WAGE DISPERSION BETWEEN AND WITHIN
U.S. MANUFACTURING PLANTS, 1963-1986

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ABSTRACT

This paper exploits a rich and largely untapped source of
information on the wages and other characteristics of individual
manufacturing plants to cast new light on recent changes in the
United States wage structure. Our primary data source, the
Longitudinal Research Datafile (LRD), contains observations on
more than 300,000 manufacturing plants during Census years (1963,
1967, 1972, 1977, 1982) and 50,000-70,000 plants during
intercensus years since 1972. We use the information in the LRD
to investigate changes in the plant-wage structure over the past
three decades. We also combine plant-level wage observations in
the LRD with wage observations on individual workers in the
Current Population Survey (CPS) to estimate the between-plant and
within-plant components of overall wage dispersion.

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I. Introduction

Overview

This paper exploits a rich and largely untapped source of information on the wages and other characteristics of individual manufacturing plants to cast new light on recent changes in the United States wage structure. Our primary data source, the Longitudinal Research Datafile (LRD), contains observations on more than 300,000 manufacturing plants during Census years (1963, 1967, 1972, 1977, 1982) and 50,000-70,000 plants during intercensus years since 1972. We use the information in the LRD to investigate changes in the plant-wage structure over the past three decades. We also combine plant-level wage observations in the LRD with wage observations on individual workers in the Current Population Survey (CPS) to estimate the between-plant and within-plant components of overall wage dispersion.[1]

The main phenomenon motivating our investigation is the dramatic, continuous rise in wage inequality in the United States since the late 1960's. Most of the rise is accounted for by inequality increases within groups of workers defined by experience, education and gender. We interpret the large and growing role for inequality within groups of workers with similar characteristics, as observed in household surveys, as strong motivation for our investigation into the relationship between wages and observable plant characteristics. Since observable worker characteristics fail to explain the bulk of both the level and rise in wage inequality, it is natural to inquire into the role of employer characteristics. As we show below, since the late 1960's there have been striking changes in the distribution of observable plant characteristics and in the wages associated with plant characteristics.

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[1] We make no attempt in this paper to systematically survey the large body of existing research on the plant-wage structure, but a few remarks are in order. First, our investigation differs from previous work on the plant-wage structure with respect to the superior size, scope, and (in many respects) quality of the data set we bring to the analysis. Dunne and Roberts (1989) are the only other researchers to exploit a large segment of the LRD for the analysis of the wage structure. Recent papers by Groshen (1990a,b) that use plant-level data focus on many of the same issues that we take up in this paper. Second, employer size is found to be an important correlate of wages across a wide range of previous studies, a result that emerges strongly in our results reported below. An important recent study by Brown and Medoff (1989) contains extensive references to the literature on employer size-wage differentials. Third, very few previous studies examine time-series changes in the plant-wage structure with an eye toward explaining rising wage inequality. Groshen (1990b) is the only exception known to us.

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The paper proceeds as follows. In the balance of the introduction, we review the major changes in the U.S. wage structure over the past three decades, show that the manufacturing sector also experienced large increases in overall and within-group wage inequality, and document some major institutional and structural changes in the manufacturing sector. We also discuss the main hypotheses about rising wage inequality that play a role in the ensuing analysis. In section II, we combine information from household and establishment surveys to decompose the total variance of wages into between-industry, between-plant, and within-plant components for both production and nonproduction workers. This decomposition allows us to measure the components of rising wage inequality and to begin evaluating competing explanations for the rise. Section III describes alternative explanations for the findings reported in section II and elsewhere in the paper. We discuss reasons for wage differentials across plants, and we outline a simple competitive model that illustrates the contrasting implications of product demand shifts and skill-biased technical change for changes in the wage structure. We also discuss the possible role of noncompetitive and institutional factors in the growth of wage dispersion. Section IV investigates the role of observable plant characteristics in the distribution of wages across plants. We use time-series changes in the plant wage structure to help identify the driving forces behind rising wage inequality. Section V investigates the impact of changing trade patterns and unionization rates on the plant wage structure. Section VI presents concluding remarks that summarize the central messages of the paper.

The Changing U.S. Wage Structure and Alternative Explanations

The United States economy experienced pronounced shifts in the structure of wages over the past three decades. Wage differentials between more and less experienced workers widened substantially between 1963 and 1987, with the sharpest increases occurring during the 1980's. The college wage premium rose between 1963 and 1971, fell between 1971 and 1979, and then rose dramatically during the 1980's. The wage gap between men and women changed little from 1963 to 1979 but shrank significantly during the 1980's.[2]

On net, these between-group changes had little effect on overall wage inequality during the 1960's and 1970's, but after 1979 they contributed toward an increasingly unequal distribution of wages. Wage inequality within groups of workers defined by experience, education and gender rose continuously after 1970 (Juhn, Murphy and Pierce, 1990).

[2]Katz and Murphy (1990) document all of these changes. Other recent research documenting some or all of these changes includes the papers by Blackburn, Bloom, and Freeman (1989), Bluestone (1989), Bound and Johnson (1989), Juhn, Murphy and Pierce (1990), Levy (1989), Murphy and Welch (1990), and Katz and Revenga (1989).

While within-group wage inequality increased at a smooth pace over the past two decades, the increase in overall wage inequality accelerated during the 1980's as the experience, education and within-group components each made substantial contributions to the growth of wage inequality (Juhn, Murphy and Pierce, 1990).

Researchers have advanced several hypotheses to explain these large changes in the wage structure. Observed fluctuations in the growth rate of the relative supply of college graduates, coupled with the assumption of steady relative demand growth for more educated workers, provide a simple and coherent explanation for movements in the college wage premium over the past thirty years (Katz and Murphy, 1990). The continuous expansion of experience differentials and within-group inequality over the past twenty years also point toward explanations that stress steady relative demand growth of more highly skilled workers.

One set of explanations for the relative demand growth of high-skill workers centers around the consequences of an increasingly integrated world economy. U.S. exports plus imports rose from less than 13% to more than 24% of gross national product between 1970 and 1988 (Abowd and Freeman, 1990). Since less skilled workers are disproportionately employed in import-intensive sectors, this pronounced shift toward a more open economy has decreased the relative demand for less skilled U.S. workers. Borjas, Freeman and Katz (1990) analyze the labor skill content embodied in U.S. flows of traded goods and immigrants and conclude that these flows greatly increased the effective supply of less educated workers during the 1980's. They attribute one-third of the rising college wage premium between 1980 and 1987 to the effects of trade and immigration flows.

A second set of explanations for the relative demand growth of high-skill workers centers around skill-biased technical change. The spread of computer technology in the workplace and greater reliance on more flexible production techniques are factors that have perhaps increased the relative demand for more skilled workers.[3] At least three aspects of recent changes in the wage structure point toward an important explanatory role for skill-biased technical change. First, the timing of changes in education differentials contrasts sharply with the timing of increases in experience differentials and within-group inequality. This contrast indicates that these dimensions of worker skill are not close substitutes in production, and that movements in the various skill premia are driven by different

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[3]There is considerable debate about the impact of changing technology on skill requirements. While there is substantial evidence that skill requirements have increased, there is also evidence that technological advances sometimes reduce skill requirements. For a discussion of this debate and references related to the impact of changing technology on skill requirements, see Levy and Murnane (1991). We return to this issue in section III.

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disturbances. Second, the timing of trade-related disturbances, which are concentrated in the 1980's, do not conform well to the smooth growth of within-group wage inequality over the past two decades. Other product demand disturbances of sufficient magnitude to plausibly explain the large increases in within-group wage inequality are not apparent.[4] Third, since the timing and magnitude of increases in within-group inequality are roughly age-neutral, it is unlikely that they are driven by an increasing dispersion of unobservable worker quality attributes related to, say, increasingly unequal educational quality (Juhn, Murphy and Pierce, 1990). We conclude from these observations that skill-biased technical change will play a major role in any satisfactory neoclassical explanation for recent changes in the wage structure.

An alternative, and complementary, approach to explaining recent increases in wage inequality stresses institutional changes in the labor market rather than demand and supply factors. The view that unionism might have potentially important effects on overall wage inequality has a long tradition in labor economics (Freeman and Medoff, 1984, and Lewis, 1986). It is often argued that unions narrow the wage gap between less and more skilled workers and sometimes argued that they reduce the dispersion of wages among workers with similar characteristics (Freeman, 1980 and 1982). Accordingly, the dramatic fall in union density in recent decades (Freeman, 1988) suggests that it might be an important contributor to widening experience differentials and growing within-group wage inequality. Alternatively, the decline in union density might reflect deeper economic factors related to changes in the organization and nature of production activity. Under this interpretation declines in union density, and their relationship to the evolution of the wage structure, provide additional information that can help identify the deeper changes that have affected both unionism and the wage structure.

The Changing Wage Structure in the Manufacturing Sector

Since we focus on the manufacturing sector in this paper, it is important to establish at the outset the differences and similarities between developments in this sector and developments in the economy as a whole. Figure 1 displays the evolution of three inequality measures for hourly manufacturing wages from 1975 to 1988. We computed these measures

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[4]For evidence on the inability of inter-industry shifts in the structure of product demand to explain the relative decline in demand for less-skilled workers, see Juhn, Murphy and Pierce (1990, section 5) and Katz and Murphy (1990, section 5).

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from the observations on annual hours worked and annual salary and wages in the 1976-1989 Annual Demographic Supplements to the March CPS.[5] Wage figures are expressed in 1982 dollars using the GNP implicit price deflator for personal consumption expenditures. Major changes in CPS reporting and imputation procedures make it difficult to construct satisfactory inequality measures for hourly wages prior to 1975. Accordingly, here and throughout the paper, we do not report CPS-based results for years prior to 1975.[6]

The solid curve in Figure 1 shows that overall wage inequality in the manufacturing sector, as measured by the hours-weighted standard deviation of log hourly wages, rose by 20% from 1975 to 1988. The bottom curve, which depicts the standard deviation of log wage regression residuals, illustrates the importance and dramatic growth of wage inequality within experience-education-gender groups. The residuals are computed from yearly cross-sectional regressions of log wages on years of schooling, four schooling class variables, years of schooling interacted with the schooling class variables, sex, and a quartic in experience fully interacted with the other regressors. Within-group hourly wage inequality accounted for 74% of overall inequality in 1975 and 78% in 1988. Between 1975 and 1988, within-group inequality rose by 25%, accounting for 95% of the rise in overall inequality. Thus, the standard explanatory variables available in household surveys account for a fairly small, and declining, fraction of total wage variation. In this respect, developments in the manufacturing sector mirror developments in the economy as a whole.

Most previous studies of earnings inequality focus on the distribution of log wages. Given the information available in the LRD, we investigate the distribution of wages measured in natural units throughout the rest of the paper. The top curve in Figure 1 shows that the coefficient of variation in raw wages rose by 19% between 1975 and 1988, slightly less than the rise in the standard deviation of log wages. There are minor differences in the two measures over short time periods, but the pronounced rise in wage inequality emerges clearly in both series. We conclude that differences in the unit of measurement should not seriously hamper comparisons between our findings and the results reported in previous research.

One simple way to motivate our inquiry into the role of employer characteristics is to compare the information content of the LRD and CPS with respect to the ability of

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[5]We restrict our March CPS sample to manufacturing workers who report hourly wages greater than 75% of the minimum and less than $250 in 1982 dollars. Each March file of the CPS contains information for the previous calendar year on roughly twelve to fifteen thousand manufacturing workers.

[6]On the reporting and imputation changes in the CPS, see Lillard, Smith and Welch (1986) and Juhn, Murphy and Pierce (1990).

observable worker characteristics and observable plant characteristics to account for inter-industry wage differentials. Since these wage differentials have been the focus of a large and controversial body of work in recent years (Katz and Summers, 1989), this comparison is intrinsically interesting as well.

To carry out the comparison, we calculated the ratio of the hours-weighted variance of mean wages across industries to the same measure computed from the residuals in hours-weighted cross-sectional regressions on observable worker (CPS) or plant (LRD) characteristics. Reciprocals of these variance ratios, essentially the unexplained fraction of inter-industry wage variation, are plotted in Figure 2. The LRD ratios are for selected years between 1963 and 1986 for one set of plant-level controls, and for selected years between 1975 and 1986 for a second, and more extensive, set of plant-level controls. To compute the CPS residuals, we regressed raw hourly wages on nine region dummies, sex, four schooling classes, years of schooling, years of schooling interacted with the schooling class variables, and a quartic in experience fully interacted with all other variables except region. To compute the LRD residuals corresponding to Set 1 (the 1963-86 results), we regressed the mean plant wage on nine region dummies, three energy cost-share classes, five capital intensity classes, two ownership-type dummies, five product specialization classes, and a quartic in size with no interaction terms. For Set 2 of the LRD plant controls (the 1975-86 results), we added three age classes, fully interacted the class variables, and interacted the quartic in size with the class variables.[7]

The results of the comparison are striking. In overlapping years, observable plant characteristics more successfully account for inter-industry wage differentials than observable worker characteristics. The unexplained component of industry wage differentials in the CPS are two and one-half times as large as in the LRD using the more extensive set of plant controls. The unexplained component of industry wage differentials in the CPS rises from 14.5% in 1975 to 20.5% in 1988. The unexplained component of industry wage differentials in the LRD falls dramatically from 1967 to 1972 and then falls slightly further by 1986. In 1986, and with the extensive set of plant controls, the LRD accounts for all

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[7]The plant-level variables are more fully defined in section IV. Here and throughout the paper, we restrict the LRD sample to plants with a mean wage (by worker type) at least 75% of the minimum wage and no more than $250 per hour in 1982 dollars. We also dropped plants with missing production worker observations on the plant characteristics used in this study. Appendix A provides information on sample counts before and after the imposition of selection criteria.

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but 9% of the variance of industry wage differentials. Combined with the inability of observable worker characteristics to account for increases in manufacturing wage inequality, Figure 2 indicates that further study of the plant-wage structure is strongly warranted.

Major Institutional and Structural Changes in the Manufacturing Sector

We now document some major institutional and structural changes in the manufacturing sector that play a role in the ensuing analysis. Where data are available, we also compare changes in the manufacturing sector to changes in the economy as a whole.

Figure 3 plots measures of union membership density in the private sector and the manufacturing sector of the U.S. economy. The BLS figures show a steep, continuous decline in private-sector union density from 1960 to 1978. The CPS figures show a continuing pronounced decline through 1988. These figures also show a comparable decline in union density within the manufacturing sector since 1975.[8] Given the numerous studies that find important connections between unionism and the wage structure, Figure 3 suggests that the decline in unionism may be an important factor in recent changes in the wage structure.

Empirical studies consistently find higher wages at larger plants after controlling for observable worker characteristics and other observable plant characteristics.[9] Some of our recent research (Davis and Haltiwanger, 1989) documents major changes in the distribution of employees by plant size in the U.S. economy since 1967. We summarize these changes in Figures 4.A and 4.B, which plot time series for the coworker mean (the number of workers at the average employee's workplace) and the standard deviation of plant size

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[8]The 1974 to 1980 CPS figures are from Kokkelenberg and Sockell (1985), who estimated union density as a fraction of the workers covered by the National Labor Relations Act. Since most managers and supervisors are not covered by the Act, the Kokkelenberg and Sockell figures overstate union membership as a fraction of the private sector workforce and, at least for manufacturing, probably understate the decline in union density. The 1983 to 1988 CPS figures are from Curme, Hirsch and Macpherson (1990). For the analysis in subsequent sections, we adjusted the Kokkelenberg and Sockell data to be comparable to the Curme *et al* data using 1974 data in Freeman and Medoff (1979). Freeman and Medoff estimate union density in a way comparable to Curme *et al.*

[9]Brown and Medoff (1990) investigate explanations for size-wage differentials based on (i) sorting by worker skill, (ii) compensating differentials, (iii) union effects, (iv) rent sharing and (v) efficiency wage considerations. They find supportive evidence only for explanations based on sorting by worker skill. We discuss sorting and other explanations for the size-wage differential in section III.

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across workers.[10] According to Figure 4.A, the coworker mean fell from 1,139 in 1967 to 665 in 1985, a striking 42% decline. The standard deviation of employer size across workers in the private sector fell by 45% over the same period. Figure 4.B shows that the pronounced shift toward smaller plants and greater uniformity in plant size across workers also occurred within the manufacturing sector. The coworker mean in the manufacturing sector fell from 2,239 employees in 1967 to 1,587 employees in 1986.[11] Coupled with the existing literature on the relationship between employer size and wages, these facts point to plant size as a potentially important factor in recent developments in the wage structure.

Another major structural change that occurred in the manufacturing sector is a shift toward more specialized plants. Gollop and Monohan (1989) construct generalized Herfindahl indexes of product diversification within manufacturing plants using Census-year data in the LRD.[12] They find increasing product specialization within manufacturing plants between 1967 and 1982, with sharper increases occurring among smaller plants. The shift toward more specialized plants over this period occurs in seventeen of twenty two-digit manufacturing industries. Using simpler measures, we present evidence below that plant-level product specialization increased greatly between 1963 and 1986 in the manufacturing sector. The shift toward greater plant-level product specialization is a potentially important factor in explaining movements in wage dispersion within plants.

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[10]Davis (1990) describes the methodology for estimating these statistics. The coworker mean differs greatly from the establishment mean (average plant size) in terms of both its magnitude and time-series behavior. The coworker mean and associated higher moments of the distribution of workers by plant size are the appropriate measures to use when investigating labor market issues involving distributions across workers. See Davis and Haltiwanger (1989) and Davis (1990) for further discussion of this point.

[11]As Figure 4.B reveals, over 80% of this decline occurred from 1967 to 1972. Preliminary investigation indicates that a large fraction of the 1967-1972 decline is attributable to massive shrinkage of a few large plants in aerospace industries as expenditures related to NASA and the Vietnam War fell sharply. After excluding these plants, the coworker mean still declines from 1967 to 1972 but at a substantially slower rate. (We thank Tim Dunne for this information.) In addition, Davis and Haltiwanger (1989) find that the shift away from large plants is widespread among two-digit manufacturing industries over this time period. Taken together, these observations suggest that the pronounced 1967-1972 decline in the the coworker mean reflects special factors in the aerospace industries and other factors with a more widespread impact.

[12]Their generalization takes into account the distance between different SIC products in the space of factor cost share vectors.

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The manufacturing sector also experienced significant shifts in the occupational and skill mix of labor inputs in recent years. The top panel of Table 1 shows large shifts away from operatives and toward managerial and professional workers since the mid-1970's. The middle panel shows dramatic shifts in the educational attainment of the manufacturing workforce. Workers with less than twelve years of schooling accounted for 40% of manufacturing hours in 1967-69 but only 20% in 1985-87. Over the same time span, the percentage of manufacturing hours accounted for by workers with at least some college rose from 20% to 37%. This shift toward a more educated workforce in the manufacturing sector is much greater than the corresponding shift in the economy as a whole. Summarizing the main message of Table 1, there has been a substantial increase in the skill intensity of manufacturing labor inputs since the late 1960's.

The preceding results document remarkable changes in the manufacturing workplace and workforce during recent decades. Relative to the 1960's, the typical manufacturing workplace in the late 1980's is more likely to be a small or mid-sized plant, a specialized plant, and a nonunion plant. The typical manufacturing worker is more highly educated and more likely to engage in a nonproduction activity. In what follows, we examine the effects of these and other factors on the distribution of wages between and within manufacturing plants.

II. Between-Plant and Within-Plant Components of Manufacturing Wage Dispersion

In this section, we combine information from household and establishment surveys to decompose the variance of hourly manufacturing wages into between-industry, between-plant, and within-plant components for production and nonproduction workers. The decomposition quantifies the contribution of each component to the dispersion of manufacturing wages and to changes in wage dispersion over time.

Decomposition Methodology

The variance of hourly wages across hours worked in the manufacturing sector can be written as

$$V = \alpha V^p + (1-\alpha)V^n + \alpha(1-\alpha)(\overline{W}^p - \overline{W}^n)^2,$$
$$= \alpha(V_{BP}^p + V_{WP}^p) + (1-\alpha)(V_{BP}^n + V_{WP}^n) + \alpha(1-\alpha)(\overline{W}^p - \overline{W}^n)^2, \tag{1}$$

where α denotes production workers' share of hours worked, V^p denotes the variance of wages across hours worked by production workers, $\overline{W}^p$ denotes the hours-weighted mean wage for production workers, V_{BP}^p denotes the hours-weighted variance of mean

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production worker wages across plants, V_{WP}^p denotes the hours-weighted mean of the production worker wage variances within plants, and the remaining terms denote analogous quantities for nonproduction workers. The first line of (1) expresses the total variance of hourly wages as the hours-weighted sum of within-worker-type and between-worker-type components. The second line further decomposes the within-worker-type components into between-plant and within-plant components.[13]

The between-plant and within-plant variance terms in (1) cannot be isolated from standard household surveys like the CPS, although the CPS does permit estimation of their sums, V^p and V^n. To isolate the separate components of these sums, we first calculate V_{BP} directly from wage data in the LRD. We then estimate the within-plant wage variance

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[13]The decomposition of overall variation into between-plant and within-plant components is derived as follows. Temporarily suppressing superscripts for worker type, total variation in wages across hours worked (for a particular worker type) is given by:

$$\sum_e \sum_h (W_{eh} - \overline{W})^2 = \sum_e \sum_h \left[(W_{eh} - W_e) + (W_e - \overline{W}) \right]^2$$
$$= \sum_e \sum_h (W_{eh} - W_e)^2 + \sum_e \sum_h (W_e - \overline{W})^2$$
$$= \sum_e H_e V_e + \sum_e H_e (W_e - \overline{W})^2$$

where H = total hours worked, H_e = hours worked at plant e, W_{eh} = the wage for hour h at plant e, W_e = the mean hourly wage at plant e, and V_e = the variance of wages across hours worked at plant e. Dividing through by H, and re-introducing superscripts for worker type, yields

$$V^p = V_{BP}^p + V_{WP}^p \qquad \text{and} \qquad V^n = V_{BP}^n + V_{WP}^n,$$

where, for example,

$$V_{WP}^p = \left(\frac{1}{H^p} \right) \sum_e H_e^p V_e^p,$$

and

$$V_{BP}^p = \left(\frac{1}{H^p} \right) \sum_e H_e^p (W_e^p - \overline{W}^p)^2.$$

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as a residual in a standard variance decomposition,

$$\hat{V}_{WP} = V(W_h^C) - V_{BP}, \qquad (2)$$

where $V(W_h^C)$ is the variance of measured wages in the CPS. To appreciate the assumptions implicit in this straightforward approach, it is useful to consider the bias that results from measurement error in the CPS.

Let W_h^L be the LRD wage for the hth hour worked at the eth plant, and write this wage as

$$W_h^L = e_h W_e^L + \eta_h, \qquad (3)$$

where e_h is a plant indicator vector, W_e^L denotes the vector of hours-weighted mean plant wages, and η_h denotes the deviation of the wage for the hth hour worked about its mean plant wage. We observe the vector W_e^L in the LRD, but we do not not observe W_h^L for each hour worked. Assuming that mean plant wages are measured without error in the LRD, and computing variances on both sides of (3), we have

$$V \equiv V(W_h^L) = V_{BP} + V_{WP}, \qquad (4)$$

where V_{BP} is calculated from plant-level observations in the LRD.[14]

Write the CPS wage observation for the hth hour worked as the sum of the true (LRD) wage and measurement error,

$$W_h^C = W_h^L + U_h. \qquad (5)$$

Computing variances on both sides of (5) and rearranging terms, we obtain an expression for the within-plant wage variance involving measured quantities and measurement error:

$$V_{WP} = V(W_h^C) - V_{BP} - [V(U_h) + 2C(W_h^L, U_h)], \qquad (6)$$

where $V(U_h)$ is the variance of measurement error in the CPS wage observations, and $C(W_h^L, U_h)$ is the covariance between the true wage and the CPS measurement error.

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[14]The plant-level data in the LRD on employment, size, age, ownership type and, for production workers, hours worked and hourly wages are of high quality and relatively free of measurement error. Hence, we view the assumption of no measurement error in production worker hourly wages in the LRD as a reasonable basis for analysis. Measurement error in the LRD wages for nonproduction workers is much more severe for reasons discussed at length in the appendixes.

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Comparison of equations (6) and (2) makes clear that our use of $\hat{V}_{WP}$ to estimate the within-plant variance of wages relies on the identifying assumption that $[V(U_h) + 2C(W_h^L, U_h)] = 0$. Testing this assumption requires both employer-reported and worker-reported wages for a sample of workers. Unfortunately, we know of no employer-worker matched data sets that correspond closely to the CPS and LRD in terms of sample design and execution and in terms of the compensation measure we use – hourly wages computed as annual salary and wages divided by annual hours worked. Appendix B reviews the available evidence on the structure of measurement error in household and establishment survey measures of wages. The appendix also reports estimates of the measurement error terms in (6) for a sample of six hundred manufacturing production workers drawn from a special supplement to the January 1977 CPS. The supplement contains employer-reported and worker-reported observations on usual hourly earnings. Previous research and our analysis of the CPS supplement point to considerable mean reversion in the measurement error component of worker-reported wages. In other words, $C(W_h^L, U_h) < 0$. This result indicates that the identifying assumption underlying (2) is consistent with available evidence. We refer the reader to Appendix B for further discussion on this point.

Even if measurement error biases our estimate of the within-plant wage variance in any given year, it is unlikely to seriously distort our estimate of time-series changes in the within-plant variance of wages. A stable measurement error structure through time, as reflected in a relatively constant value of $[V(U_h) + 2C(W_h^L, U_h)]$, will lead to accurate estimates of the change in V_{WP} under our methodology.

Returning to the variance decomposition in (1), we further decompose the between-plant components into between-industry (V_{BI}) and between-plant, within-industry (V_{BPI}) components to obtain

$$V = \alpha(V_{BI}^p + V_{BPI}^p + V_{WP}^p) + (1 - \alpha)(V_{BPI}^n + V_{BPI}^n + V_{WP}^n) + \alpha(1 - \alpha)(\overline{W}^p - \overline{W}^n)^2. \quad (7)$$

Equation (7) expresses overall manufacturing wage dispersion in terms of the wage gap between production and nonproduction workers and decompositions of production worker and nonproduction worker wage dispersion into between-industry, between-plant, and within-plant components.[15]

To estimate the components of (7), we proceed as follows. From the individual-level wage observations in the CPS March files, we calculate α, $\overline{W}^p$, and $\overline{W}^n$ for the manufacturing sector, and we calculate V^p and V^n for each two-digit manufacturing industry. From the plant-level wage observations in the LRD, we calculate V_{BP} for each two-digit industry. Using (2), we then estimate V_{WP} for each industry. Aggregating industry-level

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[15]By construction, $V_{BP} = V_{BPI} + V_{BI}$ for each worker type.

values (using LRD weights) yields the total manufacturing value of V_{BP}, and applying (2) once more yields the total manufacturing value of V_{WP}. Finally, we decompose V_{BP} into its between-industry and within-industry components. In both the CPS and LRD, hourly wages are measured as annual salary and wages divided by annual hours worked.[16] All calculations on individual, plant, and industry observations are carried out on an hours-weighted basis.

Decomposition Results

Table 2 reports the results of the decomposition exercise for selected years between 1975 and 1986 based on a breakdown of the manufacturing sector into twenty-two industries. According to line 2 of the table, the standard deviation of hourly manufacturing wages rose from \$4.88 in 1975 to \$6.16 in 1986 (in 1982 dollars). Lines 3-9 show measures of wage dispersion corresponding to each of the components in the variance decomposition in equation (7). Line 10 reports the fraction of hours accounted for by production workers. The bottom panel of Table 2 shows the contribution of each component to the overall variance of manufacturing wages. Several results stand out.

First, 51-58% of the total variance in wages is accounted for by the dispersion in mean wages across plants. This figure is arrived at by summing the contributions of the V_{BI} and V_{BPI} terms in the bottom panel of Table 2 (summing the contributions of lines 4, 5, 7 and 8). The mean wage gap between production and nonproduction workers accounts for 6-9% of the total variance in wages. The remaining source of wage variation in equation (7), the within-plant variance of wages for each worker type, accounts for 35-40% of the total variance in wages.

Second, within-plant wage dispersion is much greater among nonproduction workers than production workers. The within-plant standard deviation of wages is roughly three-to-five times larger among nonproduction workers, depending on year. In addition, the between-plant standard deviation of wages within industries is 39-50% larger for nonproduction workers. A related point is that nonproduction workers account for

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[16]For production workers, the LRD reports annual hours worked and the annual wage bill (exclusive of fringes and supplemental labor costs) for each plant. For nonproduction workers, the LRD reports only the annual wage bill and the number of employees in the mid-March payroll period during the year. To estimate V_{BP}^n, we combine information from the CPS and LRD to impute hours worked per nonproduction workers in each two-digit industry. Appendix A describes the imputation method. Appendix B discusses the bias in our estimates of V_{BP}^n and V_{WP}^n that potentially arises due to our inability to measure cross-plant variation in hours per nonproduction worker.

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a disproportionate fraction of overall wage dispersion. In 1986, for example, production workers account for 60% of hours worked in the manufacturing sector but only 28% of the overall wage variance, whereas nonproduction workers account for 63% of the overall variance.

Third, between-industry wage dispersion is of comparable magnitude for production and nonproduction workers, but the relative importance of the between-industry component differs greatly by worker type. Between-industry wage dispersion accounts for about one-quarter of the overall variance in wages among production workers but never more than 7% of the overall variance among nonproduction workers. In this sense, almost all wage variation among manufacturing nonproduction workers occurs within two-digit industries.

Table 3 uses the figures in Table 2 to calculate the contribution of each variance component to the rise in manufacturing wage dispersion between 1975 and 1986. The top panel in Table 3 reports the change in each term of (7), divided by the change in the total variance. The bottom panel carries out a similar exercise, but it fixes the production worker share of hours worked at its 1975 value. Comparing the two panels provides information about the importance of the changing occupational distribution of manufacturing employment to the rise in manufacturing wage dispersion.

The top panel of Table 3 indicates that each variance component in (7) accounts for part of the increase in overall wage dispersion. Between-plant components account for 48% of the growth in the wage variance, and within-plant components account for 41%.[17] A rising wage gap between production and nonproduction workers accounts for the remaining growth in the overall wage variance.

Table 3 reveals sharply different patterns of wage inequality growth for production and nonproduction workers. Among nonproduction workers, most (56%) of wage inequality growth occurred within plants. In contrast, among production workers, within-plant wage dispersion accounts for a small (9%) fraction of wage inequality growth. Within-plant wage dispersion among production workers accounts for a minuscule 1.7% of the growth in the overall variance of wages between 1975 and 1986. Even with production workers' share of hours worked held constant at its 1975 value, within-plant wage dispersion among production workers accounts for only 3.0% of the growth in the variance of wages between 1975 and 1986.

The findings in Tables 2 and 3 speak to at least three alternative views about the underlying causes of rising wage inequality in the United States. First, the results cast

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[17]Between-plant components include between-industry and between-plant, within-industry components for both production and nonproduction workers.

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doubt on the view that rising wage inequality reflects the weakening of social norms or egalitarian forces that constrain the wage-setting process. To the extent that these constraints compress wage differentials at the workplace, one expects their relaxation to result in rising within-plant wage inequality among both production and nonproduction workers. While stories along this line that account for disproportionate wage inequality growth among nonproduction workers can undoubtedly be crafted, the virtual absence of rising within-plant wage inequality among production workers stands as an uncomfortable fact for this view.

Second, the results in Table 3 cast doubt on the view that deunionization has been an important contributing factor to the growth of wage inequality in the manufacturing sector or in the economy as a whole. If unionism compresses the distribution of wages among production workers through standard rate compensation policies, as argued in the institutional literature (Reynolds and Taft, 1956, Slichter *et al*, 1960, and Freeman, 1980), then we would expect the sharp recent decline in unionism to be associated with disproportionately large increases in wage dispersion among production workers. As Table 3 makes clear, the facts are otherwise. While the results in Table 3 do not rule out a role for deunionization in rising between-plant wage inequality or the rising wage gap between production and nonproduction workers, unionism-based stories are ill-suited to explaining the tremendous growth in wage dispersion among nonproduction workers or the rapid shift in employment toward nonproduction workers in the manufacturing sector. In short, the results in Table 3 suggest that deunionization played at most a minor role in the growth of manufacturing wage dispersion between 1975 and 1986. Deunionization probably had even less impact on the structure of wages outside the manufacturing sector.

Third, the facts in Tables 2 and 3 are consistent with the view that skill-biased technical change has been a major impetus behind the growth of wage inequality in the U.S. manufacturing sector. Hours worked by nonproduction workers rose from 33% of total manufacturing hours in 1977 to 40% in 1986. Over the same time span, the wage gap between nonproduction and production workers expanded by nearly one-third. Taken together, these two facts constitute strong prima facie evidence that the manufacturing sector experienced sharp increases in the relative demand for more highly skilled labor. This increase in the demand for more highly skilled labor could have been caused by skill-biased technical change that favors high skill workers or by shifts in the composition of manufacturing product demand toward goods that intensively utilize high skill labor inputs.

The bottom panel in Table 3 provides additional evidence on the important role played by skill-biased technical change and/or product demand shifts. Fixing α at its 1975 value and summing the contributions of the various components accounts for only 80% of the

overall rise in the wage variance. The remaining 20% reflects the compositional shift from low-variance production workers to high-variance nonproduction workers. This finding suggests the following interpretation of rising wage inequality. Modes of production differ greatly in terms of the scope they offer for individual ability and skill differences to manifest as differences in productivity. At one extreme, assembly-line production processes require that all workers, from the most skilled to the least skilled, adhere to the line speed, thereby compressing the distribution of productivities (and wages) relative to the distribution of abilities. Other production processes have the character that each worker's productivity is affected multiplicatively by the ability of certain or all coworkers, thereby magnifying the distribution of productivities relative to the distribution of abilities.[18] Production-worker intensive modes of production apparently offer less scope for ability and skill differentials to manifest as productivity differentials than nonproduction-worker intensive modes. These remarks suggest that the portion of the wage variance increase not accounted for by the entries in the bottom panel of Table 3, 20% of the total increase, reflect a shift toward more ability-sensitive modes of production. The large contribution of within-plant wage dispersion among nonproduction workers, even with fixed α, is also suggestive of a shift toward more ability-sensitive modes of production.

III. Explanations for Wage Differences Across Plants

Why should wages differ greatly across employers within the same industry? Why should wages differ across workers within a plant? There are a host of candidate explanations for observed wage differentials and an enormous literature that seeks to evaluate the proposed explanations. See, for example, the list of potential explanations and the related literature surveyed in Katz and Summers (1989). In our discussion, we focus on the implications of alternative explanations for the between-plant and within-plant distribution of wages and for *time-series* changes in these distributions.

Competitive Explanations

Technological heterogeneity across plants within the same industry arises for many reasons. The anticipated scale and variability of future production, as well as the probability distribution over future factor prices, vary across locations and over time. Available production technologies also vary over time. These considerations influence the firm's choice of production technology when it constructs a new plant or reinvests in an old plant. Given that the choice of production technology and plant location entail significant

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[18]Miller (1982) and Rosen (1982) develop hierarchical models of the firm in which each worker's ability multiplicatively affects the productivity of all subordinates to the worker.

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sunk costs, these time- and location-specific differences in initial conditions generate persistent heterogeneity in production techniques among operating plants. Lambson (1990) shows that even when competitive firms face identical initial conditions and have identical information sets, they may choose different production technologies. Lucas (1978) and Oi (1983) develop models in which firm heterogeneity arises due to heterogeneity in entrepreneurial ability.[19]

These and other sources of technological heterogeneity among plants induce sorting by worker ability, which in turn leads to between-plant wage dispersion within industries.[20] This sorting takes many forms. Hamermesh (1980) suggests that larger plants use higher quality workers more intensively because of greater capital intensity at large plants and complementarities between physical capital and worker skill. Alternatively, Oi (1983) argues that large plants employ higher quality workers to reduce monitoring costs per unit of labor services. Clearly, both of these sorting mechanisms generate a positive, skill-based relationship between wages and employer size. Oi also argues that firm-specific human capital accumulation occurs primarily at large firms and plants. If higher quality workers have an advantage in accumulating firm-specific skills, then the dynamics of specific human capital accumulation provide another sorting mechanism that generates a positive, skill-based relationship between wages and employer size. In addition, many forms of skill complementarities across workers lead to ability sorting across plants. Oi, for example, argues that large plants often operate with technologies that rely heavily on standardization and teamwork and therefore require homogeneous, high quality workforces. Finally, plants of different ages will exhibit differences in their workforce distributions over tenure and experience, which in turn generates plant-wage differentials in theories of human capital, job shopping, and employer-worker matching.

Within-plant wage dispersion is tied to these technological differences among plants as well. To the extent that plants use a mix of skill types, within-plant wage dispersion naturally arises. The degree of within-plant dispersion is likely to vary systematically by

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[19]Time- and location-specific differences in initial conditions are likely to generate significant heterogeneity in the choice of technology across firms and across plants within firms. Similarly, differences in entrepreneurial ability are likely to generate differences across firms and across plants within firms. While it would be useful to separate between-plant dispersion into distinct between-firm and within-firm components, we do not undertake that task here.

[20]Technological heterogeneity in a competitive environment can also generate differences in working conditions across plants, leading to between-plant wage dispersion associated with compensating wage differentials. See Rosen (1986).

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plant type. For example, if large plants require a more homogenous type of production worker, then within-plant dispersion among production workers will be smaller at larger plants.

A simple supply and demand framework helps illustrate the role of competitive influences on the between-plant and within-plant structure of wages. In what follows, we focus on skill differentials, but job attribute differentials could be characterized in a similar fashion.

Suppose there are J types of labor skills and K types of plants. Without loss of generality, normalize the number of plants of each type to be 1. It is easily shown that the equilibrium wage and hours for skill type j can be represented as

$$h_j = \sum_k h_{jk}(\theta, \alpha) \qquad \text{and}$$

$$w_j = w_j(\theta, \alpha),$$

where h_{jk} is the hours for skill j at plant k, w_j is the wage for skill j, θ is a vector of plant-level demand shifters, and α is a vector of supply shifters for skill types.

The equilibrium mean wage at plants of type k is given by

$$w_k = \sum_k \left(\frac{h_{jk}(\theta, \alpha)}{h_k(\theta, \alpha)} \right) w_j(\theta, \alpha),$$

where h_k is the total quantity of hours demanded by plants of type k. The total variance in wages across hours worked is easily decomposed into between- and within-plant components:

$$V = V_{BP} + V_{WP}$$

where

$$V_{BP} = \sum_k \left(\frac{h_k(\theta, \alpha)}{h(\theta, \alpha)} \right) (w_k(\theta, \alpha) - \overline{w}(\theta, \alpha))^2,$$

and

$$V_{WP} = \sum_k \left(\frac{h_k(\theta, \alpha)}{h(\theta, \alpha)} \right) \sum_j (w_{jk}(\theta, \alpha) - w_k(\theta, \alpha))^2,$$

This representation makes clear that changes in demand and supply conditions affect between-plant and within-plant wage dispersion through a number of channels. Changes in demand and supply conditions affect the wage distribution for skill types, thereby

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affecting both within-plant and between-plant wage dispersion for a fixed distribution of skill types. Further, changes in demand and supply conditions alter the distribution of skill types between and within plants, thereby altering between-plant and within-plant wage dispersion.

A special case of this framework helps interpret some of the subsequent empirical findings. Suppose there are two skill types (high and low) and two plant types (large and small). Suppose technologies are such that only large plants can take advantage of the difference in skills. Consider an equilibrium in which initially all high skilled labor is employed at large plants, high skilled labor earns a higher wage than low skilled labor, large plants employ both skill types, and small plants employ only low skilled labor.

Within the context of this special case, consider two distinct types of labor demand disturbances. First, consider a skill-biased technology shock that increases the difference between the productivity of high and low skilled labor at large plants. For example, we suggested in the introduction that the spread of computer technology and greater reliance on more flexible production techniques are factors that have perhaps increased the relative demand for more skilled workers.[21]

Skill-biased technical change of this sort increases the demand for high skilled labor and (assuming substitution effects dominate) reduces the demand for low skilled labor at large plants. While the effect on total employment at large plants is ambiguous, average labor quality at large plants rises. Wages for high skilled labor rise, and wages for low skilled labor fall. Wages at small plants fall, and (with reasonable assumptions about supply and demand elasticities) wages at large plants rise because of the rising wage for high skilled labor and an increase in workforce quality at large plants. Overall then, this skill-biased technology shock induces a reallocation of low skilled labor to small plants and an increase in both the size-wage differential and the skill-wage differential. While

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[21] Case studies reported by Bailey (1989, 1990) provide direct evidence that the spread of computer technology and more flexible production techniques have influenced the demand for more skilled workers in this manner. For example, on the basis of his case studies of plants in textiles and apparel industries he states that "the increasing need for technical skills is particularly acute among repair and maintenance personnel." This need resulted from factors like the installation of "state-of-the-art air-jet looms" and the expansion of the number of "weaves and colors" produced (Bailey, page 24, 1990). Other types of workers have been similarly affected. For example, "Even the loom cleaners, who are among the lowest paid workers in the plant, now must at least be able to read instructions and punch numbers into a key pad." (Bailey, page 25, 1990).

this technology shock induces a reallocation of low skill workers towards small plants, the impact on the distribution of total employees by plant size is ambiguous.[22]

This technology shock affects overall wage dispersion through several channels. The increase in the employer size-wage differential tends to increase between-plant wage dispersion. The increase in the skill-wage differential tends to increase within-plant dispersion at large plants.[23] Compositional effects from the reallocation of low skilled labor to small plants and the increased use of high skilled labor at large plants also affect between- and within-plant dispersion.

Alternatively, consider a shift in relative product demands that reduces demand for the products produced by large plants. This case is of interest given increased foreign competition for products produced by large plants in the U.S. (e.g., in auto and steel).[24] This product demand shift reduces demand for both high and low skill labor at large plants and total employment at large plants falls. Again, some low skilled labor is reallocated from large to small plants. For reasonable supply elasticities, the skill differential falls since the demand for high skilled labor (which derives entirely from large plants) falls disproportionately relative to the fall in demand for low skilled labor (which derives from both large and small plants). The impact of this decrease in the skill-wage differential on the size-wage differential is ambiguous. For fixed skill shares at large plants, the decrease in the skill-wage differential decreases the size-wage differential. However, the decrease in the skill-wage differential induces an increased reliance on high skilled labor at large plants. This substitution response increases the size-wage differential. If these substitution effects are weak, then the first effect dominates. Overall, this product demand shift induces a reallocation of low skilled labor towards small plants, a decrease in the skill-wage differential, and an ambiguous change in the size-wage differential. In addition to

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[22]Note that a very different type of skill-biased technical change can produce similar results. Suppose high and low skilled workers are strong complements in the production process at large plants and suppose further that high and low skilled labor are inelastically supplied. Then a technology shock that raises the productivity of low skilled workers relative to high skilled workers can generate (i) an increase in the skill differential, (ii) an increase in the employer size differential, and (iii) the reallocation of low skilled workers from large to small plants.

[23]Our example has the obvious limitation that it does not incorporate factors that generate within-plant wage dispersion at small plants.

[24]Changing trade patterns can influence the wage and employment structure through channels other than simple shifts in relative product demand across plants. We return to this matter in section VI.

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the shift in the size distribution of low skilled labor, there is a shift in the size distribution of total employment towards small plants.

This product demand shift also affects overall wage dispersion through both between-plant and within-plant effects. The decrease in the skill-wage differential acts to decrease within-plant dispersion. If the size-wage differential falls as well, between-plant dispersion declines. Composition effects from the reallocation of low skilled labor to small plants and the increased use of high skilled labor at large plants also affect between-plant and within-plant wage dispersion.

We will return to these two examples of labor demand disturbances in section IV. There, the evidence we develop on time-series changes in size-wage differentials and changes in the distribution of hours worked by plant size will help us to discriminate between explanations for rising wage inequality based on biased technical change and explanations based on relative product demand shifts.

Noncompetitive and Institutional Explanations

Now let us turn to noncompetitive and institutional factors that influence wage dispersion between and within plants. These noncompetitive explanations have been discussed extensively in research on inter-industry wage differentials (e.g., Katz and Summers (1989)). Many explanations for inter-industry wage differentials are based on the idea that the nature of the employer-employee relationship differs systematically across industries. These same arguments can be applied to argue that the nature of the employer-employee relationship differs systematically across plants within industries. For example, monitoring technologies can vary both across and within industries. If monitoring is imperfect and more difficult at larger plants, then employer size-wage differentials can emerge following standard efficiency wage arguments.

Wage dispersion across industries or plants can also reflect differences in rent sharing. Rents can arise when employers have product market power or when employers have cost differentials with respect to nonlabor inputs. If wages are partly determined by rent sharing considerations, then cross-plant differences in rents or in worker ability to extract rents would generate between-plant wage dispersion.

While these noncompetitive factors can account for cross-sectional dispersion, it is less clear that they yield additional and plausible explanations for *time-series* changes in the distribution of wages. Consider, for example, an efficiency-wage explanation for between-plant wage dispersion. In the absence of standard demand or supply disturbances, a time-series increase in between-plant dispersion could be generated by changes in the monitoring technology that make it relatively more difficult to monitor workers at large plants. As an explanation for major shifts in the wage structure, this line of argument seems far fetched.

More plausibly, these noncompetitive factors might influence the response to standard demand and supply disturbances that affect wage dispersion.

Consider briefly how a product demand shift might interact with a noncompetitive explanation of cross-sectional dispersion. Suppose that the size-wage differential is due to efficiency wages in the manner discussed above, and consider a product demand shift that reduces the demand for products at large plants relative to those at small plants. This disturbance induces a reallocation of labor away from large plants towards small plants, and wages at both types of plants fall. The impact on the size-wage differential depends on the relative demand and supply elasticities. For sufficiently elastic demand at small plants, the size-wage differential falls.[25] Overall, then, the effects of a product demand shift in this noncompetitive environment are similar to the effects in the competitive model discussed above. (However, there are no skill-composition effects influencing the wage response at large plants in this noncompetitive example.) Thus, regardless of whether between-plant wage dispersion is generated by ability sorting or efficiency-wage considerations, a reduction in the demand for products produced by large, high-wage plants induces a reallocation of low skill labor towards small, low-wage plants. Under plausible auxiliary assumptions, the demand shift also causes a decline in the size-wage differential in both models.

Finally, unions clearly seek to influence the between-plant and within-plant structure of wages, and unionism often figures prominently in noncompetitive explanations for wage differentials. The well-documented union wage gap is associated with wage differentials between plants and between worker types. Freeman (1980, 1982) argues that, on net, unionism compresses wage differentials across workers. In light of these considerations, one might suspect that the large recent declines in union density are an important factor contributing to rising wage dispersion in the manufacturing sector. But, as we argued previously, the evidence presented in Table 3 supports the view that unionism-based factors played little role in rising wage dispersion. Below, we present additional evidence that supports this view.

IV. The Role of Observable Plant Characteristics

In this section, we investigate the role of observable plant characteristics in the distribution of wages across plants. We focus on three questions. What are the basic patterns of variation that link observable plant characteristics to plant wages? How much of the between-plant dispersion of wages is accounted for by observable plant characteristics?

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[25]We have in mind an upward-sloping no-shirking condition in the efficiency-wage sector.

What information do time-series changes in the plant-wage structure provide about the underlying driving forces behind rising wage inequality? The observable plant character-istics we consider are industry, size, age, region, ownership type (single- or multi-unit), energy intensity, capital intensity, and product diversification. Our reported results place relatively little emphasis on wage differentials by industry and region, since they have been studied at length in research based on household surveys, and since we have already quantified the contribution of industry effects in Tables 2 and 3.

Wage Differentials and Hours Worked by Plant Type

Table 4 reports wage differentials and between-plant standard deviations by plant type for production and nonproduction workers. Wage differentials by plant type for a given year are defined as the difference between the mean wage for the plant type and the overall mean wage for the given year. All figures are in 1982 dollars. The table reports time-series averages as well as the 1963-86 change.[26]

Mean wages are higher at larger plants, older plants, multi-unit plants, more energy intensive plants, more specialized plants and more capital intensive plants. The most striking differentials involve plant size. The average wage gap between plants with 5000+ employees and plants with 20-49 employees is \$4.92 per hour for production workers and \$3.60 per hour for nonproduction workers. These size-wage gaps are quite large relative to the average wage of \$8.56 for production workers and \$12.96 for nonproduction workers.

Large size-wage gaps occur within detailed manufacturing industries as well. In un-reported results, we recomputed the wage differentials in Table 4 while controlling for 22 two-digit industry effects in each year. These size-wage differentials exhibit the same pattern as the raw differentials, although the magnitudes are muted. When we control for two-digit industry effects, the mean production worker wage gap between plants with 5000+ employees and plants with 20-49 employees is \$2.82 per hour. Controlling for two-digit industry effects reduces the standard deviation of the mean wage differentials across size classes by 39%.

Table 4 also shows considerable cross-plant wage dispersion within size, age, ownership type, energy share, product specialization, and capital intensity classes. For production workers, between-plant wage dispersion displays a modest tendency to fall as plant size increases. This tendency is somewhat more pronounced when we control for two-digit industry effects. For nonproduction workers, the inverse relationship between plant size and between-plant wage dispersion is much sharper and nearly monotonic. Although mean

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[26]We do not report time-series changes for our capital intensity classes given the way these classes are constructed. See Appendix A for details.

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nonproduction worker wages rise sharply with plant size, between-plant wage dispersion falls from \$6.37 per hour at plants with 20-49 employees to \$2.65 per hour at plants with 5000+ employees. These results point to much greater heterogeneity in average workforce quality among small manufacturing plants than among large manufacturing plants, especially with respect to nonproduction workers.

The distribution of hours worked by plant types reveals several clear patterns. There is a greater concentration of nonproduction worker hours at large plants. On average, 36% of nonproduction worker hours, but only 27% of production worker hours, are worked at plants with 1000+ employees. Perhaps the most striking aspect of the hours distribution is the large fraction of hours worked at older and multi-unit plants. The fraction of hours worked at plants that produce a single five-digit SIC product is also quite large.[27]

Turning to time-series changes in the plant-wage structure, wage differentials by age, ownership type, energy intensity and product specialization exhibit modest changes over the sample period. Size-wage differentials exhibit dramatic increases. For production workers, the hourly wage gap between plants with 20-49 employees and plants with 5000+ employees rose by \$2.78. For nonproduction workers, the equivalent size-wage gap rose by \$1.53.

Between-plant wage dispersion grew for all plant classifications for production workers and for virtually all classifications for nonproduction workers. Greater increases occurred among larger plants, multi-unit plants, young plants, and less specialized plants. The reported statistics also show substantial increases in the fraction of hours worked at smaller plants, older plants, multi-unit plants, plants with higher energy costs, and a dramatic increase in the fraction of hours accounted for by more specialized plants. Note that the shift away from hours worked at large plants is more pronounced for production workers than for nonproduction workers.

Between-Type and Within-Type Components of Wage Dispersion Among Plants

The basic tabulations of wages by plant type point to systematic relationships between plant characteristics and wages. To help gauge the magnitude of these relationships, Table 5 decomposes the total between-plant variance of wages into between and within components for various observable plant characteristics.[28] Taken individually, the between-type contributions to total between-plant wage variation is modest for most characteristics,

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[27]The SIC system contains roughly 1300 five-digit product classes for manufactured goods.
[28]Table 5 is based on the categories used in Table 4: nine size classes, three age classes, two ownership types, three energy cost share classes, and five product specialization categories.

typically accounting for 8% or less. Wage variation by plant size is the exception, accounting for 26% of between-plant variation among production workers and 9% among nonproduction workers.[29]

Turning to time-series changes in between-plant wage dispersion, a parallel story emerges. Most of the observable characteristics, taken individually, account for modest amounts (often less than 5%) of the 1963-1986 increase in between-plant wage dispersion. In sharp contrast, size-class differentials alone account for 36% of the change for production workers and 20% of the change for nonproduction workers.

A Closer Look at Wage Differentials and Hours Worked by Plant Size

The dramatic rise in size-wage differentials motivates a more detailed investigation into this aspect of the changing plant-wage structure. Table 6 reports wage differentials by plant size and year for both worker types. Figures 5 and 6 depict mean hourly wages by size class for selected years.

Figures 5 and 6 show that real hourly wages rose steadily for most plant size classes over the 1963 to 1986 period. Much larger wage increases took place at larger plants. Table 6 indicates that size-wage differentials expanded continuously after 1967. In 1967, production workers at plants with 20-49 employees earned, on average, $3.40 less per hour than their counterparts at plants with 5000+ employees. By 1986, this wage gap rose to $6.31. For nonproduction workers, the corresponding hourly wage gap rose from $2.54 in 1967 to $4.66 in 1986. These 1986 wage gaps are enormous relative to the mean hourly wage of $9.18 for production workers and $13.73 for nonproduction workers.

Our finding of substantial size-wage differentials in any given cross-section is consistent with previous findings in the literature (Brown and Medoff, 1989). The striking and novel finding here is the dramatic and continuous increases in size-wage differentials dating from 1967. This finding and its connection to rising wage dispersion are new facts that any potential explanation of the changing structure of wages must accommodate. As we noted in the introduction, research based on household surveys find that skill differentials in the U.S. economy have widened dramatically since the late 1960's. Thus, the time-series changes in the size-wage gap documented in Table 6 are consistent with explanations

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[29]In multi-variate cross-sectional regressions of plant wages on a quartic in size, nine regions, three energy cost classes, two ownership types, five product specialization classes, 22 two-digit industries and no interaction terms, the observable plant characteristics account for about one-half of total between-plant wage variation. For production workers, the time series of R^2 values is .48 (1963), .47 (1967), .50 (1972), .54 (1977), .48 (1982) and .46 (1986). Adding three age classes to the 1986 regression increases the R^2 to .48.

for the gap that stress sorting by worker ability. While efficiency-wage or ability-to-pay explanations for wage differentials by plant size could, in principle, account for the time-series changes, a coherent and plausible explanation along these lines is not evident to us.

The tremendous magnitude of the rise in the size-wage gap indicates that sorting by worker ability across plants of different sizes probably increased over time. Table 7 presents evidence consistent with this view. The table shows the evolution of the hours-weighted mean plant size in number of employees for both worker types and using two alternative measures of size. Based on production worker hours and the current size measure, the hours-weighted mean plant size fell from 2097 employees in 1967 to 1406 employees in 1986. Most of this decline occurs between 1967 and 1972, but the decline continues after 1972. The nonproduction worker hours-weighted mean plant size also peaks in 1967 and falls dramatically by 1972. However, beginning in 1977 the nonproduction worker hours-weighted mean plant size begins rising. These facts indicate that the rising fraction of total manufacturing hours accounted for by nonproduction workers (Table 2) occurs disproportionately at large plants. Thus, at least at the crude level of the production worker/nonproduction worker distinction, we have direct evidence that average workforce quality at large manufacturing plants has risen relative to average quality at small plants since 1977.

Full Distribution Accounting for the Changing Plant-Wage Structure – Methodology

The preceding results report bivariate relationships between wages and particular plant characteristics. To provide a more comprehensive characterization of the contribution of observables and unobservables to changes in the plant-wage distribution over time, we use the full distribution accounting methodology developed by Juhn, Murphy and Pierce (1990). Using the JMP methodology, we estimate the effects – on various parts of the plant-wage distribution – of (i) changes in the distribution of observable plant characteristics, (ii) changes in the wage effects associated with observable plant characteristics, and (iii) changes in the distribution of regression residuals.

To understand the methodology, consider the regression equation

$$W_{et} = X_{et}\beta_t + u_{et},$$

where W_{et} is the wage at establishment e in period t, X_{et} is a vector of plant characteristics, and u_{et} represents the part of the wage unaccounted for by observables. Following JMP, we think of this residual as reflecting the establishment's percentile in the residual distribution, ω_{et}, and the distribution function of the residuals, $F_t(\cdot | X_{et})$. Here, we allow

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for the possibility that the residual distribution function varies with certain observable plant characteristics. It follows from the preceding definitions that

$$u_{et} = F_t^{-1}(\omega_{et}|X_{et}),$$

where $F_t^{-1}(\cdot|X_{et})$ is the inverse cumulative residual distribution for plants with characteristics X_{et} in t.

We can now decompose time variation in the plant-wage distribution into three parts: changes in the distribution of plant characteristics (the X's), changes in the wage effects (the β's) associated with a given set of plant characteristics, and changes in the residual distributions. Defining $\overline{\beta}$ as the average of the estimated wage effects in the cross-section regressions and $\overline{F}(\cdot|X_{et})$ as the average cumulative distribution, we can represent this decomposition by

$$W_{et} = X_{et}\overline{\beta} + \overline{F}^{-1}(\omega_{et}|X_{et}) + X_{et}(\beta_t - \overline{\beta}) + (F_t^{-1}(\omega_{et}|X_{et}) - \overline{F}^{-1}(\omega_{et}|X_{et})). \tag{8}$$

The first two terms in this decomposition capture the contribution of changes in the distribution of observable plant characteristics for fixed wage effects. The third term captures the contribution of changing wage effects. The final term captures the contributions of changes in the distribution of regression residuals that are unexplained by changes in the β's and changes in the distribution of the X's. We can use the decomposition in (8) to isolate the contribution of these three types of change to the total change in the wage structure.

To isolate the contribution of changes in the distribution of observable plant characteristics, consider

$$W_{et}^1 = X_{et}\overline{\beta} + \overline{F}^{-1}(\omega_{et}|X_{et}). \tag{9}$$

The time path of the distribution over the W_{et}^1 represents an estimate of how the changing distribution of observable plant characteristics affects the wage structure.

To generate the marginal contribution of changes in wage effects to changes in the wage structure, consider

$$W_{et}^2 = X_{et}\beta_t + \overline{F}^{-1}(\omega_{et}|X_{et}). \tag{10}$$

The distribution over the W_{et}^2 reflects both wage effects and observable plant characteristics. Now think of calculating the time path of the distribution over the W_{et}^2, as well as the time path of the distribution over the W_{et}^1. For each of these time paths, we can calculate time series on various summary statistics. Comparing the 90-10 percentile range, for example, as generated by distributions over the W_{et}^1 and the W_{et}^2, yields an estimate of

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the marginal contribution of changing wage effects to changes in the 90-10 range. Similar remarks apply to other measures of inequality..

Likewise, we can generate the marginal contribution of changes in the unobservables to changes in the wage structure by considering

$$W_{et}^3 = X_{et}\beta_t + F^{-1}(\omega_{et}|X_{et}) = X_{et}\beta_t + u_{et} = W_{et}. \tag{11}$$

Hence, comparing the time path of the distribution over the W_{et} to the time path of the distribution over the W_{et}^2 yields the marginal contribution of changes in the unobservables to changes in the wage structure.

Full Distribution Accounting Results

The top left panel of Figure 7 plots the time-series of the between-plant wage dispersion for production workers as measured by the wage differential between the 90th and 10th percentiles of the plant-wage distribution. The 90-10 differential rose from roughly six-and-one-half dollars per hour in 1967 to more than ten dollars per hour in 1986. The increase in the 90-10 differential holds fairly steady from 1967 to 1982 and then slows between 1982 and 1986.

The other three panels in Figure 7 break down the growth in the 90-10 plant-wage differential into the three components of the JMP accounting exercise. Each component is measured as a deviation from its overall mean. The regression specification underlying the decomposition represented by the solid curves contains two-digit industry effects, nine region effects, a quartic in size, two ownership types, three energy cost classes, five product specialization classes and no interaction terms. In this specification, we permit the distribution function of the residuals to vary across two-digit industries. The specification underlying the decomposition represented by the dashed curve contains only the quartic in size (and the year-specific intercept terms) and a residual distribution function that does not vary by industry or any other plant characteristic.

Several interesting results emerge from the time-series decomposition in Figure 7. First, changes in the distribution of observable plant characteristics (holding fixed the wages associated with these characteristics) had little effect over the 1963-1986 period on between-plant wage dispersion, as measured by the 90-10 differential.

Second, changes in the wages associated with observable plant characteristics account for two-thirds of the total increase in the 90-10 wage differential. Over the sample period, the 90-10 wage differential rose by $3.74 per hour. Wage effects alone account for a rise in the 90-10 differential equal to $2.47 per hour. The dominant role of observable wage effects in accounting for rising between-plant wage dispersion contrasts sharply with the

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dominant role of unobservables in accounting for the overall rise in between-worker wage dispersion. Indeed, Juhn, Murphy and Pierce (1990) find that observable wage effects and observable quantity effects combined account for only one-third of the increase in the 90-10 worker wage differential over the 1963-1987 time period.

Third, the wage effects associated with plant size alone account for a remarkably large fraction of the total increase in between-plant wage dispersion. According to the dashed curve in the lower left panel of Figure 7, changing wage effects associated with plant size account for $1.45 of the $3.74 increase in the 90-10 plant-wage differential. Thus, the dramatic expansion of size-wage differentials that we found in previous tables accounts for nearly 40% of the total increase in between-plant wage dispersion.

An attractive feature of the JMP methodology is that it enables one to quantify the effect of changes in the observables and unobservables on all parts of the wage distribution. Table 8 exploits this feature of the methodology to report the decomposition of time-series changes in the 90-50 and 50-10 wage differentials. Two facts stand out in the table.

First, for production workers, observable characteristics and wages together account for over 60% of the increase in between-plant dispersion for all of the reported measures. For nonproduction workers, observable characteristics and wages account for a smaller but still substantial fraction of the time-series change in the various measures of between-plant wage dispersion.

Second, almost 90% of the increase in between-plant wage dispersion among production workers occurs in the upper half of the distribution. This latter finding is interesting in the context of recent controversies about whether the economy has been providing too many "bad jobs" (e.g., Bluestone and Harrison, 1988). According to the top panel in Table 8, changes in the distribution of observable plant characteristics between 1963 and 1986 actually contributed to a substantial decrease in the differential between mean wages at the average plant (50th percentile) and mean wages at low-wage plants (10th percentile). In other words, the manufacturing sector is (in 1986) providing relatively fewer jobs at the type of plants that traditionally provided low-wage employment opportunities.[30] Note that the small increase in the 50-10 differential over the 1963-1986 period also indicates that the erosion of the real minimum wage played little role in rising wage inequality in the manufacturing sector.

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[30]In this context, it is useful to observe that the median real wage for manufacturing jobs has risen over our sample period.

Interpretation of Findings

At this point in our investigation, we have accumulated several facts that help discriminate between the skill-biased technical change explanation and the trade growth/product demand shift explanation for rising wage inequality in the U.S. economy. These facts are: (1) The manufacturing sector experienced dramatic and continuous expanansion of wage differentials by plant size from 1967 to 1986. These rising size-wage differentials account for about 40% of the overall increase in between-plant wage dispersion among production workers and a large fraction of the increase among nonproduction workers. (2) The manufacturing sector experienced a sharp leftward shift in the distribution of hours worked by plant size after 1967. Most of this shift occurred by 1972. Since 1977 the distribution of hours worked by nonproduction worker hours has reversed course and shifted substantially to the right. (3) The manufacturing sector experienced a pronounced upgrading of labor skill intensity, as indicated by changes in the educational and occupational mix of manufacturing workers. (4) Since 1977 improvements in workforce quality have occurred disproportionately at large manufacturing plants. (5) In addition, research based on household surveys points to steady relative demand growth for more highly skilled workers in recent decades.

These facts are consistent with the view that skill-biased technical change has been the major driving force behind rising wage inequality in the United States. The facts are difficult to square with the view that product demand shifts have been the major driving force behind rising wage inequality. Given sharply rising skill and size differentials, an explanation based solely on product demand shifts is very difficult to reconcile with the shift in the distribution of hours worked toward small plants, and the relative increase in the average workforce quality of large plants. To accommodate the rising skill differential, the product demand shift story must postulate an increase in the demand for products that intensively utilize high-skill labor inputs. If this product demand increase impinges directly on large plants, then the distribution of hours worked will shift toward large plants. This implication is sharply at odds with the leftward shifts in the distribution of hours worked by plant size. If this product demand increase directly affects only the subset of small plants that intensively utilize high skill labor (and not large plants), then large plants will substitute away from high skill labor and the relative workforce quality of large plants will deteriorate. This prediction is sharply at odds with evidence that average workforce quality at large plants rose relative to workforce quality at small plants. Finally, explanations for rising wage inequality based on product demand shifts offer no apparent explanation for the explosion of within-plant wage dispersion among nonproduction workers documented in Table 3.

In contrast, the skill-biased technical change story that we outlined in section III predicts rising skill differentials, rising size-wage differentials, and rising average workforce quality at large plants. This story also accommodates the leftward shift in the distribution of hours worked by plant size.[31] Skill-biased technical change is also suggested by the pattern of increasing wage dispersion that appears in Table 3, as we argued earlier. However, the simple skill-biased technical change story developed in section III does not seem sufficiently rich to explain the explosion of within-plant wage inequality among nonproduction workers. This observation suggests to us that a shift toward more ability-sensitive modes of production has played an important role in rising wage inequality.

Another finding not obviously explained by our skill-biased technical change story is the difference between the timing of changes in the distribution of hours worked by plant size and the timing of changes in size-wage differentials. As Figures 5 and 6 indicate, size-wage differentials rise continuously after 1967. But, as Figure 4.B and Table 7 indicate, most of the leftward shift in the size distribution of hours and employment occurs between 1967 and 1972. Several observations help reconcile these timing differences with the skill-biased technical change story. First, a substantial fraction (approximately 1/3) of the overall increase in size-wage differentials also occurs between 1967 and 1972. Second, the leftward shift in the size distribution of hours and employment continues after 1972, albeit at a slower rate. Preliminary investigation (see footnote 11) indicates that the sharp 1967-1972 decline in the hours-weighted mean plant size partly reflects special factors that are unrelated to the structural changes on which this study focuses. Third, skill-biased technical change carries no strong implications for shifts in the distribution of hours worked by plant size. Our skill-biased technical change story carries stronger implications regarding changes in the skill composition of labor inputs by plant size. Consistent with our story, Tables 4 and 7 show systematic shifts toward greater reliance on nonproduction workers at large plants.

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[31]Reasonable assumptions about the marginal rate of technical substitution in the production function between high skill and low skill workers can lead to either a rightward or leftward shift in the distribution of hours worked by plant size in response to skill-biased technical change. The skill-biased technical change story carries stronger implications about the distribution of output by plant size and the rate of growth of output per worker by plant size. We have not yet investigated these implications.

V. Further Investigation of the Plant-Wage Structure: Size, Trade, and Union Effects

In this section, we directly investigate the role of changing patterns of unionization and international trade on the plant-wage structure. We also re-estimate the size-wage differentials, while controlling for a host of plant-level and industry-level observables, to examine the robustness of our earlier findings.

Size-Wage Differentials with Extensive Controls

Table 9 reports estimated size-wage differentials in the presence of plant-level and industry-level controls. These differentials are estimated from a pooled time-series cross-section regression containing year effects; plant-level controls for age, energy cost, product specialization and four-digit industry; and additional time-varying industry-level measures of union membership density, workforce characteristics, the import penetration ratio and exports' share of shipments. The reported estimates are coefficients on the size-class indicators interacted with the year effects.

Comparing Tables 6 and 9 reveals that the controls substantially reduce the production worker size-wage differentials, especially for the 5000+ class. In 1986, for example, the production worker wage differential between plants with 20-49 employees and plants with 2500-4999 employees is $6.96 without controls and $2.84 with controls. Comparing Tables 6 and 9 reveals that the controls less successfully account for the nonproduction worker size-wage differentials. The controls also typically account for a smaller portion of the growth in the size-wage differentials and, in some cases, lead to larger increases in the differentials. For example, between 1977 and 1986 the production worker wage differential between plants with 20-49 employees and plants with 2500-4999 employees rises by $.76 without controls and by $1.13 with controls. In short, the results in Table 9 reinforce our earlier findings on the impressive magnitude and dramatic growth of size-wage differentials. A convincing explanation for rising wage dispersion across plants and workers will provide a coherent interpretation of rising size-wage differentials.

Trade and Union Effects

Turning to the effects of trade patterns and unionization on the wage structure, we have argued that the accumulated evidence is unfavorable to the trade growth/product demand shift explanation and the deunionization explanation for rising wage inequality. It remains to be seen whether a closer examination of the data will reveal important effects of trade shocks or deunionization on the plant-wage structure. We take up this matter now.

Our ability to directly investigate the impact of trade effects and unionization rates on the plant-wage structure is restricted by data limitations, particularly with respect to union

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effects. The LRD contains no information on union presence at the plant. Neither does the LRD contain reliable information regarding exports by plant. Our methodology here is based on the presumption that differential changes in trade patterns or unionization rates across industries should be reflected in systematic responses of the plant-wage structure within manufacturing. These responses can arise either because of imperfect labor mobility across industries and plants, or because trade and union shocks lead to changes in workforce quality that are not captured by our crude controls. Even if labor is imperfectly mobile, there may be significant cross industry effects missed in our analysis. (See Revenga, 1989.) Nevertheless, if changing trade patterns or unionization rates have played an important role, then we should be able to detect direct effects of these changes on the structure of wages in the impacted industries.

To investigate trade effects, we match detailed (four-digit) industry-level information on the time series of imports and exports to the plant-level data using the plant's four-digit industry code. We also match two-digit industry-level figures for union membership density to the plant-level data. The time span covered by the union density data limits our analysis to the 1975-1986 period. By interacting the industry-level data with observable plant characteristics, we investigate whether industry-level variation in the import penetration ratio, exports' share of shipments, or union membership density accounts for a significant fraction of between-plant wage dispersion or time-series changes in between-plant wage dispersion.

Table 10 presents estimated wage effects associated with the interaction of industry-level trade and union variables with plant characteristics. The wage effects are estimated by OLS in a pooled time-series cross-sectional regression specification that includes year effects, 450 four-digit industry effects, time-varying industry measures of workforce quality and capital intensity, and a battery of plant-level characteristics. While virtually all of the reported interaction coefficients are statistically significant, the estimated impact of the trade and union variables on the plant-wage structure is quite modest.

Consider, for example, the interactions of the industry-level variables with plant size. For production workers, an increase in an industry's import penetration ratio is associated with a rise in the size-wage differential. The relevant estimated coefficient is 0.000235. (Note that the coefficients on plant size in the table are multiplied by 10^3 - see the notes to Table 10.) This estimate implies that even a large increase in the import penetration ratio, say ten percentage points, increases the size-wage differential between a plant with

50 workers and a plant with 5000 workers by less than $0.12 per hour.[32]. Carrying out a similar exercise for a ten percentage point increase in the export share, the estimated effect on the size-wage differential is only $.04.[33] These effects are tiny relative to observed increases in the size-wage differential and overall between-plant wage dispersion.

Changes in industry-level union density also have small estimated effects on the size-wage differential. Union threat-effect models of wage determination predict that a higher unionization rate reduces the size-wage differential (Freeman and Medoff (1984), Podgursky (1986)). The argument is that large nonunion plants pay union wages because they face a strong threat of unionization, whereas small nonunion plants facing a lesser threat are less compelled to match the union wage. Accordingly, an increase in industry-wide union density disproportionately increases the wages of small plants and thus narrows the size-wage differential. The negative estimated coefficient on the size-union interaction term is consistent with this hypothesis. However, the magnitude of the effect is trivial. A ten percentage point increase in union density would, according to the estimate, reduce the wage differential between a plant with 50 employees and a plant with 5000 employees by one penny per hour.[34]

The largest interaction effect reported in Table 10 is the interaction between export share and energy use. A ten percentage point increase in the export share is estimated to increase the production worker wage differential between plants with low energy costs (less

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[32]This calculation is the product of the estimated coefficient, 0.000235, the change in the import penetration ratio under consideration, 0.10, and the difference in plant sizes under consideration, 4950.

[33]This calculation is the product of the estimated coefficient, 0.000083, the change in the export penetration ratio under consideration, 0.10, and the difference in plant sizes under consideration, 4950.

[34]This calculation is the product of the estimated coefficient, -0.0000002, the change in union density under consideration, 10, and the difference in plant sizes under consideration, 4950. As noted in section II, unions may have an important effect on within-plant wage dispersion. In regression results not reported here, we investigated the relationship between industry-level unionization rates and industry level-measures of within-plant wage dispersion (generated by the method described in section II). We considered numerous specifications that allowed for different combinations of year effects, industry effects, trade variables, workforce composition variables and plant composition variables. We found no evidence that union density has a statistically significant effect on within-plant wage dispersion in any of our regression specifications, although several of the other variables were significantly related to within-plant dispersion.

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than 1% of sales) and plants with high energy costs (greater than 5% of sales) by $0.40.[35] For nonproduction workers, this same conceptual experiment is estimated to increase the energy cost wage differential by $0.34. In both cases, the effects are modest relative to observed increases in plant-wage differentials over this time interval. We stress that these effects are by far the largest ones in the table.

In sum, these results indicate that changing patterns of trade and unionization played a small role in recent changes in the plant-wage structure. To restate the point, neither trade nor union effects appear to account for much of the rise in between-plant wage dispersion or the size-wage differential. Conceivably, a careful treatment of potential simultaneity and measurement problems associated with our trade and union variables might yield different inferences, but the results in Table 10 are fully consistent with the other evidence in this paper that neither trade shocks nor deunionization explain the growth of wage dispersion. One expects the impact of changing trade and (private sector) unionization patterns on the wage structure to be even smaller outside of the manufacturing sector. As a final point, the results in Table 10 do not speak to the issue of whether trade shocks, for example, caused important changes in the distribution of employment across plants with different characteristics. We leave this issue for future research.

VI. Conclusion

To conclude, we summarize the central results and main conclusions to emerge from the research in this paper.

First, between-plant wage dispersion is a large component of overall wage dispersion. Over one-half of the total wage variance in the U.S. manufacturing sector is accounted for by the dispersion in mean wages across plants. In addition, between-plant dispersion accounts for 48% of the growth in overall manufacturing wage dispersion from 1975 to 1986.

Second, there are striking differences across production and nonproduction workers in the relative contributions of between-plant and within-plant components to overall wage dispersion and to the growth in overall wage dispersion. For production workers, between-plant dispersion accounts for most of the cross-sectional dispersion at any point in time and for more than 90% of the time-series increase from 1975 to 1986. In contrast, for nonproduction workers, within-plant wage dispersion accounts for most of the cross-sectional

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[35]This calculation is the product of the estimated coefficient on the dummy variable for energy costs less than 5% of sales, -4.089, and the change in the export share under consideration, 0.10.

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dispersion and for most of the time-series increase in cross-sectional dispersion. These findings cast strong doubt on the view that rising wage inequality reflects the weakening of social norms that constrain wage dispersion within the firm. This view implies rising within-plant inequality for both types of workers, an implication sharply at odds with the virtual absence of rising within-plant wage inequality for production workers. These findings also cast doubt on the view that deunionization played a significant role in rising wage inequality, since deunionization would seem to imply disproportionate increases in within-plant inequality for production workers.

Third, between-plant dispersion is not simply due to random effects or unobserved plant characteristics. Over half of between-plant wage dispersion in a given year can be accounted for by basic plant characteristics like industry, size, age, region, ownership type, degree of product specialization, energy costs and capital intensity. Furthermore, these plant characteristics account for over two thirds of the time-series increase in between-plant dispersion among production workers and a large fraction of the increase among nonproduction workers.

Fourth, the most important plant characteristic in terms of its ability to explain wage dispersion is plant size. Rising size-wage differentials explain about 40% of the overall rise in between-plant wage dispersion for production workers over the 1963 to 1986 time period. The production worker wage differential between plants with 5000+ employees and plants with 20-49 employees rose from $3.53 per hour (1982 dollars) in 1963 to $6.31 per hour in 1986. A noteworthy aspect of the time-series increase in size-wage differentials is that it accompanies a market leftward shift in the distribution of employment and hours worked by plant size.

Fifth, a direct investigation into the impact of changing industry patterns of unionization and international trade revealed little role for deunionization and trade shocks in accounting for changes in the manufacturing sector's plant-wage structure. Furthermore, we found no evidence that cross-sectional and time-series variation in industry-level union density is associated with variation in within-plant wage dispersion. We also note that any product demand shift explanation, whether or not based on trade factors, is difficult to reconcile with the shift in the distribution of hours worked toward small plants and the relative increase in average workforce quality at large plants in the manufacturing sector.

Combining these findings with the findings of previous research discussed in the introduction points towards skill-biased technical change as the major driving force behind rising wage inequality in the United States. Skill-biased technical change stories can explain the rising skill differential, the rising size-wage differential, the shift toward modes of production that more intensively utilize nonproduction labor inputs, observed shifts in the distribution of hours worked and employment by plant size, steady relative demand

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growth for more experienced and more educated workers, the steady growth in wage inequality within experience-education-gender groups, and the age-neutral character of rising within-group wage inequality.

Naturally, there are caveats to these interpretations of our results, especially regarding our conclusion that changing trade patterns played little role in the evolution of the plant-wage structure or the rise in wage inequality. Our conclusion on trade effects is essentially a statement that shifts in relative product demand across plants and across industries within manufacturing have not been a major driving force behind rising wage inequality or the other phenomena documented in this paper. Shifting trade patterns may have played important roles through channels other than shifts in relative product demand across plants and industries within manufacturing. One potentially important consequence of weakening barriers to international trade is production outsourcing of intermediate goods that are low skill labor intensive. Increased outsourcing is consistent with our key findings. For example, suppose large plants initially produced both intermediate and final goods, and that intermediate goods are low-skill intensive. Then outsourcing of intermediate goods produced at large plants could lead to an increase in the size-wage differential, an increase in the skill-wage differential, downsizing of large manufacturing plants, and increased average labor quality at large plants. Another potentially important aspect of shifting trade patterns that we have not investigated involve changes in the structure of wages between the manufacturing and the non-manufacturing sectors of the economy (Murphy and Welch, 1990). More generally, since our empirical analysis is restricted to the manufacturing sector, factors outside of manufacturing that influence wages within manufacturing are neglected. Evaluating these links between changing trade patterns and the wage structure requires further research.

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Appendix A – Data Appendix

The plant level data used in the analysis is from the LRD. The LRD is a comprehensive probability sample of establishments in U.S. manufacturing industries. An establishment is defined as a single physical location engaged in manufacturing activity. The LRD is basically a series of contiguous five-year panels with annual survey data on manufacturing establishments, plus Census-year data on the universe of manufacturing establishments. Census years in the LRD are 1963, 1967, 1972, 1977, and 1982. Annual data are available from 1972. From the Census-year universe, the Bureau draws a sample of establishments which are then surveyed during five successive years. This five-year panel, which commences two years after a Census year, comprises the sample of establishments that makes up the Annual Survey of Manufactures (ASM). New establishments are added to the panel as it ages to incorporate births and to preserve the representative character of the panel. In 1977, the ASM sample included roughly 70,000 out of the 360,000 establishments in manufacturing industries. These sampled establishments accounted for 76% of manufacturing employment. The only manufacturing establishments excluded from the sampling frame of the ASM are those with fewer than five employees. These establishments account for one percent of manufacturing employment, based on tabulations from either the Census of Manufactures or County Business Patterns.

For Census years (1963, 1967, 1972, 1977, 1982), we used the complete Census for our tabulations and analysis. For the selected non-Census years (1975, 1979, 1984, and 1986), we used the ASM sample and the given sample weights to make tabulations comparable. Some establishments were excluded from the analysis. First, we excluded establishments in a given year that were in the LRD but with industry codes out of manufacturing. Second, we excluded establishments in a year that did not have positive economic activity (i.e., nonzero shipments, employment, and hours). After these restrictions the number of establishments in the sample in 1982 (a Census year) is 327,143 and 52,323 in 1986 (an ASM year). For analysis involving production (nonproduction) workers, an establishment was excluded in any year in which the mean plant hourly wage for production (nonproduction) workers was less than 75% of the minimum wage or more than 250 in 1982 dollars. For production workers, these criteria resulted in the exclusion of 5.5% of the establishments in 1982 and 0.4% of the establishments in 1986. In terms of hours worked, these criteria resulted in the exclusion of 1.7% of hours in 1982 and 0.3% of hours in 1986.

The mean plant production worker hourly wage is constructed for each plant by dividing total wages for production workers by total production worker hours, where both data items are reported in the LRD. In the LRD, total wages means salaries, wages, commissions, dismissal pay, paid bonuses, vacation and sick leave pay, and the cash equivalent of

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compensation paid in kind. Salaries and wages do not include supplementary labor costs such as employer's Social Security contributions, other legally required expenditures, or payments for voluntary employer programs like health insurance.

For nonproduction workers, data limitations required a different procedure. Reported data items in the LRD include nonproduction worker employment for mid-March and total annual wages (defined as above). Annual nonproduction worker hours are not available in the LRD. To estimate them, we first generated annual hours per nonproduction worker from the CPS by two-digit industry. We then estimated nonproduction worker hours as the product of nonproduction worker employment (LRD) and the annual hours per nonproduction worker in the industry (CPS).

Some of the establishment-level data in the LRD is imputed. For all establishments, IRS and SSA information is typically available for name, address, payroll, employment, gross business receipts, and industry; these data items are generally not imputed. Accordingly, the measures we use based upon this information are quite reliable. For this paper, our measures of size (average and current), age, region, ownership type, and industry fall into this category.[36] Imputation procedures for missing data items are based upon industry average ratios of the missing item to payroll and sales.

Data for administrative record (AR) cases are based entirely upon information from the IRS and SSA. AR cases are small establishments, typically with less than five employees, that have been excused from filing Census forms. All data items other than that from IRS and SSA records are imputed for AR cases. These cases account for only 3-4% of total manufacturing employment in a typical census year. Also, recall that there are no AR cases in the ASM sample.

Establishments other than AR cases can also have some data imputed in Census or ASM years. The need for imputation results from differences in filing requirements across establishments (some small establishments get abbreviated forms to reduce filing burdens) and the failure of some firms to fully report on all data items. Small establishments receive less attention than large establishments in terms of edits and follow-ups for missing data. If a large plant fails to report an item, the Census is likely to contact the plant to obtain the information. The nature and extent of imputation bias is the focus of current research at the Center for Economic Studies at the Bureau of the Census.

Imputation and related missing data problems potentially generate a systematic bias in our calculated size-wage differentials. Small establishments are more likely to have imputed data and, since imputation is based upon average industry ratios, estimated wages

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[36]The age variable is based upon the first appearance of the establishment in the manufacturing universe – that is, the first Census year that the establishment appears.

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for small plants will be biased upwards. Also there are a number of plants that report zero nonproduction workers. This reporting pattern appears to be related to two distinct phenomena. First, some small plants lump nonproduction workers together with production workers. Since nonproduction worker wages are on average higher, this reporting pattern will bias upwards the wages of small plants. Second, some multi-unit firms appear to report nonproduction worker employment at auxiliary and administrative manufacturing plants rather than at the production plants. Since the auxiliary plants are not included in the LRD, this reporting pattern generates a downward bias in the wages for nonproduction workers at large plants. In sum, there are several factors that appear to work in the same direction of generating a downward bias in our calculated size-wage differential. We believe that these biases are small.

Appendix B: Measurement Error and the Wage Variance Decomposition

Previous investigations of measurement error in the earnings data from household surveys like the CPS find significant mean reversion. In other words, the covariance between the measurement error in earnings and true earnings is negative. See Mellow and Sider (1983), Duncan and Hill (1985), Bound *et al* (1989), and Bound and Krueger (1989). Unfortunately, the results in these previous studies are not directly applicable to our decomposition of the wage variance into between-plant and within-plant components because of differences in the sampling frame, the compensation measures considered, and the experimental design underlying earlier measurement error studies. To the best of our knowledge, there are no data sets with matched employer and worker observations on hourly earnings that are close analogs to the LRD and CPS data used in this study.

The most comparable data set appears to be a special supplement to the January 1977 CPS. In this supplement, a subset of the regular CPS interviewees were queried for the name and address of their employer. Employers were then contacted and asked an identical set of questions about individual workers' wages and other items. From the matched data, one can construct employer and worker measures of usual hourly earnings based on a direct question for hourly wage earners and based on typical hours per week and earnings per week for other workers. These data differ from the CPS and LRD data used in this study in several respects: the method for constructing hourly earnings, the apparently much greater noise in the CPS supplement data on wages than in the CPS March files, and the absence of any careful consistency checks and other edits in the employer responses to wages and other items. See Mellow and Sider (1983) for a fuller description of the data and sample design.

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Using the January 1977 CPS supplement, we estimated the sign and magnitude of the measurement error component in square brackets on the right side of equation (6) for manufacturing production workers. The data set contains 638 observations on manufacturing production workers. We deleted 11 observations because either the employer or worker-reported hourly wage was less than 75% of the minimum wage or greater than $250 per hour. We deleted five additional observations because of large discrepancies between employer and worker responses that were obviously due to employer-response error. Such errors would be unlikely to survive the data checks used in the development of the LRD.

Using the remaining 622 observations, we computed the measurement error component in equation (6) and the total variance of worker-reported hourly wages. The measurement error component was negative, indicating mean reversion, and equal to about 10% of the variance in worker-reported wages. If these results are representative of the measurement error structure in the March CPS and LRD data, then our results in Table 2 understate the relative importance of within-plant wage dispersion. There is little reason, however, to think that measurement error seriously biases the time-series changes reported in Table 3.

Another potentially important source of measurement error in our between-plant, within-plant decomposition pertains only to nonproduction workers. The LRD does not contain plant-level information on hours worked per nonproduction worker. We used two different methods to impute hours per nonproduction worker in estimating plant-level hourly wages for nonproduction workers. In the first method, we computed average annual hours per nonproduction worker by two-digit industry from the March CPS files. We then applied this figure to plant-level observations on annual earnings and nonproduction worker employment in the LRD to estimate plant-level hourly earnings for nonproduction workers. This method underlies all results in sections IV and V, except the industry-level regressions discussed in footnote 34. Computed in this way, mean hourly earnings for nonproduction workers in the LRD typically exceed mean hourly earnings in the CPS by 10-30%. (For production workers, where no hours imputation is necessary, the discrepancy is only about 3%.) Furthermore, this first method often led to individual industry-level estimates of within-plant wage variance that were negative.

To address this difficulty, we used a second method to impute hours per nonproduction worker when carrying out the variance decomposition in section II. First, for each two-digit industry we computed the ratio of mean hourly wages in the LRD to mean hourly wages in the CPS for production workers. Then, we chose hours per nonproduction worker in each two-digit industry, so that the implied ratio of LRD to CPS mean hourly wages matched the corresponding ratio for production workers. This method gave sensible industry-level

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estimates for within-plant wage dispersion. Only one estimate (out of 132) was negative. All results in section II are based on this imputation method.

Applying the imputed figure for hours per nonproduction worker to plant-level observations on nonproduction worker employment and wage bill yields an estimate for V_{BP}^n. If unmeasured cross-plant variation in hours per nonproduction worker is unrelated to mean plant wages, this procedure introduces an upward bias in the estimated V_{BP}^n and, hence, a downward bias in $\hat{V}_{WP}^n$. This bias is reinforced (mitigated or reversed), if plants that pay relatively high hourly wages to nonproduction workers also have relatively high (low) hours per nonproduction worker. Using all manufacturing nonproduction workers in the January 1977 CPS supplement, we find a zero correlation between worker-reported wages and employer-reported hours and a weak positive correlation between employer reported wages and worker-reported hours. Taken together, these observations indicate that our inability to measure plant-level variation in hours per nonproduction worker leads to an upward bias in the estimated V_{BP} and a downward bias in $\hat{V}_{WP}$.

Table 1. The Distribution of Manufacturing Hours Worked by Occupation, Education
and Potential Experience, 1967-69 to 1985-87

	1967-69	1970-72	1973-75	Years 1976-78	1979-81	1982-84	1985-87
	Percent of Hours Worked	Percent of Hours Worked	Percent of Hours Worked	Percent of Hours Worked	Percent of Hours Worked	Percent of Hours Worked	Percent of Hours Worked
Occupation							
Prof., Tech.	11.05	10.75	10.73	10.76	12.02	12.75	13.13
Manag., Ad.	7.26	7.11	7.61	7.91	8.36	10.47	11.22
Clerical	11.43	11.42	11.39	10.98	11.52	11.54	11.35
Sales	2.55	2.32	2.23	1.93	2.05	2.60	2.88
Craft	22.45	21.53	21.60	21.36	21.24	21.04	20.60
Operatives	37.09	36.49	35.94	36.47	35.12	32.79	31.97
Trans. Op.	3.03	4.25	4.18	4.44	3.99	3.59	3.55
Laborers	3.88	4.15	4.58	4.43	4.06	3.59	3.72
Service	1.27	2.00	1.74	1.72	1.65	1.63	1.57
Educational Attainment							
Less Than HS	40.13	37.24	32.95	29.97	25.89	22.35	20.24
High School	39.55	41.92	43.08	43.66	45.59	45.59	44.51
Some College	11.04	11.35	13.10	14.55	15.34	15.91	16.83
College Degree	9.28	9.49	10.87	11.80	13.17	16.15	18.32
Experience							
1-5 Years	9.43	10.32	12.28	12.83	13.02	10.57	9.88
6-10	12.17	12.50	13.35	14.47	15.68	15.32	14.99
11-15	11.55	11.64	11.98	12.90	13.49	14.86	15.46
16-20	11.30	10.56	10.52	11.43	11.72	12.67	14.17
21-25	11.69	10.79	10.03	10.12	10.24	11.08	11.71
26-35	23.13	22.75	21.06	19.03	17.75	18.64	18.14
36+	20.72	21.44	20.78	19.22	18.10	16.87	15.85

Source: Authors' calculations from the March CPS files.

Table 2. Decomposition of Hourly Wage Variance into Between-Industry, Between-Plant and Within-Plant Components, U.S. Manufacturing, 1975-1986

Wage Figures in 1982 Dollars

Component	Year					
	1975	1977	1979	1982	1984	1986
1. Total Variance of Hourly Wages in Manufacturing, V	23.86	23.14	23.29	29.40	33.16	38.00
2. Standard Deviation of Hourly Manufacturing Wages	4.88	4.81	5.13	5.42	5.76	6.16
3. Standard Deviation of PW Hourly Wages w/i Plants	1.46	1.54	1.48	1.35	1.00	1.66
4. Standard Deviation of Mean PW Hourly Wages between Plants	2.62	2.72	2.93	3.16	3.31	3.33
5. St. Dev. of Mean PW Hourly Wages between Industries	1.77	1.94	1.99	1.98	1.94	2.04
6. Standard Deviation of NPW Hourly Wages w/i Plants	4.86	4.39	4.79	4.89	5.31	5.81
7. St. Dev. of Mean NPW Hourly Wages between Plants	3.94	3.91	4.16	4.37	4.68	4.63
8. St. Dev. of Mean NPW Hourly Wages between Industries	1.44	1.64	1.68	1.62	1.75	2.02
9. Mean NPW Wage Minus Mean PW Wage	2.86	2.78	2.65	3.15	3.34	3.69
10. Production Worker Fraction of Mfg. Hours Worked, α	.66	.67	.65	.62	.61	.60

Percentage of Total Wage Variance Accounted for by the Term in:

	1975	1977	1979	1982	1984	1986
Line 3, αV_{WP}^p	5.9	6.9	5.4	3.8	1.8	4.3
Line 4, αV_{BPI}^p	18.9	21.4	21.2	21.1	20.0	17.3
Line 5, αV_{BI}^p	8.6	10.9	9.8	8.3	6.9	6.5
Line 6, $(1 - \alpha)V_{WP}^n$	33.8	27.6	30.6	30.8	33.6	36.0
Line 7, $(1 - \alpha)V_{BPI}^n$	22.1	21.9	23.1	24.6	26.0	22.8
Line 8, $(1 - \alpha)V_{BI}^n$	3.0	3.8	3.8	3.4	3.7	4.4
Line 9, $\alpha(1 - \alpha)(W^{p,CPS} - W^{n,CPS})^2$	7.7	7.4	6.1	8.0	8.0	8.6

Notes: (1) The variance decomposition relies on data from the LRD and CPS and is based on equation (7) in the text. (2) All figures are computed on an hours-weighted basis. (3) PW denotes production workers, and NPW denotes nonproduction workers.

Table 3. Accounting for the 1975-1986 Change
in the Total Variance of Hourly Manufacturing Wages

1975-1986 Change in Variance of Hourly Wages	14.13
1975-1986 Change in the St. Dev. of Wages	1.28

Percentage of Wage Variance Change Accounted for by:

With time-varying α

Variance of PW wages within plants	1.7
Variance of Mean PW wages between plants	14.6
Variance of Mean PW wages between industries	3.0
Variance of NPW wages within plants	39.7
Variance of Mean NPW wages between plants	24.0
Variance of Mean NPW wages between industries	6.7
Wage Gap between Mean PW and Mean NPW wages	10.2

With α fixed at its 1975 value

Variance of PW wages within plants	3.0
Variance of Mean PW wages between plants	19.6
Variance of Mean PW wages between industries	4.9
Variance of NPW wages within plants	24.6
Variance of Mean NPW wages between plants	14.4
Variance of Mean NPW wages between industries	4.9
Wage Gap between Mean PW and Mean NPW wages	8.6

See notes to Table 2.

Table 4. Wage Differentials and Between-Plant Dispersion by Observable Plant Characteristics

	Production Workers			Nonproduction Workers		
	Time Series Averages					
	Mean Wage Diff.	Between Plant S.D.	Fraction of Hours Worked	Mean Wage Diff.	Between Plant S.D.	Fraction of Hours Worked
Plant Size:						
1-19 employees	-1.08	3.16	0.06	-1.92	5.99	0.05
20-49	-1.27	2.91	0.09	-0.89	6.37	0.08
50-99	-1.35	2.73	0.10	-0.77	5.74	0.09
100-249	-1.15	2.63	0.18	-0.93	4.84	0.16
250-499	-0.84	2.70	0.16	-0.85	4.24	0.14
500-999	-0.01	2.86	0.14	-0.42	3.78	0.13
1000-2499	1.41	2.94	0.12	0.43	3.61	0.14
2500-4999	3.18	2.59	0.07	1.65	3.51	0.09
5000+	3.65	2.19	0.08	2.71	2.65	0.13
Plant Age:						
0-4 years	-1.19	3.19	0.12	-0.78	4.92	0.11
5-9	-1.26	3.05	0.12	-0.78	5.14	0.12
10+	0.45	3.52	0.75	0.26	4.64	0.77
Ownership Type:						
Single Plant	-1.46	2.84	0.27	-0.81	6.07	0.21
Multi-Plant	0.53	3.15	0.73	0.22	4.12	0.79
Energy Costs as % of Sales:						
less than 1%	-0.15	3.26	0.45	0.07	4.72	0.53
1% to 5%	-0.13	3.08	0.46	-0.25	4.53	0.40
more than 5%	1.24	3.14	0.09	0.44	4.26	0.07
Degree of Product Specialization:						
Specialized	-1.05	2.98	0.39	-0.56	5.43	0.31
1st quartile	0.40	3.06	0.16	0.23	4.40	0.14
2nd quartile	0.48	3.12	0.15	-0.14	4.23	0.18
3rd quartile	0.73	3.22	0.16	0.33	4.34	0.19
4th quartile	1.17	3.21	0.14	0.79	4.05	0.18
Capital Intensity:						
1st quintile	-2.43	2.74	0.20	-1.77	5.23	0.15
2nd quintile	-1.00	2.90	0.20	-0.81	4.61	0.21
3rd quintile	-0.05	2.98	0.20	-0.18	4.42	0.22
4th quintile	0.84	3.18	0.20	0.59	4.54	0.21
5th quintile	2.63	3.40	0.20	1.76	4.51	0.20

Table 4 (continued)

1963-1986 Changes

	Mean Wage Diff.	Between Plant S.D.	Fraction of Hours Worked	Mean Wage Diff.	Between Plant S.D.	Fraction of Hours Worked
Plant Size:						
1-19 employees	0.06	0.97	-0.02	0.67	1.04	-0.03
20-49	-0.56	0.53	0.01	-0.32	0.73	0.00
50-99	-0.60	0.51	0.02	-0.88	0.19	0.01
100-249	-0.51	0.65	0.04	-0.76	0.48	0.02
250-499	-0.28	0.89	0.02	-0.63	0.45	0.01
500-999	0.02	1.13	0.00	-0.02	0.72	-0.00
1000-2499	0.99	1.77	-0.02	0.21	0.83	-0.01
2500-4999	2.21	1.35	-0.01	1.10	1.10	-0.01
5000+	2.22	1.27	-0.02	1.21	1.18	0.00
Plant Age (1972-86 Change):						
0-4 years	0.97	1.53	-0.13	0.62	-0.74	-0.11
5-9	-0.48	0.65	0.03	-0.52	-0.08	0.03
10+	-0.21	0.91	0.10	-0.07	0.81	0.08
Ownership Type:						
Single Plant	-0.58	0.73	-0.10	-0.43	0.81	-0.09
Multi-Plant	-0.06	1.45	0.10	-0.02	1.05	0.09
Energy Costs as % of Sales:						
less than 1%	0.02	1.31	-0.24	0.00	0.70	-0.22
1% to 5%	-0.18	1.19	0.19	0.22	0.96	0.19
more than 5%	0.26	1.62	0.06	0.21	1.06	0.03
Degree of Product Specialization:						
Specialized	0.38	1.16	0.31	0.12	-0.05	0.30
1st quartile	0.59	1.25	-0.05	0.68	0.84	-0.02
2nd quartile	0.41	1.27	-0.06	-0.01	0.82	-0.04
3rd quartile	0.85	1.46	-0.08	0.51	0.97	-0.11
4th quartile	0.83	1.61	-0.12	1.17	1.06	-0.14

Notes: (1) Time-series averages are based on 1963, 1967, 1972, 1977, 1982, and 1986 observations, except for age values which exclude 1963 and 1967. (2) All statistics are computed on an hours-weighted basis. (3) The product specialization ratio equals the fraction of plant shipments accounted for by the primary five-digit product class. Completely specialized denotes plants with a ratio of one. The other rows report figures by pooled-sample quartiles of the product specialization ratio for nonspecialized plants. The pooled-sample quartile values are .53, .72, and .90. (3) Capital intensity is defined as the ratio of book value of capital to total employment. Reported statistics by capital intensity quintiles were constructed for each birth cohort/year cell and then averaged across cells.

Table 5. Decomposition of Wage Dispersion Across Plants
into Between-Type and Within-Type Components

| | *Time-Series Averages* | | | | |
	Total Std Dev.	Between Std Dev.	Within Std Dev.	Contribution of Between	Contribution of Within
			Production Workers		
Plant Characteristic:					
Size	3.21	1.65	2.74	0.26	0.74
Age	3.50	1.00	3.35	0.08	0.92
Ownership	3.21	0.88	3.08	0.08	0.92
Energy Cost	3.21	0.41	3.18	0.02	0.98
Prod. Spec.	3.21	0.83	3.10	0.07	0.93
			Nonproduction Workers		
Plant Characterstic:					
Size	4.63	1.35	4.44	0.09	0.91
Age	4.78	0.60	4.74	0.02	0.98
Ownership	4.63	0.42	4.62	0.01	0.99
Energy Cost	4.63	0.27	4.62	0.00	1.00
Prod. Spec.	4.63	0.48	4.61	0.01	0.99

| | *Time-Series Changes* | | | | |
	Tot. Chg. Variance	Change in Between	Change in Within	Contribution of Between	Contribution of Within
			Production Workers		
Plant Characteristic:					
Size	8.22	2.94	5.28	0.36	0.64
Age	6.18	0.64	5.54	0.10	0.90
Ownership	8.22	0.22	8.00	0.03	0.97
Energy Cost	8.22	0.13	8.09	0.02	0.98
Prod. Spec.	8.22	0.09	8.13	0.01	0.99
			Nonproduction Workers		
Plant Characteristic:					
Size	7.34	1.52	5.77	0.21	0.79
Age	5.12	0.34	4.78	0.07	0.93
Ownership	7.34	0.11	7.23	0.02	0.98
Energy Cost	7.34	-0.04	7.38	-0.01	1.01
Prod. Spec.	7.34	0.28	7.06	0.04	0.96

Notes: (1) Time-series averages are based on observations for 1963, 1967, 1972, 1982 and 1986 except for age values, which do not include 1963 and 1967. (2) Time-series changes are for 1963 to 1986 except for age values, which are for 1972 to 1986. (3) Decompositions are carried out on an hours-weighted basis.

Table 6. Mean Wage Differentials by Plant Size and Year

Plant Size	1963	1967	1972	1977	1982	1986	Mean
			Year				
			Production Workers				
1-19 employees	-0.93	-0.85	-1.08	-1.12	-1.66	-0.87	-1.08
20-49	-1.04	-0.88	-1.16	-1.42	-1.54	-1.60	-1.27
50-99	-1.10	-1.03	-1.24	-1.52	-1.50	-1.70	-1.35
100-249	-0.94	-0.99	-1.08	-1.26	-1.16	-1.46	-1.15
250-499	-0.70	-0.80	-0.87	-0.96	-0.71	-0.98	-0.84
500-999	-0.03	-0.10	-0.08	-0.07	0.23	-0.01	-0.01
1000-2499	1.07	0.99	1.16	1.38	1.83	2.06	1.41
2500-4999	2.15	2.11	2.85	3.64	3.96	4.36	3.18
5000+	2.49	2.52	3.37	4.13	4.68	4.71	3.65
All Plants	7.86	8.18	8.51	8.80	8.82	9.18	8.56
			Nonproduction Workers				
1-19 employees	-2.90	-1.13	-1.43	-1.22	-2.59	-2.23	-1.92
20-49	-1.05	-0.50	-0.75	-0.75	-0.92	-1.38	-0.89
50-99	-0.49	-0.41	-0.70	-0.84	-0.82	-1.37	-0.77
100-249	-0.56	-0.74	-0.87	-1.06	-1.04	-1.31	-0.93
250-499	-0.46	-0.67	-0.92	-1.06	-0.89	-1.09	-0.85
500-999	-0.26	-0.54	-0.46	-0.64	-0.32	-0.29	-0.42
1000-2499	0.47	0.03	0.35	0.44	0.62	0.67	0.43
2500-4999	1.14	0.82	1.60	2.22	1.88	2.24	1.65
5000+	2.07	2.04	2.57	3.06	3.25	3.28	2.71
All Plants	12.01	12.76	13.08	13.17	13.02	13.73	12.96

Notes: (1) The mean hourly wage differential is the difference between the mean hourly wage for the indicated size class and the overall mean wage. (2) The mean hourly wage differential is computed on an hours-weighted basis. (3) The all plants row reports the overall mean hourly wage, (4) The last column reports the simple mean of the six annual observations. (5) Plant size is computed as the employment-weighted mean over all sample observations on the plant.

Table 7. Hours-Weighted Mean Plant Size (Number of Employees)

Production Worker Hours

Year

	1963	1967	1972	1977	1982	1986
Mean Based on Current Size	1678	2097	1538	1467	1242	1406
Mean Based on Average Size	1734	1827	1568	1480	1357	1458

Nonproduction Worker Hours

Year

	1963	1967	1972	1977	1982	1986
Mean Base on Current Size	2606	3393	2045	1968	2097	2443
Mean Based on Average Size	2637	2879	2302	2199	2261	2442

Notes (1) Each panel reports the hours-weighted mean plant size for a particular measure of plant size. Current size is simply the number of employees (production workers plus nonproduction workers) in the current year. Average size is the employment-weighted mean number of employees for the plant, where the average is computed over all sample observations on the plant.

Table 8. Observable and Unobservable Components of Changes in the Plant-Wage Structure, Manufacturing Workers, 1963-1986

	Total Change 1963-1986	Observable Quantities	Observable Wages	Unobservables
Production Workers				
Std. Deviation	1.26	-0.12	0.74	0.64
90-10 diff.	3.74	-0.20	2.47	1.46
90-50 diff.	3.32	0.33	1.82	1.17
50-10 diff.	0.41	-0.53	0.65	0.29
Production Workers (controlling only for plant size)				
Std. Deviation	1.26	-0.05	0.51	0.80
90-10 diff.	3.74	0.38	1.45	1.90
90-50 diff.	3.32	0.88	1.22	1.22
50-10 diff.	0.41	-0.50	0.23	0.68
Nonproduction Workers				
Std. Deviation	0.81	-0.14	0.31	0.51
90-10 diff.	2.90	-0.13	1.31	1.72
90-50 diff.	1.46	0.05	0.71	0.70
50-10 diff.	1.44	-0.18	0.60	1.02

Notes: (1) See text for a description of the regression specifications that underlie the calculations in this table.

Table 9. Mean Wage Differentials by Plant Size and Year (1982 Dollars),
Controlling for Plant and Industry Characteristics

			Year			
	1975	1977	1979	1982	1984	1986
			Production Workers			
Plant Size						
1-19 employees	-0.46	-0.26	-0.64	-1.05	-0.32	-0.41
20-49	-0.40	-0.53	-0.75	-0.89	-0.70	-1.09
50-99	-0.33	-0.65	-0.69	-0.88	-0.76	-1.20
100-249	-0.37	-0.53	-0.60	-0.65	-0.53	-1.00
250-499	-0.23	-0.40	-0.35	-0.37	-0.14	-0.59
500-999	-0.05	-0.13	-0.05	0.05	0.33	-0.07
1000-2499	0.29	0.35	0.51	0.69	1.16	0.99
2500-4999	0.97	1.18	1.33	1.47	1.78	1.75
5000+	0.57	0.97	1.24	1.63	1.52	1.62
			Nonproduction Workers			
Plant Size						
1-19 employees	-1.82	-1.86	-1.46	-3.08	-1.56	-2.56
20-49	(0.11)	-0.64	0.18	-0.49	-0.33	-0.79
50-99	0.45	-0.33	0.03	0.18	0.00	-0.50
100-249	-0.11	-0.27	-0.34	-0.04	-0.03	-0.40
250-499	-0.22	-0.39	-0.46	0.03	0.18	-0.45
500-999	-0.32	-0.37	-0.23	0.21	0.51	-0.01
1000-2499	0.05	0.46	0.06	0.73	1.03	0.90
2500-4999	0.88	1.91	1.17	1.00	2.03	2.22
5000+	0.98	1.50	1.06	1.46	1.37	1.58

Notes: (1) The mean hourly wage differential is the difference between the mean hourly wage for the indicated size class and the overall mean wage for the year. The mean hourly wage for each size-year entry is the coefficient from plant-level regressions with size class and year interacted, controlling for other plant and industry characteristics. (2) All regressions are estimated by OLS on a pooled time-series cross-sectional data set containing plant-level observations for the years 1975, 1977, 1979, 1982, 1984, and 1986. The other controls are (i) class variables for four-digit industry, plant age, region, ownership type, product specialization, energy intensity and (ii) industry-level workforce controls (percent female, mean experience, mean education), industry-level import penetration ratio and export share, union density and capital-labor ratio. Union density is from the CPS at the two-digit level. The import and export variables are from the NBER Trade Data Set at the four-digit level. (3) Standard errors of coefficients for production workers range from 0.11 and 0.12. Standard errors for nonproduction workers range from 0.24 and 0.29.
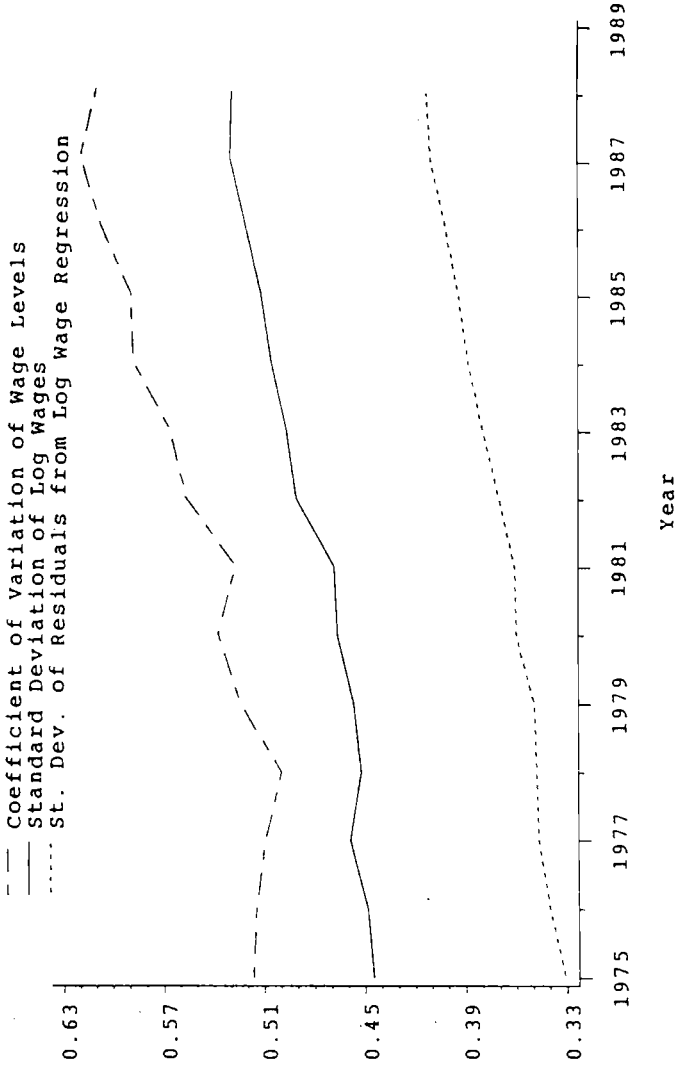
Table 10. Regression Estimates of the Impact of Imports, Exports, and Union Density
on the Plant-Wage Structure

	Production Workers			Nonproduction Workers		
	Import Penetr. Ratio	Export Share of Shipments	Union Density	Import Penetr. Ratio	Export Share of Shipments	Union Density
Mean	0.079	0.083	30.48	0.079	0.083	30.48
Std Dev	0.093	0.103	13.53	0.093	0.103	13.53
Coefficient on:						
Variable itself	-0.674	0.684	-0.0027	-1.314	2.603	0.0074
	(0.155)	(0.153)	(0.0016)	(0.468)	(0.459)	(0.0047)
Variable-squared			-0.00047			-0.0001
			(0.00002)			(0.00005)
Interacted with:						
Plant Size	0.235	0.083	-0.0002	-0.221	0.064	0.0005
	(0.018)	(0.008)	(0.00009)	(0.053)	(0.024)	(0.00027)
Plant Age	-0.780	0.196	0.008	0.033	-1.496	-0.001
	(0.097)	(0.091)	(0.0007)	(0.293)	(0.274)	(0.002)
Energy Costs as % of Sales:						
less than 1%	0.783	-4.029	0.005	0.403	-3.498	-0.014
	(0.146)	(0.146)	(0.0009)	(0.437)	(0.436)	(0.0027)
1% to 5%	0.651	-2.182	0.014	0.392	-2.308	-0.003
	(0.145)	(0.143)	(0.0009)	(0.435)	(0.426)	(0.003)
Product Specialization:						
1st quartile	0.407	-0.269	0.011	0.330	1.464	0.007
	(0.125)	(0.113)	(0.0008)	(0.371)	(0.336)	(0.002)
2nd quartile	0.692	-0.436	0.0008	0.675	-0.815	-0.016
	(0.138)	(0.114)	(0.0009)	(0.411)	(0.340)	(0.003)
3rd quartile	0.231	-0.292	0.005	1.221	0.121	0.001
	(0.133)	(0.119)	(0.0009)	(0.396)	(0.354)	(0.003)
4th quartile	-0.098	0.241	0.004	0.466	1.296	-0.004
	(0.145)	(0.123)	(0.001)	(0.431)	(0.366)	(0.003)

Notes: (1) All regressions are estimated by (hours-weighted) OLS on a pooled time-series cross-sectional data set containing observations on manufacturing plants for the years 1975, 1977, 1979, 1982, 1984, and 1986. The import penetration ratio (imports divided by imports plus shipments) and the export shares are generated from the NBER Trade Data set at the 4-digit level. The union density measures are 2-digit measures from various CPS tabulations. The other controls are (i) year, four-digit industry and (nine) region effects, (ii) plant age, ownership type, product specialization, energy cost share, (iii) a quartic
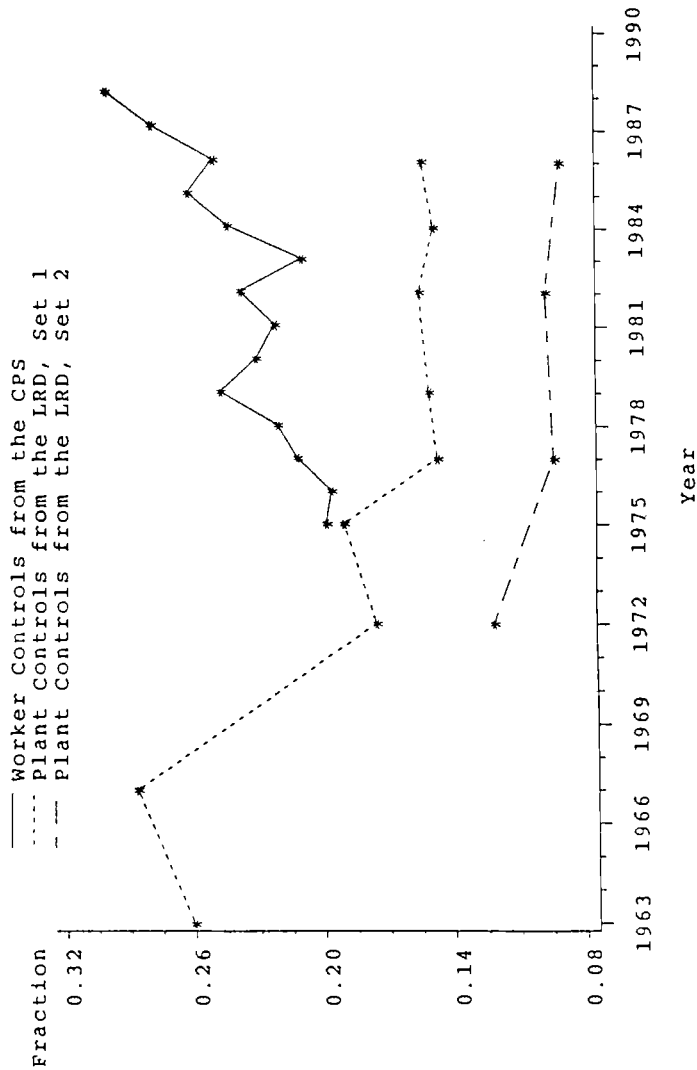
in plant size, and (iv) two-digit industry-level workforce composition variables (percent female, mean experience, mean education), and four-digit industry measures of the capital-labor ratio. (2) Standard errors of coefficients are in parentheses. (3) Omitted group for energy intensity is more than 5%, omitted group for product specialization is completely specialized. (4) Regression coefficients and standard errors for size are multiplied by 10^3.

Figure 1
Inequality Measures for Hourly Wages in U.S. Manufacturing, 1975-1988

--- Coefficient of Variation of Wage Levels
--- Standard Deviation of Log Wages
..... St. Dev. of Residuals from Log Wage Regression

Source: Authors' calculations from the March files of the Current Population Survey.

Figure 2. Inter-Industry Wage Differentials, Production Workers
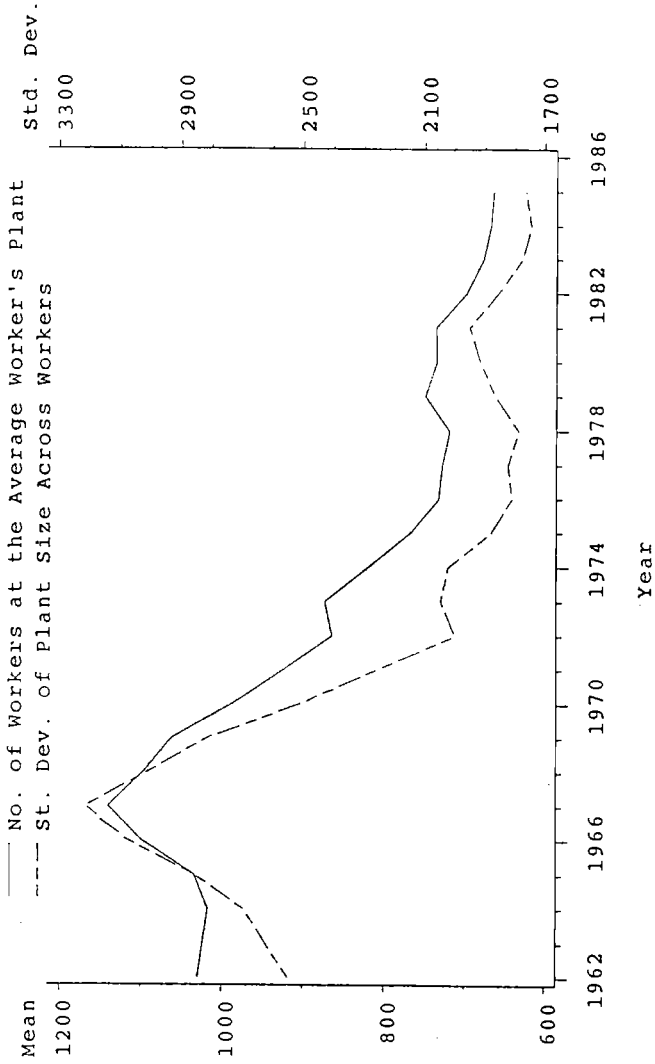Fraction of Variance Not Accounted for by:

——— Worker Controls from the CPS
-·-·- Plant Controls from the LRD, Set 1
— —— Plant Controls from the LRD, Set 2

See text for a description of regression controls.

Figure 3
Union Membership Density in the United States, 1960–1988

-- Private Sector, BLS Data
— Private Sector, CPS Data
---- Manufacturing Sector, CPS Data

Year
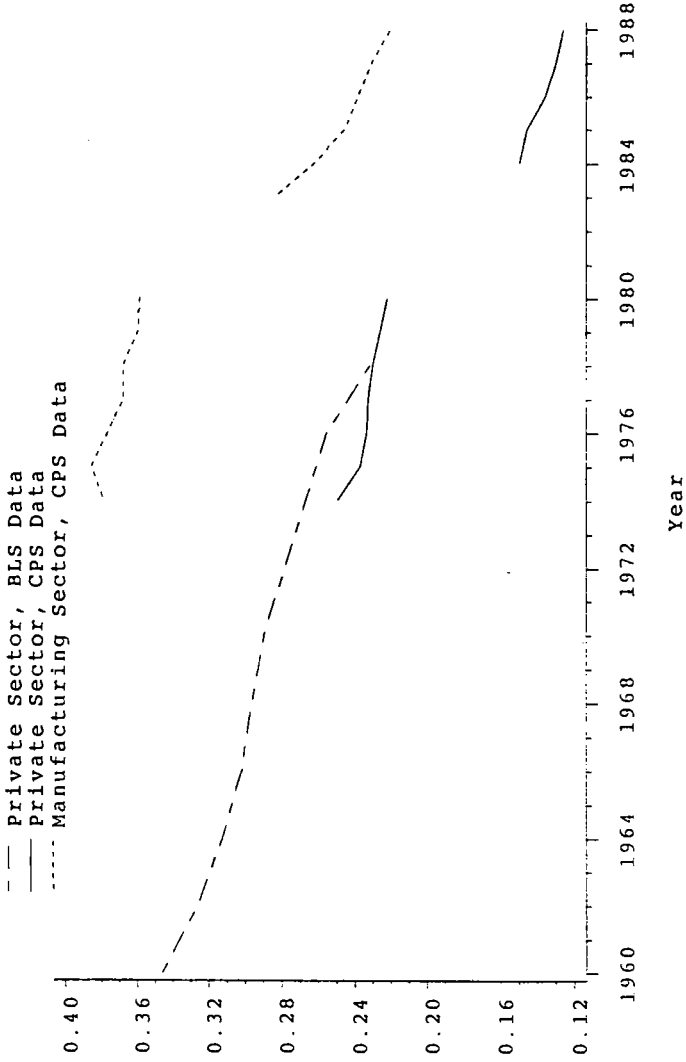
Sources: See text.

Figure 4.A
The Dist. of Employees by Plant Size in the U.S. Private Sector, 1962-1985

Mean

―――― No. of Workers at the Average Worker's Plant

――― St. Dev. of Plant Size Across Workers

Std. Dev.

Year

Source: Authors' estimates based on the Longitudinal Reseach
Datafile and County Business Patterns Data.

Figure 4.B
The Distribution of Employees by Plant Size in U.S. Manufacturing, 1962-1986

——— No. of Workers at the Average Worker's Plant
– – – St. Dev. of Plant Size Across Workers
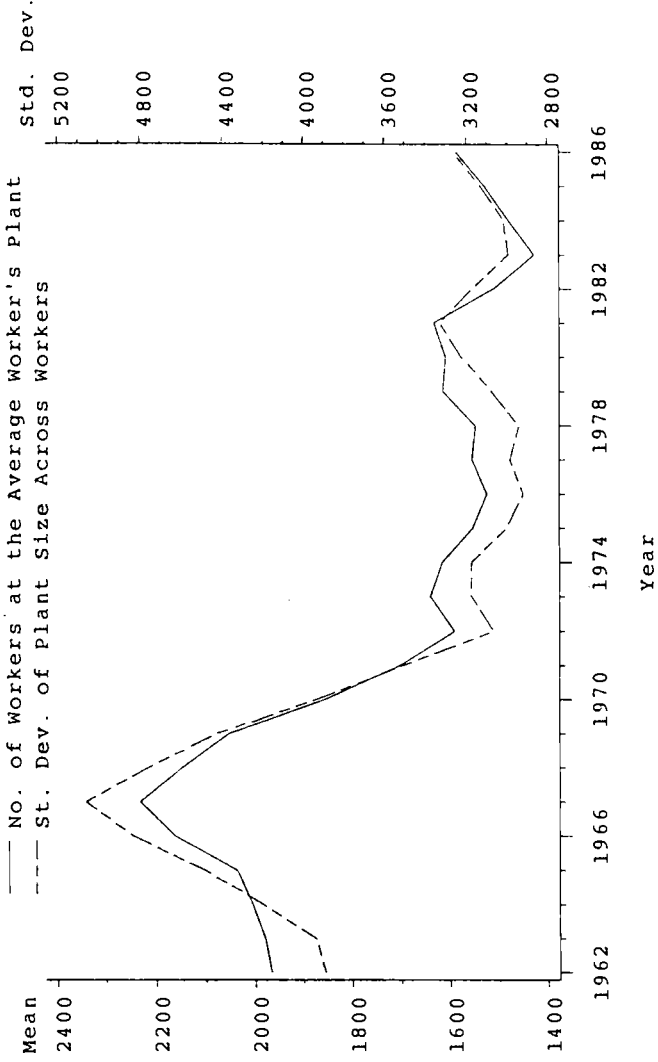
Source: Authors' estimates based on the Longitudinal Research Datafile and County Business Patterns Data.

Figure 5. Hourly Wages by Size Class
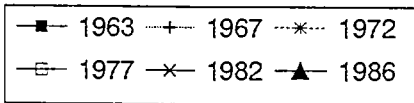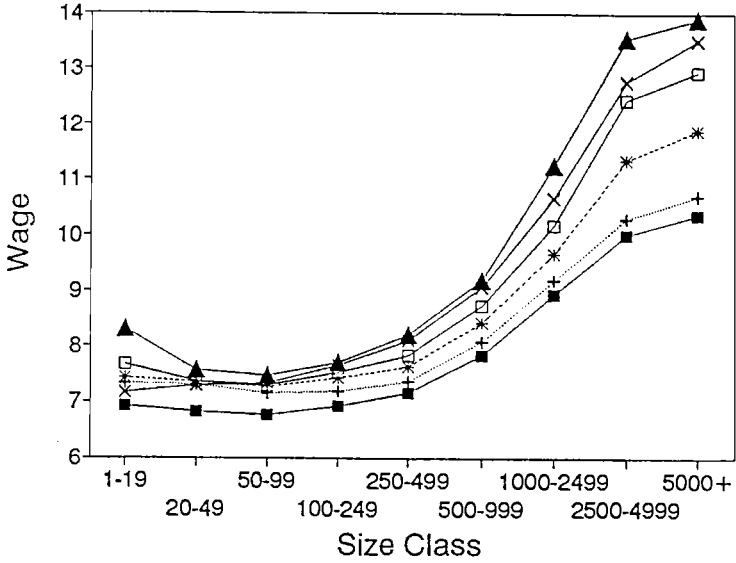## Production Workers (1963-86)

Figure 6. Hourly Wages by Size Class
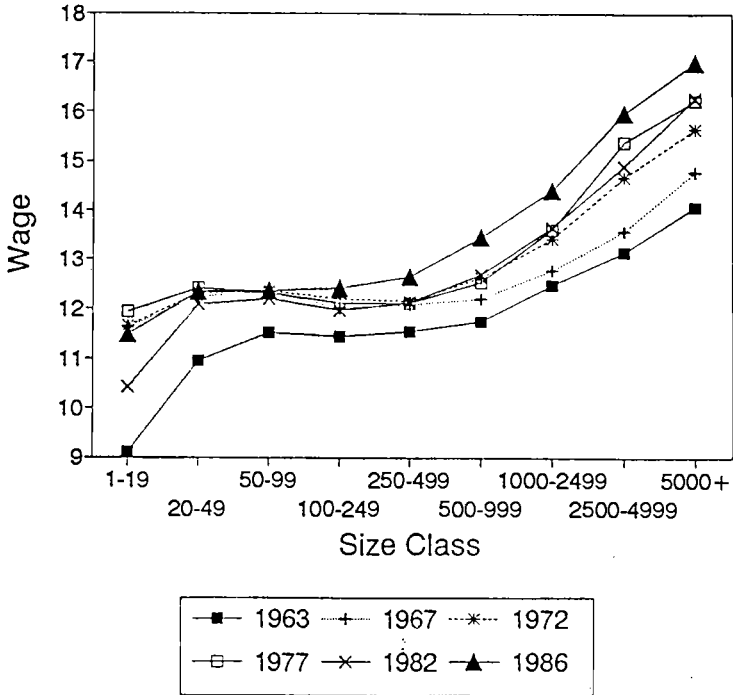
Nonproduction Workers (1963-86)

Legend:
- ■— 1963 ···+··· 1967 ···*··· 1972
- ─□─ 1977 ─×─ 1982 ─▲─ 1986

Figure 7

A. Actual 90-10 Differential

B. Observable Characteristics

C. Observable Plant Wages

D. Unobservables