Wage and productivity stability in U.S. manufacturing plants

Wages and productivity were substantially dispersed across all manufacturing plants in 1987, but the dispersion narrowed modestly from then until 1997; the connection between a plant's level of productivity and its hourly wages weakened over the same period, and many plants exhibited substantial movements within the relative wage and productivity distributions

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Manufacturing plants vary considerably, even within industries. Consequently, the "representative plant" view of the economy, which contends that all plants within an industry face the same technological changes and respond similarly, is likely mistaken.[1] Previous work using the U.S. Census Bureau's Longitudinal Research Database[2] has demonstrated considerable plant-level heterogeneity in productivity and wages, even within narrowly defined industries.[3] Further, the data indicate the presence of "plant effects" that persist over time.[4] The implication is that unobserved, long-term, plant-specific factors—perhaps including the size and nature of a plant's capital endowment, as well as its managerial skills and approach—play a sizable role in determining productivity and wage levels.

The nature of these plant-specific effects is of interest to anyone concerned with microlevel programs aimed at improving the performance of U.S. manufacturers. For example, the Manufacturing Extension Partnership of the National Institute of Standards and Technology aims to boost the performance of the small-firm segment of the U.S. manufacturing economy through assessment, training, and technical assistance. This and similar efforts, however, beg important questions with regard to plants' productivity or wage dynamics—for example, Are large improvements realistic? How often do plants make relatively large movements within their industry? and Over what period of time do they effect such movements?

This article presents evidence on the degree of manufacturing plants' wage and productivity stability during the period from 1987 to 1997. Following on the work of Martin N. Baily, Charles Hulten, and David Campbell, as well as that of Eric J. Bartelsman and Phoebus J. Dhrymes, the article examines the degree of stability both in the total manufacturing sector and, separately, for two-digit Standard Industrial Classification (SIC) industry groups. Baily, Hulten, and Campbell compute plant-level productivity transition matrices for an aggregate of 23 manufacturing industries at the four-digit SIC level for the years 1972 to 1982.[5] Bartelsman and Dhrymes compute plant-level productivity transition matrices for an aggregate of 3 two-digit manufacturing industries for the years 1972 to 1986.[6] The analysis presented in the sections that follow extends this literature by estimating these matrices for all manufacturing plants and computing the matrices for plant-level wages. In addition, several other topics are examined: the degree of heterogeneity in wages and productivity levels within industries, the connection between wages and productivity, and how these measures have changed over time. The central findings to come out of the analysis are as follows: over the period studied, (1) the substantial dispersion of wages and productivity across all manufacturing plants narrowed modestly; (2) the connection between a plant's level of productivity and its hourly wages declined; and (3) although plants' 1987 levels of wages and productivity were significant predictors of their 1997 levels, many plants exhibited substantial movements within the relative wage and productivity distributions.

Theories of plant-level heterogeneity

If the "representative plant" view were correct, then all plants within an industry should have essentially the same productivity and wage levels. Under this model, observed differences would be caused only by measurement error, and there should be no persistence in relative rankings.[7] However, there is much evidence to support the view that plants are indeed heterogeneous. For example, Steven J. Davis and John Haltiwanger find that most of the variation in employment shifts is within-sector variation, indicating that there must be plant-level heterogeneity in labor demand.[8] Several models of plant dynamics have been proposed in the literature. Following is a brief discussion of two such models, along with some of the empirical evidence supporting them.

The plant fixed-effects model. According to this model, each plant has a productivity level that is not associated with the vintage of the plant. This fixed effect may be due to managerial quality or specific locational advantages. Whatever the cause, productivity levels would be expected to persist over time. One variant of the model is the passive learning model of Boyan Jovanovic,[9] according to which plants are "born" with a fixed quality level that they learn over time. Some plants learn that they have a low level of productivity and exit the marketplace. The surviving plants would have strong productivity persistence. The evidence for plant fixed-effect models is mixed. Mark Doms, Timothy Dunne, and Kenneth R. Troske find that the adoption of technology has had an insignificant effect on labor productivity.[10] Rather, plants with high wages, high skill levels, and a productive workforce in 1977 were more likely to adopt various technologies by 1992. The authors give the following possible interpretation of one of their findings: "plants at the forefront of manufacturing technology tend to stay at the forefront."[11] This finding supports the plant fixed-effects model and suggests that productivity levels are indeed persistent. Baily, Hulten, and Campbell argue that their finding of relative stability in productivity also is evidence for the plant fixed-effects model (and argue as well that any nonpersistence found may be due to measurement error and random shocks). However, on the basis of a study of the textile industry, and using a nonparametric approach, Douglas W. Dwyer rejects the fixed-effects model and concludes that the "'fixed' effects actually have a half life of approximately 10 to 20 years."[12]

The active exploration model. Proposed by Richard Ericson and Ariel Pakes in 1995, this model holds that firms can opt to permanently raise their productivity through investment.[13] Dwyer's findings are consistent with the active exploration model.[14] Similarly, Ron Jarmin finds positive effects of manufacturing extension programs on plant productivity, showing that plants can change their levels of productivity.[15]

The results that follow show a fair amount of movement within the wage and productivity distributions. This finding would be consistent with the active exploration model, because the absence of persistence implies the absence of a fixed effect. However, any characterization of the observed movements as demonstrating "instability" remains in the eye of the beholder: Baily, Hulten, and Campbell characterize their results as showing "stability" despite the fact that they find *less* productivity persistence than that found here.[16]

Data

The primary source of data for this article is the Census of Manufactures, which is collected every 5 years on essentially all known establishments. The associated Longitudinal Research Database links plants across the 5-year periods. Data for the analysis are from 1987 and 1997. These years are convenient to study because they come at about the same point in the business cycle.[17] Of course, the 1990-91 recession occurred in the middle of this period. Despite the fact that that recession was relatively mild, the analysis presented herein finds a high birth and death rate for manufacturing plants: fully one-third of the plants in the 1987 Census of Manufactures had relocated or ceased to exist by 1997.[18] Conversely, almost 40 percent of plants listed in the 1997 Census were new since 1987.

Individual manufacturing plants (rather than firms) are the unit of analysis presented here. Excluded are plants that had fewer than 20 employees. Hourly wages are defined as production and nonproduction workers' salaries and wages, divided by production and nonproduction workers' hours.[19] The measure of labor productivity is the plant's average product of labor, or Q/L, where Q denotes the plant's value-added output and L denotes the total hours worked by both production and nonproduction workers.[20] The average product of labor can rise due to an increase in the plant's total factor productivity or an increase in any of its factor-labor ratios (for example, its capital-to-labor ratio).

Tables 1 and 2 present, repectively, the dispersion in hourly wages and the dispersion in productivity by showing the cut points for the 10th percentile, the median, and the 90th percentile for all manufacturing plants and for each two-digit SIC industry.[21] For hourly wages, there is a great deal of heterogeneity, even within industries. Across the 20 two-digit industries, the 90th-percentile wage divided by the 10th-percentile wage averaged 2.51 in 1987 and 2.45 in 1997. Thus, within industries, the highest paying plants paid more than double the lowest paying plants. The decline in this ratio implies a mild reduction in heterogeneity. Across all manufacturing plants, the standard deviation of log hourly wages declined significantly, from 0.402 to 0.399. Nine of the 20 industries exhibited significant declines in the intraindustry standard deviation of log hourly wages, while 6 showed significant increases and 5 had insignificant changes.

This modestly declining dispersion runs counter to previous trends. For example, Linda A. Bell and Richard B. Freeman find that interindustry wage dispersion (measured by the standard deviation of log wages) increased between 1970 and 1987 for both manufacturing and services.[22] Similarly, Davis and Haltiwanger find that, for the period from 1963 to 1986, "between-plant wage dispersion grew for all plant classifications for production workers and for virtually all classifications for nonproduction workers."[23] These authors argue that skill-biased technical change could prompt high-skill workers to sort themselves into higher skill-intensive plants, leading to widening cross-plant wage dispersion. However, Davis and Haltiwanger also find that the pace of increasing dispersion between the 90th and the 10th percentile of the plant-wage distribution slowed between 1982 and 1986. Finally, finding rising wage and productivity dispersion over the period from 1975 to 1992, Dunne and colleagues[24] note that the link between widening wage and productivity dispersions across plants is consistent with the theoretical model of Francesco Caselli,[25] as well as that of Michael Kremer and Eric Maskin.[26] The finding of declining dispersion in the analysis that follows is further surprising, because earnings inequality increased during the 1990s at about the same rate that it did during the 1980s.[27]

There are several ways to reconcile the seemingly contradictory evidence of widening wage inequality at the individual worker level yet declining wage dispersion across plants during the period examined. First, there could be widening inequality of wages within plants.[28] Second, there could be increases in the share of employment at plants that pay both high and low wages relative to the share of employment at plants that pay average wages. Finally, the widening inequality at the individual level could be due to changes in the wage structure outside of manufacturing, as well as to the decline in manufacturing's share of total employment.

The overall compression in wages across plants can be partially explained by an increasing share of plants in industries with less wage dispersion. The weighted average of 1987 industry-level 90–10 ratios with each industry weighted by its number of plants that year is 2.47. Calculating the corresponding number for 1997, with each industry weighted by its number of plants *that* year, yields an average 90–10 ratio of 2.35. However, repeating this analysis with the standard deviation of log wages produces an average of 0.355 under both weighting schemes.

Productivity shows an even greater amount of heterogeneity across plants. (See table 2.) Across all manufacturing industries, the 90th-percentile productivity divided by the 10th-percentile productivity declined from 5.4 to 5.0 and the standard deviation of log productivity declined significantly from 0.685 to 0.657. These results imply declining productivity dispersion. However, within two-digit SIC industries, the story is reversed: twelve of the 20 industries exhibited significant increases in the intraindustry standard deviation of log productivity, while 6 showed significant decreases and 2 had insignificant changes. Thus, productivity is diverging within most two-digit industries.[29]

Relation of hourly wages to productivity

Earlier studies found a positive relation between plant-level wages and productivity. [30] According to Dunne and colleagues, "wages and productivity are strongly positively correlated in both levels and changes."[31] There are theoretical reasons to expect this productivity-wage connection. Davis, Haltiwanger, and Scott Schuh discuss a number of explanations of heterogeneity in productivity and job growth across plants within industries, including "uncertainty that surrounds the development, adoption, distribution, marketing, and regulation of new products

Table 1. Plant-level hourly wage dispersion, 1987 and 1997

Industry	1987 hourly wages					1997 hourly wages					Change, 1987–97		
	10th percentile	Median	90th percentile	90th percentile/ 10th percentile	Standard deviation of log wages	10th percentile	Median	90th percentile	90th percentile/ 10th percentile	Standard deviation of log wages	Change in 90th percentile/ 10th percentile ratio	Change in standard deviation of log wages	Probability of *F*-statistic for change in standard deviation of log wages
All manufacturing	$8.2	$14.3	$23.0	2.80	0.402	$8.8	$14.6	$23.4	2.66	0.399	–0.15	–0.003	0.003
SIC 20: Food and kindred products	8.1	13.7	21.1	2.60	.297	8.0	13.1	20.5	2.56	.335	–.04	.038	.007
SIC 21: Tobacco manufactures	(1)	11.7	(1)	3.96	.404	(1)	15.4	(1)	4.38	.399	.42	–.005	.417
SIC 22: Textile mill products	7.3	11.0	15.7	2.15	.315	7.9	11.2	17.0	2.15	.303	.00	–.012	.000
SIC 23: Apparel and other textile products	6.2	8.8	15.2	2.45	.377	6.1	8.5	14.8	2.43	.311	–.03	–.066	.000
SIC 24: Lumber and wood products	7.5	12.2	18.9	2.52	.393	8.2	11.9	17.4	2.12	.350	–.40	–.043	.000
SIC 25: Furniture and fixtures	7.3	11.5	18.0	2.47	.367	8.5	12.4	18.6	2.19	.371	–.28	.004	.000
SIC 26: Paper and allied products	9.9	15.7	22.6	2.28	.347	10.6	15.7	22.8	2.15	.333	–.13	–.014	.004
SIC 27: Printing and publishing	9.4	16.0	26.0	2.77	.340	9.9	15.8	26.3	2.66	.319	–.11	–.020	.066
SIC 28: Chemicals and allied products	11.2	19.5	28.2	2.52	.375	11.4	18.8	28.0	2.46	.392	–.06	.017	.223
SIC 29: Petroleum and coal products	12.7	20.1	29.5	2.32	.348	13.0	19.4	29.5	2.27	.329	–.05	–.019	.237
SIC 30: Rubber and miscellaneous plastics products	8.6	13.2	19.4	2.26	.316	9.1	13.5	20.6	2.26	.331	.01	.015	.000
SIC 31: Leather and leather products	6.8	9.6	15.1	2.22	.506	6.8	9.5	15.4	2.26	.519	.04	.012	.398
SIC 32: Stone, clay, glass, and concrete products	9.2	14.9	22.0	2.39	.354	9.7	14.6	21.7	2.24	.345	–.15	–.009	.001
SIC 33: Primary metal industries	10.4	15.7	22.6	2.17	.388	10.7	15.7	22.8	2.13	.404	–.04	.016	.009
SIC 34: Fabricated metal products	9.5	15.0	22.0	2.32	.380	10.3	15.0	22.1	2.15	.419	–.17	.039	.000
SIC 35: Industrial machinery and equipment	10.8	17.2	25.4	2.35	.371	11.5	17.2	26.1	2.27	.361	–.08	–.010	.001
SIC 36: Electrical and electronic equipment	8.9	14.7	23.4	2.63	.326	9.5	15.1	26.0	2.74	.323	.11	–.003	.000
SIC 37: Transportation equipment	9.4	15.0	23.6	2.51	.331	9.9	15.2	23.9	2.41	.317	–.10	–.013	.253
SIC 38: Instruments and related products	9.8	16.9	26.0	2.65	.363	10.9	18.4	29.6	2.72	.360	.06	–.004	.004
SIC 39: Miscellaneous manufacturing industries	7.6	12.6	20.4	2.68	.378	8.6	13.2	20.3	2.36	.388	–.32	.010	.000

[1] Disclosure concerns prevented the release of the 10th- and 90th-percentile values for tobacco manufactures.

NOTE: All 1987 values are converted into 1997 dollars with the use of the Consumer Price Index.

SOURCE: 1987 and 1997 Census of Manufactures (excluding plants with fewer than 20 employees).

Table 2. Plant-level productivity dispersion, 1987 and 1997

Industry	1987 productivity					1997 productivity				Change, 1987–97			
	10th percentile	Median	90th percentile	90th percentile/10th percentile	Standard deviation of log productivity	10th percentile	Median	90th percentile	90th percentile/10th percentile	Standard deviation of log productivity	Change in 90th percentile/10th percentile ratio	Change in standard deviation of log productivity	Probability of *F*-statistic for change in standard deviation of log productivity
All manufacturing	11.2	26.8	60.3	5.4	0.685	14.6	32.2	73.5	5.0	0.657	–0.3	–0.028	0.000
SIC 20: Food and kindred products	13.1	34.1	96.7	7.4	.785	15.3	39.0	115.0	7.5	.778	.1	–.007	.190
SIC 21: Tobacco manufactures	([1])	40.2	([1])	27.2	1.217	([1])	79.9	([1])	21.4	1.045	–5.8	–.172	.090
SIC 22: Textile mill products	9.1	17.3	37.5	4.1	.569	11.1	24.0	50.1	4.5	.608	.4	.039	.000
SIC 23: Apparel and other textile products	6.6	12.3	32.7	5.0	.629	7.9	14.6	38.8	4.9	.647	.0	.018	.004
SIC 24: Lumber and wood products	12.5	25.9	55.3	4.4	.602	13.0	24.5	48.0	3.7	.538	–.7	–.064	.000
SIC 25: Furniture and fixtures	11.8	21.2	39.5	3.3	.493	13.7	24.3	48.9	3.6	.532	.2	.040	.000
SIC 26: Paper and allied products	15.9	30.3	61.7	3.9	.563	19.7	37.0	76.7	3.9	.552	.0	–.012	.086
SIC 27: Printing and publishing	16.6	32.0	67.8	4.1	.577	18.4	33.4	68.6	3.7	.544	–.4	–.033	.000
SIC 28: Chemicals and allied products	24.6	59.7	164.8	6.7	.741	25.4	63.8	176.8	7.0	.756	.3	.015	.075
SIC 29: Petroleum and coal products	21.7	52.8	147.6	6.8	.744	24.7	77.1	215.8	8.7	.872	1.9	.128	.000
SIC 30: Rubber and miscellaneous plastics products	12.8	24.5	48.3	3.8	.541	16.5	31.2	65.7	4.0	.561	.2	.020	.001
SIC 31: Leather and leather products	9.3	17.4	35.8	3.8	.559	10.4	20.0	48.2	4.6	.623	.8	.064	.002
SIC 32: Stone, clay, glass, and concrete products	14.1	30.0	59.8	4.2	.585	17.1	35.9	75.5	4.4	.599	.2	.014	.047
SIC 33: Primary metal industries	14.8	28.6	59.2	4.0	.573	18.3	36.2	78.1	4.3	.598	.3	.025	.005
SIC 34: Fabricated metal products	13.9	26.9	49.4	3.6	.526	17.1	31.3	59.9	3.5	.521	–.1	–.004	.159
SIC 35: Industrial machinery and equipment	12.6	28.3	52.8	4.2	.618	18.3	34.4	67.3	3.7	.545	–.5	–.073	.000
SIC 36: Electrical and electronic equipment	8.2	21.9	48.8	6.0	.734	16.3	34.3	76.4	4.7	.633	–1.3	– .100	.000

See footnotes at end of table.

Table 2. Continued—Plant-level productivity dispersion, 1987 and 1997													
Industry	1987 productivity					1997 productivity					Change, 1987–97		
	10th percentile	Median	90th percentile	90th percentile/ 10th percentile	Standard deviation of log productivity	10th percentile	Median	90th percentile	90th percentile/ 10th percentile	Standard deviation of log productivity	Change in 90th percentile/ 10th percentile ratio	Change in standard deviation of log productivity	Probability of *F*-statistic for change in standard deviation of log productivity
SIC 37: Transportation equipment	12.8	26.4	51.5	4.0	.572	15.9	33.9	69.9	4.4	.619	.4	.047	.000
SIC 38: Industrial machinery and related products ..	14.4	31.6	60.7	4.2	.579	19.3	42.1	85.1	4.4	.598	.2	.019	.018
SIC 39: Micellaneous manufacturing industries	12.0	23.6	45.7	3.8	.547	14.4	29.0	56.6	3.9	.566	.1	.018	.022

[1] Disclosure concerns prevented the release of the 10th- and 90th-percentile values for tobacco manufactures.

NOTE: All 1987 values are converted into 1997 dollars with the use of the NBER-CES Manufacturing Industry Database deflator for shipments at the four-digit SIC industry level.

SOURCE: 1987 and 1997 Census of Manufactures (excluding plants with fewer than 20 employees).

and production techniques, [which] encourages firms to experiment with different technologies, goods, and production facilities"; "differences in entrepreneurial and managerial ability"; variation in local input costs, which "influence the size and type of the labor force and capital stock"; and "slow diffusion of information about technology, distribution channels, marketing strategies, and consumer tastes."[32] This heterogeneity, particularly as it relates to the types of technology used, is likely to affect the characteristics of plants' workforces and thus contribute to wage heterogeneity.

Daron Acemoglu highlights various empirical and theoretical reasons for such connections, citing Ann P. Bartel and Frank R. Lichtenberg, who "show that firms introducing new technologies hire more skilled workers," as well as Marcus Mobius, and David Thesmar and Mathias Thoenig, who "show how the size of the product market, the degree of competitive pressure and instability facing firms may affect the way firms choose to organize, and therefore demand for skills."[33] Another explanation for a connection between wages and measured productivity could be rent sharing: a plant might have market power and high prices, resulting in greater value added per worker, and workers might be able to capture some of the rents from this market power in terms of higher wages. Finally, Judith K. Hellerstein, David Neumark, and Kenneth R. Troske find that some plant-level worker characteristics (for example, sex, race, age, and education) that are shown to be associated with higher levels of productivity also are associated with higher plant-level wages.[34]

The analysis presented in this article tests the strength of the relation between wages and productivity (and its stability) for manufacturing generally and by industry. Table 3 splits each manufacturing plant that existed in 1987 into wage and productivity quintiles. The cells with boldface entries indicate plants that were in the same wage and productivity quintile in 1987 and are situated along the diagonal of the table. Excluding plants with missing wage or productivity data, 41 percent of the plants are along this diagonal and 39 percent of the plants are one cell away from the diagonal. Being more than one cell off the diagonal represents a substantial difference between the plant's wages and its productivity. Twenty percent of all manufacturing plants were more than one cell away from the diagonal (shaded in gray). Thus, although pay and productivity are positively linked, there is a great deal of "wiggle room": the highest paying employers and the most productive plants are not one and the same. Indeed, being in the top quintile of plants in productivity in 1987 implied only a 49-percent chance of being in the top quin-

Table 3. Relation between hourly wages and productivity at the plant level, all manufacturing plants, 1987

[In percent]

1987 wage quintile	1987 productivity quintile					Missing data
	< $15.7	$15.7–$23.0	$23.0–$30.8	$30.8–$43.8	> $43.8	
< $10.0	**11.3**	4.9	1.8	1.0	.6	0.4
$10.0–$12.9	4.4	**6.8**	4.3	2.4	1.5	.3
$12.9–$15.7	1.8	4.4	**6.0**	4.2	2.9	.3
$15.7–$19.6	1.1	2.4	5.1	**6.3**	5.0	.4
> $19.6	.9	.9	2.2	5.6	**9.5**	.5

NOTE: Boldface indicates entry on diagonal. Shading indicates cells that are more than one cell away from diagonal.

SOURCE: 1987 Census of Manufactures (excluding plants with fewer than 20 employees).

tile in wages. Further, the combination of being in the top quintile in productivity and in the bottom two quintiles in wages is hardly rare: eleven percent of the most productive plants were in the bottom two quintiles of their wage distribution. Likewise, 9 percent of those in the top quintile in wages were in the bottom two quintiles of the productivity distribution.

Table 4 repeats the preceding analysis for 1997. That year, 41 percent of the plants were situated along the diagonal, 38 percent were one cell away from the diagonal, and 22 percent were more than one cell away from the diagonal. The increase over 1987 in the number of plants more than one cell off the diagonal indicates that the link between productivity and wages at the plant level weakened somewhat. To assess the strength of the wage-productivity relation more directly, table 5 shows the correlation of plant-level wages and productivity for all manufacturing and, separately, by two-digit industry. For all manufacturing, the correlation between wages and productivity loosened significantly (albeit modestly), falling from 0.458 to 0.449. This weakening connection appeared broadly across industries: thirteen of the 20 industries exhibited a significant decline in the correlation of plant-level wages and productivity, while 3 industries showed a significant increase and 4 had insignificant changes.

Wage and productivity stability

Over the 1987–97 period, instability in plants' relative wage positions was common. Table 6 splits manufacturing plants into 1987 and 1997 wage quintiles. Note that some plants that existed in 1997 were not yet in business (or had fewer than 20 employees or were not in manufacturing) in 1987. These plants are listed in the last row of the table and were more likely to be in the lower wage quintiles when they entered the marketplace in 1997. Likewise, some plants that existed in 1987 were out of business (or had fewer than 20 employees or were not in manufacturing) by 1997. These plants are listed in the last column of the table. The plants that died tended to be plants that paid lower wages in 1987. Plants that offered wages within the top quintile in 1987 were a bit more likely to disappear within 10 years (39 percent) than they were to remain within the top quintile (32 percent). In contrast, more than half of the plants whose wages were within the bottom quintile in 1987 did not exist by 1997.

The cells with boldface entries indicate plants that were in the same wage quintile in both 1987 and 1997. Among the plants with valid wage data for both years, 39 percent are along the diagonal and another 39 percent are one cell away from the diagonal. The remaining 22 percent (that is, those which are more than one cell away from the diagonal) exhibited a substantial change in the plant's relative wages. Being in the top quintile of wages in 1987 implied a 53-percent chance of being in the top quintile of wages in 1997 and an 11-percent chance of being in either of the bottom two quintiles in 1997.[35]

Although the analysis does not consider any transition matrix weighted by the plants' numbers of employees, it is possible to infer whether the results would have been substantially different with such a matrix. It is well known that larger plants pay higher wages.[36] Thus, if the matrix were weighted by the plants' number of employees, it would have more weight placed on plants shown in the bottom right-hand corner of table 6. A comparison of the nine cells in the bottom right-hand corner of that table with the nine cells in the top left-hand corner reveals sim-

Table 4. Relation between hourly wages and productivity at the plant level, all manufacturing plants, 1997

[In percent]

1997 wage quintile	1997 productivity quintile					Missing data
	< $20.1	$20.1–$28.4	$28.4–$37.0	$37.0–$52.6	> $52.6	
< $10.7	**11.4**	4.3	1.7	1.2	1.0	0.5
$10.7–$13.4	4.1	**6.7**	4.3	2.7	1.8	.3
$13.4–$15.9	1.9	4.8	**6.0**	4.0	2.7	.3
$15.9–$19.7	1.3	2.6	5.3	**5.9**	4.4	.3
> $19.7	.7	1.0	2.3	5.7	**9.5**	.5
Missing data	.0	.0	.0	.0	.0	.8

NOTE: Boldface indicates entry on diagonal. Shading indicates cells that are more than one cell away from diagonal.

SOURCE: 1997 Census of Manufactures (excluding plants with fewer than 20 employees).

Table 5. Correlation of hourly wages with productivity at the plant level and across industries, 1987 and 1997

Industry	1987	1997	Difference
All manufacturing	0.458	0.449	[1]–0.01
SIC 20: Food and kindred products	.441	.417	[1]–.024
SIC 21: Tobacco manufactures	.522	.560	.038
SIC 22: Textile mill products	.557	.442	[1]–.114
SIC 23: Apparel and other textile products	.629	.555	[1]–.074
SIC 24: Lumber and wood products	.537	.427	[1]–.110
SIC 25: Furniture and fixtures	.559	.494	[1]–.065
SIC 26: Paper and allied products	.531	.445	[1]–.086
SIC 27: Printing and publishing	.550	.581	[1].031
SIC 28: Chemicals and allied products	.343	.312	[2]–.031
SIC 29: Petroleum and coal products	.319	.340	.020
SIC 30: Rubber and miscellaneous plastics products	.507	.479	[1]–.028
SIC 31: Leather and leather products	.516	.451	[2]–.065
SIC 32: Stone, clay, glass, and concrete products	.516	.460	[1]–.056
SIC 33: Primary metal industries	.455	.451	–.003
SIC 34: Fabricated metal products	.495	.469	[1]–.026
SIC 35: Industrial machinery and equipment	.404	.486	[1].083
SIC 36: Electrical and electronic equipment	.405	.527	[1].122
SIC 37: Transportation equipment	.517	.439	[1]–.078
SIC 38: Instruments and related products	.507	.478	[2]–.03
SIC 39: Miscellaneous manufacturing industries	.581	.490	[1]–.091

[1] Significant at the p = .01 level; two-tailed test.

[2] Significant at the p = .10 level; two-tailed test.

SOURCE: 1987 and 1997 Census of Manufactures (excluding plants with fewer than 20 employees).

ilar shares along the diagonal and nearly identical shares two cells off the diagonal. Hence, the degree of instability shown in table 6 is not simply a product of using an unweighted analysis.[37]

Table 7 repeats this analysis for productivity. As with the wage data, the plants that died after 1987 tended to have lower levels of productivity in 1987, and those born after 1987 tended to have lower productivity levels in 1997. Baily, Hulten, and Campbell found that 52 percent of the plants that died by 1977 came from the bottom two quintiles of the 1972 total factor productivity distribution,[38] and this finding is echoed here: forty-eight percent of the plants that died by 1997 were in the bottom two quintiles of the 1987 labor productivity distribution. By contrast, 33 percent of the plants that failed to survive came from the upper two quintiles. Many studies find that low productivity is a strong predictor of plant death.[39] Although the results presented here are consistent with this finding, a remarkable number of high-productivity plants also fail to survive (a point stressed by Baily, Hulten, and Campbell as well[40]): plants with top-quintile productivity in 1987 are a bit more likely to disappear within 10 years (38 percent) than they are to remain within the top quintile (31 percent).[41] (In contrast, more than half of the plants in the bottom productivity quintile in 1987 fail to exist by 1997.)

Restricting the analysis to those plants with valid productivity data in both years permits the overall stability

Table 6. Stability of hourly wages at the plant level, all manufacturing plants, 1987 and 1997

[In percent]

1987 wage quintile	1997 wage quintile						Dead, fewer than 20 employees, or not in manufacturing
	< $10.7	$10.7–$13.4	$13.4–$15.9	$15.9–$19.7	> $19.7	Missing data	
< $10.0	**2.6**	1.1	0.6	0.4	.2	0.0	8.4
$10.0–$12.9	1.9	**2.2**	1.4	.8	.5	.0	6.3
$12.9–$15.7	.9	2.0	**2.2**	1.6	.9	.0	5.6
$15.7–$19.6	.5	1.2	2.0	**2.7**	1.9	.0	5.3
> $19.6	.2	.5	1.0	2.1	**4.2**	.1	5.1
Missing data	.0	.0	.0	.0	.1	.1	.3
Not born, fewer than 20 employees, or not in manufacturing	7.8	6.6	6.5	6.1	5.8	.4	...

NOTE: Boldface indicates entry on diagonal. Shading indicates cells that are more than one cell away from diagonal.

SOURCE: 1987 Census of Manufactures (excluding plants with fewer than 20 employees).

Table 7. Stability of productivity at the plant level, all manufacturing plants, 1987 and 1997

[In percent]

1987 productivity quintile	1997 productivity quintile						Dead, fewer than 20 employees, or not in manufacturing
	< $20.1	$20.1–$28.4	$28.4–$37.0	$37.0–$52.6	> $52.6	Missing data	
< $15.7	**2.0**	1.1	0.8	0.6	0.4	0.1	8
$15.7–$23.0	1.6	**1.9**	1.4	1.0	.6	.1	6.5
$23.0–$30.8	1.1	1.8	**1.9**	1.6	.9	.1	5.6
$30.8–$43.8	8	1.3	1.8	**2.2**	1.6	.1	5.1
> $43.8	.5	.7	1.0	1.8	**3.9**	.3	4.8
Missing data	1	.1	.1	.1	.2	.1	1.0
Not born, fewer than 20 employees, or not in manufacturing	7.3	6.6	6.4	6.2	5.6	1.0	...

NOTE: Boldface indicates entry on diagonal. Shading indicates cells that are more than one cell away from diagonal.

SOURCE: 1987 Census of Manufactures (excluding plants with fewer than 20 employees).

of the productivity of plants that remain in operation to be evaluated. Among these plants, 35 percent are along the diagonal of table 7, 37 percent are one cell away from the diagonal, and 28 percent are more than one cell away from the diagonal.[42] Baily, Hulten, and Campbell computed a transition matrix for total factor productivity for the period from 1972 to 1982.[43] Their analysis showed 30 percent of the plants along the diagonal, 35 percent one cell away from the diagonal, and another 35 percent more than one cell away from the diagonal. These results suggest that plant-level productivity has become more stable over time. Indeed, the percentages appear to reverse a trend: looking at the successive 5-year periods 1972–77, 1977–82, and 1982–87, the same authors found declining persistence at the top of the distribution.[44]

It is useful to consider the differences in the methods presented here from those of Baily, Hulten, and Campbell, to search for possible explanations of the greater productivity persistence found in this article. First, the industries included in their analysis were restricted to those in which most plants produced a single product. As a result, that analysis should show less productivity dispersion in individual years and, in all likelihood, more productivity persistence, than is found in the analysis presented here. Thus, the inclusion of all manufacturing industries in this article should have produced estimates of *less* persistence, not more. Second, Baily, Hulten, and Campbell use only plants that are in the smaller sample in the Annual Survey of Manufactures, rather than utilizing the entire Census of Manufactures. Because the plants in the Annual Survey are typically larger, and because larger plants have more productivity persistence (see note 42), it might be reasonable to expect more observed persistence in productivity in their sample than in the one used here. Finally, Baily, Hulten, and Campbell measure productivity in terms of total factor productivity, rather than labor productivity. However, in order for labor productivity to become more persistent while persistence in total factor productivity was continuing to decline, a *much* higher degree of stability in the distribution of the capital-labor ratios or the ratios of other factors to labor (or both) would be required. Consequently, it is not likely that differences in sampling or methodology have produced this article's finding of increased productivity persistence. Rather, the results would appear to show a true increase in persistence.[45]

Table 8 shows the correlations between 1987 and 1997 wages and between 1987 and 1997 productivity for all industries and, separately, by two-digit SIC industry. The correlation between 1987 and 1997 wages across all manufacturing plants with valid data in both years was 0.464. Eighteen of the 20 two-digit industries had a smaller correlation in wages across the 2 years. (The median was 0.402.) The distribution of intraindustry wage correlations is relatively tight, with an interquartile range of 0.37 to 0.42. Industrial machinery and equipment (SIC 35) had the lowest degree of wage stability, with a correlation of 0.335.

The correlation between 1987 and 1997 productivity across all manufacturing plants with valid data in both years was 0.547. Seventeen of the 20 two-digit industries had a smaller correlation in productivity across the 2 years. (The median was 0.423.) A wider range of intraindustry correlations was found for productivity than for wages, which had an interquartile range in productivity correlations of 0.36 to 0.52. Leather and leather products (SIC 31) had the lowest degree of productivity stability, with a correlation of 0.256. This finding is consistent with that of Bartelsman and Dhrymes, who report that transition probabilities for total factor productivity varied widely for the 3 two-digit industries they studied (SIC's 35, 36, and 38).[46]

DATA FROM THE 1987 AND 1997 CENSUS OF MANUFACTURES indicate that there is a great deal of plant-level heterogeneity in wages and productivity, and moderate instability of their relative positions within wage and productivity distributions. In addition, although plant-level wages and productivity were strongly correlated, the connection weakened between 1987 and 1997 and heterogeneity declined modestly for both wages and productiv-

Table 8. Stability of hourly wages and productivity at the plant level, across manufacturing industries, 1987 and 1997

Industry	Correlation of 1987 and 1997 hourly wages	Correlation of 1987 and 1997 productivity
All manufacturing	0.464	0.547
SIC 20: Food and kindred products	.390	.544
SIC 21: Tobacco manufactures	.742	.875
SIC 22: Textile mill products	.401	.313
SIC 23: Apparel and other textile products	.517	.376
SIC 24: Lumber and wood products	.363	.339
SIC 25: Furniture and fixtures	.442	.382
SIC 26: Paper and allied products	.446	.557
SIC 27: Printing and publishing	.409	.458
SIC 28: Chemicals and allied products	.374	.520
SIC 29: Petroleum and coal products	.366	.444
SIC 30: Rubber and miscellaneous plastics products	.370	.436
SIC 31: Leather and leather products	.353	.256
SIC 32: Stone, clay, glass, and concrete products	.375	.516
SIC 33: Primary metal industries	.420	.428
SIC 34: Fabricated metal products	.351	.359
SIC 35: Industrial machinery and equipment	.335	.288
SIC 36: Electrical and electronic equipment	.404	.260
SIC 37: Transportation equipment	.446	.579
SIC 38: Instruments and related products	.409	.417
SIC 39: Miscellaneous manufacturing industries	.402	.380

NOTE: Includes only plants with 20 or more employees and with valid data in both 1987 and 1997. Plants are placed into two-digit SIC industries on the basis of their 1987 SIC designation.

SOURCE: 1987 and 1997 Census of Manufactures (excluding plants with fewer than 20 employees).

ity over the period. These declines in the heterogeneity of wages and productivity are contrary to previous trends found in the literature. By contrast, consistent with the literature, the data indicate a high birth and death rate for manufacturing plants. Neither wages nor productivity were very stable in those plants which survived. Indeed, many surviving plants exhibited substantial movements in their relative ranking within the wage and productivity distributions: twenty-two percent of plants increased or decreased by more than one quintile within the wage distribution, and 28 percent did so within the productivity distribution. Thus, improvements or declines in the comparative positions of individual plants are clearly possible and often occur during relatively short periods of time.

The degree of heterogeneity and instability at the plant level has implications as regards the training and placement of workers. Many factory jobs have moved out of the types of plants that tend to pay more (larger, more urban, unionized, northern plants) and toward the types of plants that pay less (smaller, more rural, more southern, nonunion plants). Given this trend, it is no longer obvious that new manufacturing jobs offer better long-term prospects, on average, for lower skilled workers than do new jobs in services. Nonetheless, there exist pockets of high-productivity, high-wage establishments. For those who aim at improving the relative productivity ranking of individual plants, these findings give promise. However, for workers, this instability weakens their prospects of good, long-lasting employment. On the positive side, heterogeneity in wages across plants within industries has narrowed modestly, a trend that may have reduced somewhat the burden paid by workers for plant closings, as some workers may have been more able to switch between plants without great changes in their pay. □

Notes

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[1] Eric J. Bartelsman and Phoebus J. Dhrymes, "Productivity Dynamics: U.S. Manufacturing Plants, 1972–1986," *Journal of Productivity Analysis*, January 1998, pp. 5–34.

[2] The Longitudinal Research Database contains data on manufacturing establishments collected in 1963 and every 5 years since 1967. Further discussion of these data and their development can be found in George Pascoe and Robert McGuckin, "The Longitudinal Research Database (LRD): Status and Research Possibilities," Working Paper 88–2 (U.S. Census Bureau, Center for Economic Studies, July 1, 1988).

[3] Lucia Foster, John Haltiwanger, and C. J. Krizan, "Aggregate Productivity Growth: Lessons from Microeconomic Evidence," NBER Working Paper No. 6803, November 1998.

[4] Martin N. Baily, Charles Hulten, and David Campbell, "Productivity Dynamics in Manufacturing Plants," *Brookings Papers on Economic Activity: Microeconomics* (Washington, DC, Brookings Institution, 1992), pp. 187–249; and Douglas W. Dwyer, "Whittling Away at Productivity Dispersion," CES Working Papers, CES-WP-95–5 (U.S. Census Bureau, Office of the Chief Economist, 1995).

[5] Baily, Hulten, and Campbell, "Productivity Dynamics."

[6] Bartelsman and Dhrymes, "Productivity Dynamics."

[7] Baily, Hulten, and Campbell, "Productivity Dynamics."

[8] Steven J. Davis and John Haltiwanger, "Gross Job Creation, Gross Job Destruction, and Employment Reallocation," *Quarterly Journal of Economics*, August 1992, pp. 819–63.

[9] See Boyan Jovanovic, "Selection and Evolution of Industry," *Econometrica*, May 1982, pp. 649-70.

[10] Mark Doms, Timothy Dunne, and Kenneth R. Troske, "Workers, Wages, and Technology," *Quarterly Journal of Economics,* February 1997, pp. 253–90.

[11] *Ibid.*, p. 282.

[12] Douglas W. Dwyer, "Are Fixed Effects Fixed? Persistence in Plant Level Productivity," CES Working Papers, CES-WP-96–3 (U.S. Census Bureau, Office of the Chief Economist, 1996).

[13] Richard Ericson and Ariel Pakes, "Markov-Perfect Industry Dynamics: A Framework for Empirical Work," *Review of Economic Studies,* January 1995, pp. 53–82.

[14] Dwyer, "Are Fixed Effects Fixed?"

[15] Ron Jarmin, "Manufacturing Extension and Productivity Dynamics," CES Working Papers, CES-WP-98–8 (U.S. Census Bureau, Office of the Chief Economist, June 1998).

[16] Baily, Hulten, and Campbell, "Productivity Dynamics."

[17] The expansion of the 1980s ran from November 1982 to July 1990, while that of the 1990s ran from March 1991 to March 2001 (National Bureau of Economic Research, on the Internet at **www.nber.org/cycles.html** (visited June 19, 2003). The year 1987 was the 5th year of the 8-year 1980s expansion, while 1997 was the 7th year of the 10-year 1990s expansion.

[18] The high rate of death is not a new finding. Andrew B. Bernard and J. Bradford Jensen, "The Deaths of Manufacturing Plants," NBER Working Paper No. 9026, June 2002, note that, "Over a typical five year period, more than 32% of U.S. manufacturing plants shut down, accounting for more than 22% of total job destruction" (p. 2). Thus, if anything, the death rate found in the analysis that follows is lower than in previous periods, as it is computed over a 10-year time span. Also, note that some of the births and deaths found would be more properly classified as relocations. That is, some involve short-distance moves to different facilities within the same local labor market. Census data do not distinguish these local relocations from truly new capacity or from shuttered plants.

[19] Hours for nonproduction workers are imputed with the methodology presented in Timothy Dunne, Lucia Foster, John Haltiwanger, and Kenneth Troske, "Wage and Productivity Dispersion in United States Manufacturing: The Role of Computer Investment," *Journal of Labor Economics*, April 2004, pp. 397–429. 1987 wages are inflated into 1997 dollars by means of the Consumer Price Index. Following Baily, Hulten, and Campbell, "Productivity Dynamics," hourly wages (productivity) are set to "missing" if the logarithm of the plants' wage (log wage) or the logarithm of its productivity (log productivity) is outside the range given by the four-digit SIC median value of log wage (log productivity), plus or minus 2. To give a perspective on this range, median wages for all manufacturing in 1997 were $14.60. Thus, given this median value, wages below $1.97 (that is, exp(ln($14.60) – 2)) and wages above $107.88 (that is, exp(ln($14.60) + 2)) would be set to "missing." This method of trimming the data appears quite conservative. Both Kenneth R. Troske, "The Worker-Establishment Characteristics Database," CES Working Papers, CES 95–10 (U.S. Census Bureau, Office of the Chief Economist, June 1995, and Doms, Dunne, and Troske, "Workers, Wages, and Technology," match workers in the Employment Characteristic Database to plants in the Longitudinal Research Database and find similar average worker-reported earnings and plant-level earnings in their samples, thus bolstering confidence in the quality of the plant-level wage data presented in the upcoming analysis. (The findings in the aforementioned works are discussed in more detail in note 35.)

[20] 1987 value added is inflated into 1997 dollars with the NBER-CES Manufacturing Industry Database deflator for shipments at the four-digit SIC industry level.

[21] Due to disclosure concerns, cut points were derived by averaging the hourly wages (or productivity) of plants in the four centiles surrounding the cut point in question. For example, for the 10th-percentile cut point, plants in the 9th through 12th centiles were averaged. The values were then rounded to the nearest dime.

[22] Linda A. Bell and Richard B. Freeman, "The Causes of Increasing Interindustry Wage Dispersion in the United States," *Industrial and Labor Relations Review*, January 1991, pp. 275–87. Following Bell and Freeman's methodology, the analysis presented here finds that the standard deviation of log hourly wages (weighted by the number of employees) across four-digit SIC industries is 0.263 for 1987 and 0.261 for 1997, an insignificant decline in dispersion. Across all manufacturing, roughly 28 percent of the variation in log plant-wages is explained by differences across four-digit SIC industries in both 1987 and 1997, while about 72 percent of the variation in log plant-wages is explained by differences within four-digit industries.

[23] Steven J. Davis and John Haltiwanger, "Wage Dispersion between and within U.S. Manufacturing Plants, 1963–86," *Brookings Papers on Economic Activity: Microeconomics* (Washington, DC, Brookings Institution, 1991) pp. 115–80; quote from p. 151.

[24] Dunne, Foster, Haltiwanger, and Troske, "Wage and Productivity Dispersion."

[25] Francesco Caselli, "Technological Revolutions," *American Economic Review*, March 1999, pp. 78–102.

[26] Michael Kremer and Eric Maskin, "Wage Inequality and Segregation by Skill," NBER Working Paper No. 5718, August 1996.

[27] Rebecca M. Blank and Matthew D. Shapiro, "Labor and the Sustainability of Output and Productivity Growth," in Alan B. Krueger and Robert M. Solow, eds., *The Roaring Nineties: Can Full Employment Be Sustained*? (New York, Russell Sage Foundation, Century Foundation Press, 2001), pp. 309–66.

[28] Steven J. Davis and John Haltiwanger, "Employer Size and the Wage Structure in U.S. Manufacturing," NBER Working Paper No. 5393, December 1995, find that 41 percent of total wage variance is accounted for within plants. However, there is no substantial evidence in the literature for increased wage dispersion within plants. For example, Dunne, Foster, Haltiwanger, and Troske, "Wage and Productivity Dispersion," find no trend in within-plant wage dispersion for production workers and a decline in within-plant wage dispersion for production workers during the period from 1977 to 1992.

[29] Across all manufacturing, roughly 35 percent of the variation in log productivity was explained by differences across four-digit SIC industries in 1987, while 65 percent remained within four-digit industries. In 1997, the share of the variation in log productivity explained by differences across four-digit SIC industries fell to 26.5 percent. Changes in the industrial mix explain only part of the overall decline in productivity dispersion: the weighted-average 90–10 ratio for 1987 productivity declines from 4.61 (with the 1987 plant distribution used as weights) to 4.56 (with the 1997 plant distribution used as weights), and the standard deviation of log productivity declines from 0.611 to 0.607.

[30] See, for example, Dwyer, "Whittling Away," for a discussion of the textile industry.

[31] Dunne, Foster, Haltiwanger, and Troske, "Wage and Productivity Dispersion in U.S. Manufacturing," p. 399.

[32] Steven J. Davis, John C. Haltiwanger, and Scott Schuh, *Job Creation and Destruction* (Cambridge, MA, MIT Press, 1996), pp. 158, 159.

[33] Daron Acemoglu, "Technical Change, Inequality, and the Labor Market," *Journal of Economic Literature*, March 2002, pp. 7–72; quoted material, pp. 34, 43. The works cited in Acemoglu are Ann P. Bartel and Frank R. Lichtenberg, "The Comparative Advantage of Educated Workers in Implementing New Technology," *Review of Economics and Statistics*, February 1987, pp. 1–11; Marcus Mobius, "The Evolution of Work," mimeo (Cambridge, MA, MIT, 2000); and David Thesmar and Mathias Thoenig, "Creative Destruction and Firm Organization Choice," *Quarterly Journal of Economics*, November 2000, pp. 1201–37.

[34] Judith K. Hellerstein, David Neumark, and Kenneth R. Troske,

"Wages, Productivity, and Worker Characteristics: Evidence from Plant-Level Production Functions and Wage Equations," *Journal of Labor Economics,* July 1999, pp. 409–46.

[35] An alternative hypothesis is that average wages are in fact stable at the plant level, but the apparent instability is caused by measurement error. This hypothesis, however, is unlikely on the basis of the findings in Troske, "The Worker-Establishment Characteristics Database," and Doms, Dunne, and Troske, "Workers, Wages, and Technology." Both Troske, on the one hand, and Doms, Dunne, and Troske, on the other, match workers in the Employment Characteristic Database to plants from the Longitudinal Research Database and find similar average worker-reported earnings and plant-level earnings in their samples. The workers in the Employment Characteristic Database come from the 1990 census long form, which includes 1 in 6 households. Worker's reported wages come from their responses on the long form. Troske finds that the difference between the plant's workers' average reported wage and the plant's average wage reported in the Longitudinal Research Database is less than 5 percent, on average. The correlation between the worker's reported wages and the plant's reported wages is 0.47 and rises by plant size, from 0.41 for plants with 25 to 49 workers to 0.78 for plants with more than 1,000 workers. Troske notes several reasons that perfect (unity) correlations should not be expected, even with perfect reporting by both plants and workers. First, a worker reports the total earnings received from *all* of his or her employers the previous year, while a plant's average wages are computed by dividing the total salary and wages the plant paid in 1990 by the number of workers in the plant in March 1990. Second, because the sample consists of only one-sixth of the plant's population of workers, the worker's sampled may be unrepresentative of all workers in the plant. This kind of sampling error will be less pronounced in larger firms and may account, in part, for the increasing correlation between the workers' and the plant's wages with plant size. Thus, it is reasonable to think that the correlation between the two measures would be closer to 0.78 with 100-percent sampling. Further, it is likely that workers' reports of their earnings on the Census forms have a good deal of error that is only partly mitigated by averaging. Hence, given all of the reasons that these measures should not be strongly related, the fact that they do exhibit a high correlation suggests that the underlying plant-level data are of high quality. Furthermore, implausible wage levels have been set to missing, as mentioned in note 19. Nonetheless, it is undoubtedly true that some of the instability of average wages is due to some remaining measurement error. The central argument of this paper is that measurement error is not the *main* cause of the instability.

[36] Charles Brown and James Medoff, "The Employer Size-Wage Effect," *Journal of Political Economy*, October 1989, pp. 1027–59.

[37] This conclusion differs from that of Davis and Haltiwanger, who find that wage dispersion falls sharply with establishment size for non-production workers and mildly for production workers ("Employer Size and the Wage Structure," abstract).

[38] Baily, Hulten, and Campbell, "Productivity Dynamics."

[39] See, for example, Bernard and Jensen, "The Deaths of Manufacturing Plants"; J. Bradford Jensen, Robert H. McGuckin, and Kevin J. Stiroh, "The Impact of Vintage and Survival on Productivity: Evidence from Cohorts of U.S. Manufacturing Plants," *Review of Economics and Statistics*, May 2001, pp. 323–32; and G. Steven Olley and Ariel Pakes, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, November 1996, pp. 1263–97.

[40] Baily, Hulten, and Campbell, "Productivity Dynamics."

[41] These percentages can be derived from entries in the fifth row of table 7.

[42] There is a strong connection among plants that have large movements in the productivity and wage distributions. For the analysis in this article, a dummy variable was created that equals unity if a plant moved upwards more than 20 percentage points in the wage distribution. An analogous variable was created for productivity. The correlation between the two dummy variables is 0.295. Repeating the analysis for plants that moved *downwards* more than 20 percentage points in each distribution produces a correlation of 0.298. The correlations for plants that moved upwards more than 20 percentile points in one distribution, but downwards more than 20 percentile points in the other distribution, are around –0.30.

In results that are not shown here, plant size is significantly (and positively) related to productivity (controlling for a plant's regional and urban location, capital intensity, and county unemployment). Thus, if the plants would have been weighted by their numbers of employees, more of the weight of the analysis would be placed on plants in the bottom right-hand corner of table 7. Plants falling into the nine cells at the bottom right of table 7 exhibit slightly more stability than do plants falling into the nine cells at the top left, as indicated by the fact that 11.4 percent of plants at the bottom right of the table are two cells off the diagonal, whereas 14.0 percent of plants at the top left are two cells off the diagonal. These percentages suggest that smaller plants have less stable productivity and that an analysis weighted by plant size would find slightly more stability in productivity, a result that is consistent with the findings of both Bartelsman and Dhrymes, on the one hand, and Baily, Hulten, and Campbell, on the other. The former conclude that "larger plants (in terms of employment) are less likely to exit, less likely to move down the productivity rankings and more likely to maintain their rankings, than small plants" (Bartelsman and Dhrymes, "Productivity Dynamics," p. 23). The latter present results with plants weighted by their employment and with unweighted plants. The weighted plants show more persistence, making up 35 percent of plants along the diagonal in a run of weighted plants, whereas the unweighted plants account for 30 percent of plants along the diagonal in a run of unweighted plants. (See Baily, Hulten, and Campbell, "Productivity Dynamics.")

[43] Baily, Hulten, and Campbell, "Productivity Dynamics."

[44] *Ibid.* Baily, Hulten, and Campbell argue that this declining persistence was due to powerful foreign competition arising from a strong U.S. dollar.

[45] A direct comparison of the differences between the transition matrix calculated here and the transition matrices reported in Bartelsman and Dhrymes's article is difficult due to numerous differences in methodology and sampling. Those authors focus on plants in the following industries: machinery, except electrical (SIC 35); electrical and electronic machinery, equipment, and supplies (SIC 36); and measuring, analyzing, and controlling instruments (SIC 38). Also, they limit the sample to large plants (those with 250 or more employees in any year between 1972 and 1987) and compute 1-year and 5-year transition matrices for total factor productivity for these plants. Finally, they reject the hypothesis that the transition process is Markovian—that is, that the 5-year transition matrix $A5 = (A1)^5$. (In fact, the Markovian process overpredicts dispersion.) Thus, no 10-year transition matrix can be reliably projected from their 1- and 5-year transition matrices.

[46] Bartelsman and Dhrymes, "Productivity Dynamics."