 Coated Fabrics, Not Rubberized	1,928,926	22.59	22.13	6.45	206.78	179.25	15.36
3713 Truck and Bus Bodies	8,719,326	88.47	36.96	19.70	15.28	209.64	-5.91
2515 Mattresses and Boxsprings	4,067,225	44.19	32.99	10.78	11.39	301.96	-35.18
3443 Fabricated Plate Work (Boiler Shops)	11,463,395	27.73	24.84	11.03	14.23	186.70	-2.19
2026 Fluid Milk	22,223,852	1.36	4.45	-8.01	14.78	238.93	-24.38
2541 Wood Partitions and Fixtures	5,388,485	73	71.37	45.57	108.1	231.20	-23.56
3321 Gray and Ductile Iron Foundries	11,911,623	53.19	26.73	8.98	15.32	234.68	-25.74
3792 Travel Trailers and Campers	3,076,049	45.21	45.04	32.55	12.8	167.29	-1.55
3446 Architectural Metal Work	3,536,413	49.05	40.74	24.32	12.47	157.94	3.58
3465 Automotive Stampings	23,668,110	49.77	37.96	20.77	17.8	208.23	-23.49
2426 Hardwood Dimension & Flooring Mill	3,206,954	53.84	38.85	17.36	9.74	192.80	-17.46
3363 Aluminum Die-Castings	3,791,717	34.58	21.70	2.43	72.4	192.60	-17.82
3564 Blowers and Fans	4,075,925	35.14	23.99	14.59	11.86	144.71	6.92

Table 6. *Industries with the Largest Productivity Increases*

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by Productivity Change											
3670	Electronic Components & Accessories	141,997,578	92.82	37.05	15.45	13.73	610.5	79	40.93	68.99	-40.67
3660	Communications Equipment	80,949,148	88.45	45.68	18.93	14.04	221.0	79	40.08	56.72	-29.34
5730	Radio, Television & Computer Stores	60,437,033	73.24	54.76	40.06	13.21	215.1	8	42.95	49.08	-12.49
3850	Ophthalmic Goods	3,607,813	34.86	14.04	-10.42	10.78	202.6	72	77.38	63.38	22.09
2530	Public Building & Related Furniture	7,869,175	75.53	39.69	22.12	12.49	186.5	65	164.40	212.56	-22.66
3740	Railroad Equipment	7,916,635	67.96	37.20	11.77	16.55	183.2	87	101.53	167.31	-39.32
5960	Nonstore Retailers	86,372,426	69.09	46.48	17.77	10.41	177.2	6	60.28	98.36	-38.71
3620	Electrical Industrial Apparatus	28,643,846	48.67	24.79	7.42	12.92	163.9	79	62.07	128.71	-51.78
2220	Broadwoven Fabric Mills, Manmade	10,682,267	21.84	9.46	-11.51	11.49	161.9	53	85.24	46.34	83.94
4810	Telephone Communications	256,130,797	49.28	30.64	7.73	17.66	160.9	15	37.29	34.85	7.00
3310	Blast Furnace & Basic Steel Product	77,532,783	32.65	9.59	-8.81	18.81	160.9	67	85.07	121.79	-30.15
3410	Metal Cans and Shipping Containers	13,352,606	0.68	-5.92	-15.14	16.71	160.8	59	60.41	114.31	-47.15
5720	Household Appliance Stores	10,082,894	23.63	26.21	11.97	11.54	155.5	8	65.84	110.97	-40.67
2320	Men's and Boys' Furnishings	19,192,734	7.42	-11.37	-24.27	8.27	152.4	64	90.17	211.61	-57.39
2330	Women's and Misses' Outerwear	22,962,707	6.16	-2.41	-17.93	8.41	151.5	64	22.81	86.42	-73.61
4910	Electric Services	169,783,807	16.62	1.52	-15.53	21.71	150.5	10	30.90	40.22	-23.17
2910	Petroleum Refining	157,525,704	15.36	6.78	-12.54	24.41	149.2	43	17.87	25.58	-30.14
3810	Search and Navigation Equipment	32,497,776	-7.25	-9.15	-25.88	17.57	148.9	72	18.79	45.52	-58.72
3010	Tires and Inner Tubes	14,731,472	24.69	10.96	-0.40	19.28	148.5	70	117.21	146.82	-20.17
5990	Retail Stores, NEC	44,034,282	64.06	50.53	30.85	9.96	147.3	9	21.65	94.68	-77.13

4-Digit Industries Ranked by Productivity Change

3087	Custom Compound Purchased Resins	7,818,015	70.03	39.18	17.89	245.1	101.68	127.37	-20.17
3679	Electronic Components, NEC	38,938,113	64.5	43.03	25.57	238.0	45.96	83.42	-44.91
3663	Radio & TV Communications Equipment	37,042,241	89.76	43.30	18.59	212.90	47.29	63.65	-25.70
2253	Knit Outerwear Mills	5,393,105	29.32	1.55	-17.21	202.0	27.63	98.11	-71.84
3825	Instruments to Measure Electricity	13,877,200	57.24	18.25	-7.23	194.20	39.18	67.28	-41.77
3088	Plastics Plumbing Fixtures	2,185,349	100.64	97.32	78.42	176.5	64.46	261.04	-75.31
3365	Aluminum Foundries	3,937,406	100.97	74.60	49.22	172.8	237.77	231.23	2.83
3449	Miscellaneous Metal Work	5,697,186	70.62	50.60	22.91	170.8	94.98	178.49	-46.79
3841	Surgical and Medical Instruments	18,450,024	37.73	33.55	9.24	170.1	34.30	82.13	-58.24
3312	Blast Furnaces and Steel Mills	56,796,871	34.74	6.05	-14.30	169.9	65.90	96.37	-31.62
3398	Metal Heat Treating	3,485,459	78.11	55.55	29.69	166.9	123.87	191.76	-35.40
3085	Plastics Bottles	6,423,318	42.51	23.09	4.14	166.6	43.85	97.26	-54.91
3411	Metal Cans	12,042,011	-0.58	-6.04	-15.53	165.7	50.75	99.84	-49.17
2251	Women's Hosiery, Except Socks	1,541,302	-16.37	-17.71	-32.95	165.0	24.80	70.22	-64.68
2326	Men's and Boys' Work Clothing	1,928,453	28.28	-2.18	-14.85	164.0	105.53	372.15	-71.64
2086	Bottled and Canned Soft Drinks	32,181,998	26.59	16.20	1.34	163.2	245.24	397.24	-38.26
3632	Household Refrigerators and Freezers	4,887,364	15.47	14.21	-3.26	158.2	90.10	157.75	-42.88
2282	Throwing and Winding Mills	4,333,710	56.54	50.85	24.58	157.3	53.44	59.82	-10.67
3621	Motors and Generators	11,788,281	44.33	17.57	4.76	157.1	79.53	157.80	-49.60
3695	Magnetic and Optical Recording Media	4,726,363	1.83	17.40	-5.63	157.0	45.08	68.86	-34.53

group was  $-29.37$ . The all-industry ergonomic engineering control implementation rate was  $48.91$  compared to  $52.04$  for the high-productivity industry groups. Statistically, a correlation was found for this group between 1998 MSD rates and engineering controls implementation rates ( $.394$  at the five percent level). For the high-productivity group, engineering control implementation rates correlated with labor intensity<sup>4</sup> (controls combined with revenue change minus payroll change was  $.404$  at the one percent level).

In general, the high productivity industry group gainers experienced MSD rate reductions 1992–1998 ( $-29.37$ , somewhat below the all-industry average of  $-33.53$ ) and relatively low 1998 MSD rate levels ( $67.19$  compared with the all-industry average of  $83.62$ ). Two contradictory cases, Construction and Related Machinery and Electric Distribution, combined high productivity increases with higher MSD rates in 1998 over 1992 and a 1998 level above 100.

At the more discrete 4-digit level for manufacturing, some contrasts emerged from the patterns and relationships identified at the industry group (3-digit) level of analyses.

The top productivity increase was achieved in Custom Compound Purchased Resins (3087) with  $245.1$ . Three other industries also achieved increases above 200: Electronic Components, NEC (3679) with  $238.0$ , Radio and TV Communications Equipment (3663) with  $212.0$ , and Knit Outerwear Mills (2253) with a productivity index in 1997 of  $202.0$ . The top 30 industries in manufacturing experienced productivity gains of  $44.7$  percent or higher; the top 50 industries recorded increases above  $30.5$  percent.

Among the top 50 industries, five recorded increases in their MSD rates between 1992–1998 with the largest increase in Asphalt Felts and Coatings (2952) at  $53.02$ . Four industries had smaller increases, between  $2.83$  and  $12.41$ . Sixteen of the 50 industries with productivity increases recorded rate reductions of 50 percent or more; six industries had MSD reductions greater than 70 percent.

Within this group with the highest productivity increases, 19 of 50 manufacturing industries had MSD rates above 100, and two industries had rates above 200: Bottled and Canned Soft Drinks (2086) with an MSD rate of  $245.24$  in 1998 and a  $163.2$  productivity index and Aluminum Foundries (3365) with a  $237.77$  MSD rate and a  $172.8$  productivity index. While these cases are exceptions, they make the point that productivity increases can take place while MSD levels remain high. Efforts designed to improve productivity may not significantly affect MSD rates.

Compared with the profile that emerged at the industry-group level of analyses, MSD rate reductions at the more discrete industry level (4-digit) were more modest for the high-productivity cohort and the number of industries with persistent MSD rates above 100 was higher at the more disaggregated industry level. The impression of less tractable, more difficult to solve problems emerges from analysis at the more detailed industry level.

Across all high-productivity manufacturing industries significant MSD rate reductions accompanied high productivity increases (the 1992–1998 MSD rate reduction was  $-38.92$  compared to the all-industry average of  $-33.53$ ), a finding which differed from the results at the industry group level of aggregation.

No statistically significant relationship was found between MSD rate reductions and changes in productivity for this set of manufacturing industries. However, employee hourly earnings for this high-productivity sector were below the all-industry average (\$12.72 compared to the \$13.43 average) and very low rates (below \$10) were found in several high-productivity industries, including Men's and Boy's Work Clothes (2326) at \$8.12 and a productivity index of 164.0 and Women's Hosiery (2251) at \$8.96 and a productivity index in 1997 of 165 (a 65 percent increase since 1987).

*MSD Rates in Industries with Low Productivity Increases* — Table 7. At the opposite end of the productivity spectrum industry groups (3-digit level) with the worst productivity records during the 1990s were ranked beginning with industries with productivity decreases. Eleven industry groups experienced negative productivity (index below 100 in 1997) with the worst case Logging (241) at 71.9. Manifold Business Forms (276) and Newspapers (271) also had index ratings below 80.

Among 30 industry groups with the lowest productivity indices (109.2 or below), three experienced a MSD rate rise between 1992–1998, with the largest rise in Flat Glass (321) with a 92.25 increase. Six of the 30 low-productivity industries had 1998 MSD rates above 100, with the highest Flat Glass at 154.32.

Expanding the list to include to 50 industry groups with the lowest productivity resulted in two additional groups with rising MSD rates and five additional industries with 1998 rates above 100. The totals for the 50 low-productivity industries were: five with increasing MSD rates and 11 industry groups with 1998 levels above 100. This pattern was similar to the one found in industries with high productivity increases.

The argument that MSD rate decreases came at the expense of productivity was analyzed for the low-productivity industries. The average MSD rate reduction for low-productivity industry groups was  $-32.74$  compared with the all-industry reduction rate of  $-33.53$ . The low-productivity group was slightly above average in implementing ergonomic engineering controls compared with the all-industry average, 51.78 versus 48.91, and they had a below average 1998 MSD level than the all-industry average, 77.4 versus 83.6. The average earnings rate in the low-productivity group was \$13.09, below the national average of \$13.43.

Based on these "averages" no compelling case appears to link low productivity increases with industry efforts to reduce MSD rates.

Among manufacturing industries (4-digit level) 40 separate manufacturing industries experienced declining productivity 1987–1997, led by Ammunition Except for Small Arms NEC (3483) at 53.2 (1987=100). Other industries with serious productivity declines were Electronic Connectors (3678) at 67.1, Aluminum Die-Casting (3363) at 72.4, and Canvas and Related Products (2394) at 74.2. Among the top 50 manufacturing industries with low productivity (below 104.1), only one recorded an MSD rate increase between 1992–1998, Sanitary Food Containers (2656) with a 26.5 rate increase. All other low-productivity industries registered rate reductions; only one low-productivity industry recorded a rate reduction above  $-70.0$  (Nonwoven Fabrics (2297) with a  $-87.75$  MSD reduction and a 100.9 productivity index). No data patterns

Table 7. Industries with the Lowest Productivity Indices

SIC Code	Industry	Revenue 1997	Percent Change Revenue 92-97	Percent Change Payroll 92-97	Percent Change Employees 92-97	Average Hourly Earnings 1999	Productivity Index 1997 (1987=100)	Percent of Empl. with Ergonomic Controls	MSD Rate 1998	MSD Rate 1992	Percent Change MSD Rate
3-Digit Industries Ranked by Productivity Change											
2410	Logging	13,625,734	0.25	19.26	0.01	13.21	71.9	57	70.96	80.45	-11.80
2760	Manifold Business Forms	7,737,653	4.16	-3.39	-14.71	14.42	78.9	47	111.08	97.03	14.48
2710	Newspapers	41,433,090	22.65	12.39	-3.16	13.58	79.0	47	70.17	97.64	-28.13
3930	Musical Instruments	1,356,651	38.14	33.14	9.79	11.96	83.9	64	75.35	133.08	-43.38
4840	Cable and Other Pay TV Services	45,389,578	64.98	72.85	35.19	14.6	87.6	10	60.53	138.93	-56.43
5410	Grocery Stores	397,254,457	12.68	15.05	5.84	9.35	89.2	7	96.51	168.94	-42.87
2430	Millwork, Plywood & Struc. Members	33,200,977	34.18	31.87	16.36	11.57	89.9	57	110.28	187.28	-41.11
2770	Greeting Cards	5,470,559	30.57	14.22	-3.87		92.2	47	38.35	97.54	-60.68
2260	Textile Finishing, Except Wool	8,700,874	22.74	21.88	5.6	10.81	94.0	53	49.54	77.45	-36.04
2990	Misc. Petroleum and Coal Products	7,373,013	24.39	10.05	-4.81		97.2	43	61.86	114.54	-45.99
2050	Bakery Products	34,485,647	21.03	15.64	5.03	13.01	99.3	69	86.24	175.81	-50.95
2720	Periodicals	29,972,538	35.6	47.10	19.74	15.31	100.1	47	28.16	65.89	-57.26
2270	Carpets and Rugs	11,611,217	18.14	23.17	6.05	10.75	100.3	53	55.68	104.13	-46.53
3480	Ordinance and Accessories, NEC	5,438,140	-20.67	-29.90	-38.17	15.34	100.5	59	73.98	83.39	-11.28
4830	Radio and Television Broadcasting	40,425,210	43.2	41.46	12.61	18.38	101.1	10	13.27	28.08	-52.74
2450	Wood Buildings and Mobile Homes	13,179,370	98.34	91.55	62.93	11.61	101.1	57	100.30	200.96	-50.09
2590	Miscellaneous Furniture and Fixtures	5,345,022	24.99	15.28	-0.05	11.33	102.2	65	72.29	149.65	-51.69
2730	Books	28,504,375	33.33	29.81	8.90	13.5	102.2	47	76.85	87.83	-12.50
2010	Meat Products	111,141,955	18.15	28.66	15.35	9.96	103.2	69	82.99	217.86	-61.91
5530	Auto and Home Supply Stores	35,028,316	22.63	29.06	11.85	10.37	104.2	39	73.41	112.53	-34.76

4-Digit Industries Ranked by Productivity Change

3483	Ammunition, Except for Small Arms, NEC	1,497,045	-51.45	-46.94	-59.12	16.27	53.2	58.44	73.39	-20.37
3678	Electronic Connectors	5,598,906	48.37	29.02	21.43		67.1	75.68	98.56	-23.21
3363	Aluminum Die-Castings	3,791,717	34.58	21.70	2.43		72.4	158.28	192.60	-17.82
2394	Canvas and Related Products	1,537,257	38.81	49.75	30.61		74.2	86.00	138.28	-37.81
2656	Sanitary Food Containers	2,738,109	8.06	13.52	-4.07	13.58	78.0	122.98	97.22	26.50
3083	Laminated Plastics Plate & Sheet	3,207,676	48.02	31.88	7.66		80.8	115.63	167.28	-30.88
3494	Valves and Pipe Fittings, NEC	2,827,380	47.82	25.47	12.79	13.15	81.6	134.30	143.70	-6.54
2431	Millwork	12,013,383	24.5	19.17	7.52	11.58	82.3	139.70	199.00	-29.80
3324	Steel Investment Foundries	2,341,737	34.76	20.13	12.29		84.5	90.44	201.43	-55.10
2435	Hardwood Veneer and Plywood	2,856,487	27.64	34.26	11.21	10.33	85.1	86.77	173.94	-50.11
2047	Dog and Cat Food	8,766,978	24.82	11.71	3.11		86.5	66.85	144.40	-53.70
3448	Prefabricated Metal Buildings	4,199,550	50.59	51.72	27.77		87.1	95.41	167.79	-43.14
3646	Commercial Lighting Fixtures	4,047,437	32.86	21.58	9.58		87.3	76.54	144.23	-46.93
2674	Bags, Uncoated Paper & Multiwall	2,855,811	0.39	6.77	-8.84		87.3	127.43	158.21	-19.46
3568	Power Transmission Equipment, NEC	3,301,091	37.45	14.12	-0.59	14.13	88.2	116.53	126.12	-7.60
2452	Prefabricated Wood Buildings	3,011,624	39.36	35.36	19.38		88.2	154.00	197.31	-21.95
2436	Softwood Veneer and Plywood	5,762,664	7.71	11.99	-6.59	13.91	89.3	52.17	82.60	-36.84
3644	Noncurrent-Carrying Wiring Devices	4,451,186	38.26	21.21	0.28	12.18	89.5	89.93	154.10	-41.64
3652	Prerecorded Records and Tapes	2,245,374	23.33	28.29	5.19		90.7	54.97	65.40	-15.95
2732	Book Printing	5,527,700	18.09	12.59	-2.74	14.04	90.9	79.56	157.71	-49.55

emerged to support the hypothesis that MSD rate reductions contributed in a systematic way to poor productivity. Significantly, a strong negative correlation between larger negative MSD rate changes and productivity was found for this cohort (-.424 at the one percent level).

The distribution of low-productivity industries above and below the MSD rate of 100 was similar to the high-productivity set in manufacturing. Among 50 low-productivity firms, 14 had MSD rates in 1998 above 199; one industry recorded a rate above 200 (Prepared Flour Mixes and Doughs (2045) at 217.37). Hourly earnings for the low-productivity group were slightly below the all-industry average and industry revenue change for this set was below the national average. Sixteen of 50 industries experienced employment declines 1992–1997 in low-productivity manufacturing industries.

Different from the pattern for low-productivity industry groups at the 3-digit level, manufacturing industries with relatively low productivity increases paid higher hourly earnings than the average, \$13.63 versus \$13.43, and had higher than average percent reductions in 1992–1998 MSD rates than the all-industry average, -38.81 versus -33.53. The finding for manufacturing could mean that these industries were operating at relatively high productivity levels throughout the period in absolute terms but not registering increases. Unfortunately ergonomic engineering control implementation rates were not available for industries at this level of disaggregation.

*Industries with Low 1998 MSD Rates and Large 1992–1998 Rate Reductions (3-Digit and 4-Digit Industries Combined).* This category included eleven 3-digit non-manufacturing industry groups; within the 39 industries in manufacturing, eight were at the 3-digit industry group level and 31 at the 4-digit separate industry level. A typical profile for industries in this group included a 1998 MSD rate below 52.0 combined with MSD rate reductions greater than -50 (down to -87.75).

This mixed category was slightly above average in revenue change and payroll change (36.13 versus 34.75 and 27.87 versus 25.85) and above the all-industry average for revenue change minus employment change and payroll change minus employment change (29.61 versus 26.93 and 21.34 versus 18.03). The hourly earnings for the combined group was \$13.75, compared to the all-industry average of \$13.43.

Interestingly, this group had an ergonomic engineering control implementation rate (based on the 19 3-digit industry groups for which data were available) of 40.53, below the all-industry average rate of 48.91. Presumably non-ergonomic process changes, training, changes in work practices or the use of personal protective equipment contributed to rate declines in these industries. This finding appears to support the opinion expressed by several of OSHA's ergonomic experts, that relatively minor workplace changes/interventions can result in significant MSD rate reductions.

For the 50 low-MSD/large-rate-reduction group, productivity data were available for 30. Four of the 30 experienced a decline in productivity 1987–1997 while the remaining 26 industries recorded gains. Seventeen of 26 industries with gains had productivity indices of 130 or above with the largest increase registered in Surgical and Medical Instruments (3841) of 170.1.

Forty-three of the 50 industries experienced revenue gains 1992–1997 and (as noted above) average employee hourly earnings for the group were above the national



average. A high positive correlation was found between hourly earnings and the percent change in MSD rates 1992–1998 (.756 at the one percent level). A positive correlation was also found between the percentage change in MSD rates for this group and payroll per employee in 1997 (.528 at the one percent level). The positive correlation implies that the largest rate changes took place in industries with lower earnings and payrolls per employee.

*Industries with High 1998 MSD Rates and Low 1992–98 Rate Reductions (3-Digit and 4-Digit Industries Combined).* Once again combining data for both 3- and 4- digit industries, those with 1998 MSD rates above 107 (the top quartile for all industries) and MSD 1992–1998 rate reductions of 23 percent or less (worst quartile) produced 57 industries that met the combined filter, 15 at the 3-digit level and 42 separate manufacturing industries. Among the 15 industry groups, four were nonmanufacturing and the remainder, manufacturing.

The highest recorded 1998 MSD rate in the group was 372.65 in Vitreous Plumbing Fixtures (3264); an additional six manufacturing industries had 1998 rates in the 200-300 range. Unlike manufacturing industries, no nonmanufacturing industry group had a 1998 rate above 200. The worst MSD rate change among all industries in this high-rate/low-rate reduction category was recorded in Tire Cord and Fabrics (2296) with a 1992–1998 rate increase of 160.98; the second worst record was in Flat Glass (321) with an increase of 92.25.

Statistical relationships for industries in this group were found between productivity indices and revenue changes (.421 at the one percent level), payroll changes (.316 at the five percent level), revenue change minus payroll change (.381 at the five percent level) and revenue change minus employment change (.424 at the one percent level). Ergonomic engineering control implementation rates were correlated with revenue change minus payroll change (.628 at the five percent level). The percent change in MSD rates 1992–1998 was positively correlated with hourly earnings (.357 at the five percent level) and the MSD rate change was positively related to the 1998 MSD industry rate (.344 at the one percent level) for industries in this category.

Revenue change for these industries was 38.52, above the all-industry average of 34.75 for the 1992–1997 time frame. Payroll change was very similar to the national average; hourly earnings for this high rate/low reduction group were above average at \$13.64 versus \$13.43.

The 15 industry groups in this category had an ergonomic engineering control implementation rate of 55.27, above the average for all 3-digit industries for which the statistic was calculated (48.91). The average productivity index for the 57 industries was 119.26, slightly below the all-industry average of 123.74.

## V. Conclusion

On balance, the evidence supports an association of higher productivity increases with lower MSD rates and greater reductions in MSD rates. Across all industries for which data were available, lower MSD rates were significantly correlated with higher productivity increases. Since both changes in MSDs and in productivity have many varied causes, the effects of efforts specifically intended to reduce MSDs are difficult to isolate

from these data. Nevertheless, in two subsets of industries those effects may be more likely to be discernible: industries with the largest reductions in MSD rates would be more likely to have made changes intended to reduce MSDs, and industries with lower productivity growth may reduce the effects of unrelated productivity gains on MSD/productivity observations. Statistically significant correlations between reductions in MSDs and increases in productivity were found among both of these groups. In addition, among industries with the highest MSD rates in 1992, the extent of implementation of ergonomic controls was significantly correlated with increases in productivity.

### NOTES

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<sup>1</sup>Additional research into the relationship between MSD rate changes and industry productivity change will focus on annual changes between the two with the MSD rate lagged by up to two years. In the decade of the 1990s it would have been useful to identify the effect, if any, of the decline in unemployment on productivity/MSD relationships. It would be important to have local area data and industry geographical concentrations to make sense of this factor. Certain anomalous industry situations uncovered in this research may be explained when employment/unemployment trends are carefully considered. Unfortunately this could not be accomplished within the time constraints for this paper.

<sup>2</sup>The effort was made to use the most disaggregated level of industry data available. Generally, this meant Standard Industrial Classification (SIC) 3-digit or industry-group level for nonmanufacturing and the more discrete 4-digit industry level for manufacturing. In order to track with the coverage of OSHA's proposed rule, analysis did not include agriculture, mining, and construction industries. Where possible industry results for the 3-digit group level were compared and contrasted with those at the 4-digit level of industry detail. For one important characteristic this was not possible: OSHA data on ergonomic engineering control implementation rates were available only for 178 industry groups (3-digit level).

<sup>3</sup>News release USDL 00-115 4/20/2000. Incidence rates represent the number of injuries and illnesses per 10,000 full-time workers and were calculated as:  $(N/EH) \times 20,000,000$  where N=number of cases, EH=total hours worked by all employees during the year, and 20 million is the base for 10,000 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

<sup>4</sup>In this paper, change in revenue minus change in payroll is referred to as change in labor intensity; payroll as a percent of revenue may also be considered an indicator of the level of labor intensity.

### REFERENCE

Oliner, Stephen D. and Daniel E. Sichel. "The Resurgence of Growth in the Late 1990's: Is Information Technology the Story?" Washington, D.C.: Federal Reserve Board, May, 2000.