

# *Industrial & Labor Relations Review*

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*Volume 59, Issue 3*

2006

*Article 3*

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## Unionization and Input Flexibility in U.S. Manufacturing, 1973-1996

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## Abstract

Input flexibility, as measured by the ability of firms to vary input demand in the face of changes in input prices, is an important dimension of labor market flexibility. Using a new dataset, the authors analyze the impact of unionization on input flexibility in U.S. manufacturing from 1973 to 1996, a period in which production was arguably becoming more flexible due to deep changes in the U.S. industrial relations system and in the broad macroeconomic environment. The authors quantify the effects of unionization on input flexibility by estimating elasticities of substitution between a broad range of labor and non-labor inputs, controlling for unionization. The pattern that emerges is more complex than that suggested by other research. In particular, low unionization apparently is associated with greater flexibility in the use of labor inputs but less flexibility in the use of non-labor inputs.

**KEYWORDS:** unionization and input flexibility

## UNIONIZATION AND INPUT FLEXIBILITY IN U.S. MANUFACTURING, 1973 – 1996

ELISABETTA MAGNANI and DAVID PRENTICE\*

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Input flexibility, as measured by the ability of firms to vary input demand in the face of changes in input prices, is an important dimension of labor market flexibility. Using a new dataset, the authors analyze the impact of unionization on input flexibility in U.S. manufacturing from 1973 to 1996, a period in which production was arguably becoming more flexible due to deep changes in the U.S. industrial relations system and in the broad macroeconomic environment. The authors quantify the effects of unionization on input flexibility by estimating elasticities of substitution between a broad range of labor and non-labor inputs, controlling for unionization. The pattern that emerges is more complex than that suggested by other research. In particular, low unionization apparently is associated with greater flexibility in the use of labor inputs but less flexibility in the use of non-labor inputs.

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**I**n this paper we address the issue of whether and to what extent trade unions limit input flexibility, the ability of firms to substitute away from an input in the face of changes in input prices. While many studies have estimated price elasticities of demand for different inputs, few have empirically investigated how trade unions affect input flexibility. As a result, varying views about how trade unions affect flexibility have been asserted without systematic general empirical evidence. The need for consistent empirical evidence on whether and to what extent trade unions limit input

flexibility is particularly acute during a period in which it is argued that a “new” system of industrial relations (Kochan et al. 1994) has dramatically transformed the way U.S. labor organizations and management face increased domestic and international competition.

This paper begins by extending and developing the approach to modeling taken by Ramey (1989). Using a newly compiled dataset of input consumption, prices, and unionization for U.S. 3-digit manufacturing industries from 1973 to 1996, we estimate input demand equations, specifically controlling for the effects of unionization. To analyze whether falling unionization led to increased flexibility, we

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Data and programs used to generate this paper’s results are available upon request from David Prentice at Department of Economics and Finance, La Trobe University, VIC, 3086, Australia; d.prentice@latrobe.edu.au.

compare the cross- and own-price elasticities of demand and Morishima elasticities of substitution under high and low unionization.

In presenting a general framework suitable for quantifying the impact of unionization on input flexibility, we make three contributions to the literature. First, we provide estimates of the effects of unionization on specific inputs' responsiveness to shocks and on the substitutability of inputs. Because we use new and more extensive data and techniques than the existing studies of Freeman and Medoff (1982) and Maki and Meredith (1987), our estimates update those provided by this literature. Second, the state-of-the-art analytical techniques we employ allow us to draw conclusions regarding the direction of causality between unionization and flexibility. Third, we use a broader set of inputs suggested by recent work in economics and industrial relations that provides a rich characterization of how unions affect flexibility. In particular, we estimate demand equations for overtime hours, employment of both production and non-production workers, and inventories, as well as energy and raw materials.

The U.S. manufacturing industry over the past three decades provides a particularly good case study with which to evaluate the effects of unionization on input flexibility. There is evidence that in the period under investigation, the U.S. manufacturing sector experienced deep changes in the organization of work and in the set of norms regulating industrial relations. For instance, this was a period characterized by the introduction and diffusion of Just-in-Time production methods, with their strategic use of inventories and working hours. Also, unions dramatically changed their role in the collective bargaining process, often playing an important and active part in renovating production and organizational methods within the firm. Finally, as illustrated in Magnani and Prentice (2003), despite the substantial decline in aggregate unionization, union coverage of U.S. manufacturing industries differed considerably in both levels and how it changed during the pe-

riod under investigation, a fact that we will exploit to estimate union effects on input flexibility.

### What Is Input Flexibility?

The popular interpretation of flexibility for a firm, as illustrated by the discussion in OECD (1986), is the ability to deal with all forms of turbulence in the firm's environment. Many features have been argued to characterize a flexible firm. These include ease in adding or removing employees from the firm and in reassigning existing employees to different jobs within the firm. Technological and organizational changes such as Just-in-Time production, outsourcing, and information technology have also been argued to affect firm flexibility. All of these, we argue, ultimately affect the firm's costs. In this connection, efforts to formally quantify flexibility have taken two directions associated with different origins of turbulence. Flexibility in response to output demand fluctuations was formalized by Stigler (1939), and subsequently by Marschak and Nelson (1962), in terms of the slope of the (U-shaped) average cost curve around its minimum point.<sup>1</sup> A second source of turbulence for the firm is input prices. Flexibility in response to fluctuating input prices can be identified with input substitutability, for which there exist two extensively discussed measures.

### Measuring Input Flexibility

A common measure of the sensitivity of a variable  $x$  (say the quantity demanded of input  $i$ ) to changes in the variable  $w$  (say the price of input  $j$ ) is an elasticity, that is, the ratio between the relative change of variable  $x$  ( $\Delta x/x$ ) and the relative change of variable  $w$  ( $\Delta w/w$ ). Two sets of elasticities have been proposed for estimating input substitutability. The first set is composed of

<sup>1</sup>Magnani and Prentice (2004) performed the first econometric estimation of output flexibility.

the traditional own- and cross-price elasticities of input demands (in which  $x$  is the quantity of the input of interest and  $w$  is the price of the input in the own-price elasticity or the price of another input in the cross-price elasticity). These measures are summarized by the formula

$$(1) \quad \varepsilon_{ij} = \frac{\partial x_i}{\partial w_j} * \frac{w_j}{x_i},$$

where  $x_i$  and  $w_j$  are as defined above. If  $i = j$ , we have an own-price elasticity, and otherwise we have a cross-price elasticity. If the cross-price elasticity is positive, the inputs are considered substitutes; if it is negative, they are considered complements. If the cross-price elasticity is zero, the quantity of an input is considered unresponsive to the price of another input.

The relationship between these elasticities and input flexibility is as follows. The greater a firm's ability to substitute away from an input in response to a price increase, the more flexible the firm. Hence, the greater the absolute value of the own-price elasticity, the more flexible the firm. In addition, for the cross-price elasticities, the more positive the cross-price elasticity, the greater the flexibility of the firm. The relationship between flexibility and a zero cross-price elasticity, however, is unclear. Lack of responsiveness could result from the two inputs being technologically unrelated or very tight restrictions on their use. To assess the relationship between unionization and flexibility, we compare the own- and cross-price elasticities of input demands when unionization is high and low.

Using elasticities as measures of flexibility has the advantage that these measures are simple and intuitively appealing. However, there are two disadvantages. First, the different elasticities capture different aspects of input flexibility. With more than a few inputs, getting an overall picture of changes in flexibility may be difficult unless the changes are relatively simple. Second, there is an existing economic framework for considering flexibility (formally, the curvature of the isoquant summarized by the marginal rate of substitution), and

the connection between these elasticities and standard economic models of production is not straightforward.

We therefore consider the second main type of elasticity, which is the elasticity of substitution. The elasticity of substitution measures the sensitivity of the relative use of inputs in response to a change in their relative prices. In particular, the  $x$  variable is the quantity of one input relative to the quantity of another input and the  $w$  variable is the ratio of their prices. This measure captures the change in the relative use of inputs in a cost-minimizing bundle as the relative prices of those inputs change (more formally, the marginal rate of substitution between the inputs).

Different measures of the elasticity of substitution have been proposed. First, the Allen-Uzawa elasticity of substitution has been extensively used to classify input pairs as substitutes or complements (including Freeman and Medoff [1982] and Maki and Meredith [1987], which we discuss below). However, Blackorby and Russell (1989) and Chambers (1988) instead advocated using the Morishima elasticity of substitution (as did Sharma [2002] more recently). This is because the Allen-Uzawa elasticity fundamentally measures the responsiveness of the quantity of one input to a change in the price of another, weighted by the cost share of the input for which the price has changed. In particular, it equals the cross-price elasticity multiplied by the cost share of input  $j$ . Hence it does not directly measure the change in the relative use of the inputs in response to price changes. However, the Morishima elasticity does consider changes in the use of both inputs (and hence their relative change). In particular, the Morishima elasticity of substitution between inputs  $i$  and  $j$ ,  $\sigma_{ij}^M$ , is defined and calculated as

$$(2) \quad \sigma_{ij}^M = \frac{\partial \ln \left[ \frac{x_i(w,y)}{x_j(w,y)} \right]}{\partial w_j} = \varepsilon_{ij} - \varepsilon_{jj},$$

where  $\varepsilon_{ij}$  is the constant output elasticity of demand for input  $i$  with respect to the price of input  $j$ . Including the changes in the quantities of both inputs in response

to a change in an input price makes it possible to capture the relative change in input use.

Inputs are considered Morishima-substitutes if the elasticity of substitution is positive and Morishima-complements if the elasticity is negative. Morishima-complementarity means that the firm responds to an increase in the price of an input by reducing the relative quantity of another input. A zero elasticity of substitution is consistent with either both inputs being unresponsive to price changes or mild complementarity between inputs whereby the decline in the quantity of one input is offset by a decrease in the quantity of the other. Note that Morishima elasticities of substitution are not symmetric by construction.

The relationship between Morishima elasticities of substitutes and flexibility is as follows. The greater the ability to increase the relative quantity of an input in response to an increase in the price of another input, the more flexible the firm. Hence, if two inputs are Morishima-substitutes, the greater the value of the elasticity of substitution, the more flexible the firm. If two inputs are Morishima-complements, the smaller the absolute value of the elasticity, the more flexible the firm.

To assess the relationship between unionization and flexibility, we compare the Morishima elasticities when unionization is high and low. Increasing substitutability is interpreted to mean increased flexibility. However, if a decline in unionization results in two inputs switching from a zero value to Morishima-complements, the interpretation is unclear. If complementarity has increased, then flexibility has decreased. But if previously both inputs were unresponsive to price changes, then Morishima-complementarity is consistent with a form of increased flexibility.

Besides being derived from microeconomic theory, the Morishima elasticity of substitution provides a simpler summary statistic to capture changes in input flexibility. In this paper, we report the own- and cross-price elasticities of input demand as well as the Morishima elasticities of substitution.

### Input Flexibility and Unionization

While numerous studies have reported the cross-price elasticities and elasticities of substitution between labor and other inputs (as summarized in Hamermesh 1993) and many others have examined the effects of unionization (see Booth 1995), only two studies have analyzed the effect of unionization on elasticities of substitution (Freeman and Medoff 1982; Maki and Meredith 1987). This is most likely because of the difficulty of getting data matching input used with unionization.

Freeman and Medoff (1982) estimated Allen-Uzawa elasticities of substitution for U.S. manufacturing using two different datasets. The first was a cross-section of 2-digit industries by state for 1972, with three factors: production worker hours, non-production worker employment (converted to hours), and capital. The second was plant-level data on production worker and non-production worker hours only. Performing their estimations using both CES and Translog technology, they concluded that "substitution between production labor and other inputs is generally lower in union than nonunion settings" (Freeman and Medoff 1982:220–21). Maki and Meredith (1987) applied a similar analysis for two factors—capital and number of employees—to Canadian industry-level data for the years 1971–81 and came to a similar conclusion.

These studies, however, are limited in three respects. First, wage rates and unionization are both possibly endogenous, but OLS was used in both papers. Second, as highlighted by Freeman and Medoff (1982), the direction of causality is uncertain. While input inflexibility may be the result of union-negotiated conditions of work, it may also be the case that industries with input inflexibility are preferable for unions to organize since, for example, higher wages have smaller effects on employment. This is also an issue for Maki and Meredith (1987), for which the sample period consistently featured high

unionization for total manufacturing. Third, these studies used very limited sets of inputs, neglecting the multiple margins of adjustment firms may use in response to input price turbulence.

### **Margins of Adjustment and Unionization**

The need to consider a broader set of margins of adjustment than the traditional inputs of capital, energy, raw materials, and employment is suggested by recent literature in both economics and industrial relations. Bresnahan and Ramey (1994) emphasized that manufacturers have multiple margins with which to respond to output shocks, including several ways to adjust labor inputs. Several authors have documented how unions have traded off various margins in contract negotiations (for example, Kochan et al. 1994).

To implement this specification strategy, we proceed as follows. First, we include inventories following Ramey (1989), who argued strongly that inventories can also be considered within the traditional cost function framework. In particular, a firm can substitute inventories for other factors such as capital and labor. Ramey documented how using a buffer stock system rather than a Just-in-Time system may require fewer man-hours. In addition, in the short run firms can draw on inventories, including raw materials, work-in-progress, and finished goods, to respond to short-run changes in demand, rather than adjust other factors. Finally, the shift to the Just-in-Time production methods, featuring minimal raw material inventories and intermediate good inventories, has cost implications and ambiguous effects on input flexibility. Although costs are lower, very short-term input flexibility possibly decreases, since the firm does not have buffers when subject to input price shocks.

Second, rather than just treat employment as measured by one dimension, such as number of employees or total hours, we consider three possible labor margins. In the first instance, we distinguish between production workers and non-production

workers, as they are two distinct classes of workers with different skills and characteristics. This is seen most strikingly in the abundant literature on the employment effects of technological change.<sup>2</sup> Importantly, unionization patterns differ considerably across the two types of workers, and the effects of unionization are also likely to differ.

In the second instance, we distinguish between standard weekly work hours and overtime hours. We do so for several reasons. Overtime hours, by law, are paid at a premium of at least 50% over the standard hourly rate. Furthermore, Hart (1987:102–4) argued that overtime and standard hours may differ in productivity and even in the nature of the tasks performed. Finally, Trejo (1993) demonstrated that although there is substantial noncompliance with the law, unions act to enforce it and bargain for higher premiums. The effect of these practices is lower reliance on overtime, which implies that plants with unions tend to have higher employment and therefore higher fixed labor costs, such as pensions and health benefits (Freeman and Medoff 1984) and other fringe benefits (Trejo 1993). This encourages firms to seek adjustments in the labor inputs first by changing hours of work per employee rather than by hiring and firing workers. As surveyed by Trejo (1993), unionized workers work longer hours, although they often receive higher hourly wages in return (Earle and Pencavel 1990).

A final reason for considering multiple margins for labor adjustment is that unions have been willing to include them as trade-offs in bargaining with management. In

<sup>2</sup>There is widespread evidence that technological change in the past few decades has widely increased the demand for skilled (non-production) workers and caused a substitution away from unskilled (production) workers. Furthermore, significant cuts in management have resulted from firms adopting "High-Performance Workplace Organizations" (HPWOs) and reducing their long-term commitment to their employees (see, for example, Cappelli 1992).

particular, in recent times the literature has documented widespread evidence that the bargaining agenda, in response to increased domestic and international market competition, has expanded, with labor and management in union firms agreeing to negotiate employment security as a quid pro quo for concessions in wage levels (for example, pay for new hires), the use of layoffs, productivity improvement, and improvements in flexibility (for example, McDuffie 1995; Ichniowski et al. 1997; Berg et al. 1995). For instance, in the U.S. steel industry the unions have directly participated in the implementation of changes in the internal organization of work toward both functional flexibility (introducing job rotation, for example) and numerical flexibility (relaxation of layoff rules) (Osterman 1999:173).

#### Modeling Strategy and Empirical Specification

Having chosen a broader set of inputs among those that contribute to flexibility and are affected by unionization, we now specify a cost function that allows us to capture the effects of unionization on input flexibility and that yields estimable input demand equations and estimable elasticities of substitution.

We follow Ramey (1989) in characterizing the form of the plant cost function  $C = C(p; K, Q)$ , where  $p$  is the  $6 \times 1$  vector of input prices for the six margins,  $K$  is the capital stock of the plant, and  $Q$  is the output of the plant.<sup>3</sup> Because we attempt to identify the effect of unionization in structural equations estimated with aggregate industry data, a functional form for the

plant cost function that easily aggregates up to the industry is required. As argued by Ramey (1989), under certain conditions the Generalized McFadden (GM) functional form does this and has various desirable properties (Diewert and Wales 1987), such as being quadratic in output. In particular, the plant cost function is

$$(3) \quad C_i = Q_i \left\{ \sum_{k=2}^6 \sum_{j=2}^6 \gamma_{kj} \frac{p_k p_j}{2 p_1} + K_i \sum_{j=1}^6 \kappa_j p_j + \sum_{j=1}^6 (\tau_{1j} t + \tau_{2j} t^2) p_j \right\} + Q_i^2 \sum_{j=1}^6 \theta_j p_j + \sum_{j=1}^6 (\alpha_j + \tau_{\alpha j} t + \zeta_{ij}) p_j,$$

where  $Q_i$  is the output of the  $i^{\text{th}}$  plant and  $t$  is a time trend, introduced both to capture technological change and productivity growth and to deal with some identification issues, as is discussed below. In (3) both  $j$  and  $k$  are indexes that refer to the various margins considered in this study,  $j, k = 1$  (energy), 2 (production worker employment), 3 (overtime hours), 4 (raw materials), 5 (inventories), and 6 (non-production worker employment). Since we are interested in short-run flexibility, capital  $K_i$  is treated as a fixed input. The  $\zeta$  terms represent shocks to the production function that are observed by the firm but unobserved by the econometrician (for example, technological shocks).

At this point it is worth remarking that following the labor literature, we set the price of employment of production workers as the standard weekly wage  $w_H * H$ , the product of hourly wage  $w_H$  and weekly standard hours per worker  $H$ , and the price of overtime as  $1.5w_H$ . Note that because of the way the prices are calculated, the inclusion of both standard hours and overtime hours would produce severe multicollinearity.

Applying Shephard's Lemma to the cost function in (3) yields a system of six demand equations. In the restricted Generalized McFadden cost function, linear homogeneity of the input demand equations is assured by treating one of the inputs asymmetrically, as the denominator of a price

<sup>3</sup>Even when the firm and union bargain over work conditions, the firm can be thought of as minimizing a restricted cost function, with the restrictions deriving from the agreement with the union (Eberts and Stone 1991). Importantly, estimating a cost function avoids the problems with using a profit equation, as assumptions do not have to be made on the degree of market power.

ratio. We choose energy for this role, and the energy demand equation for the  $i^{\text{th}}$  plant is

$$(4) \quad E_i = \alpha_1 + \tau_{\alpha 1} t - Q_i \left\{ \sum_{k=2}^6 \sum_{j=2}^6 \gamma_{kj} \frac{p_k p_j}{p_1^2} - K_i \kappa_1 - \tau_{11} t - \tau_{21} t^2 \right\} + \theta_1 Q_i^2 + \zeta_{1i}.$$

For the other five inputs  $X_n$  ( $n = 2$  (production worker employment), 3 (overtime hours), 4 (raw materials), 5 (inventories), 6 (non-production worker employment)), the demand equation takes the form

$$(5) \quad X_{in} = \alpha_n + \tau_{\alpha n} t - Q_i \left\{ \sum_{k=2}^6 \sum_{j=2}^6 \gamma_{nj} \frac{p_j}{p_1} + \kappa_n K_i + \tau_{1n} t + \tau_{2n} t^2 \right\} + \theta_n Q_i^2 + \zeta_{in},$$

where  $X_{in}$  is the quantity demanded by plant  $i$  of input  $n$ ,  $n = 2, 3, 4, 5, 6$ . We now characterize the cost function of the unionized plant.

### The Cost Function of the Unionized Plant

The effects of unionization on the cost function are captured in the cost function by introducing a set of union premium coefficients,  $\mu_\alpha$ ,  $\mu_{j\kappa}$ ,  $\mu_{j\theta}$ ,  $\mu_{j\gamma}$ . These premium coefficients combine both price and technological effects, as permitted by the data. The cost function for a unionized plant is

$$(6) \quad C_i = Q_i \left\{ \sum_{k=2}^5 \sum_{j=2}^5 (\gamma_{kj} + \mu_{kj}) \frac{p_k p_j}{2p_1} + K_i \sum_{j=1}^5 (\kappa_j + \mu_{j\kappa}) p_j + \sum_{j=1}^5 (\tau_{1j} t + \tau_{2j} t^2) p_j \right\} + Q_i^2 \sum_{j=1}^5 (\theta_j + \mu_{j\theta}) p_j + \sum_{j=1}^5 (\alpha_j + \mu_{j\alpha} + \tau_{\alpha j} t + \zeta_{ij}) p_j.$$

Input demands for the unionized plant are derived once again using Shephard's Lemma and are of the same form as the set of equations (4)–(5), with the addition of the premium terms. Note that,

consistent with the institutional arrangements for U.S. production workers, we assume that each plant is either unionized or nonunionized.

### Empirical Specifications

To construct industry demand equations by aggregating both union and non-union plants, we must slightly augment the assumptions made by Ramey (1989), who did not distinguish between plants in this way. These are summarized in Appendix 1. Suppressing the industry and time subscripts, the estimable demand equations for energy  $E$  and input  $X_n$ , ( $n = 2$  (production worker employment), 3 (overtime hours), 4 (raw materials), 5 (inventories) and 6 (non-production worker employment)), respectively, are

$$(7) \quad \begin{aligned} \bar{E} &= \alpha_1 + \mu_{\alpha,1} s + \tau_{\alpha 1} t + \\ \bar{Q} &\left\{ \sum_{h=2}^6 \sum_{j=2}^6 (\gamma_{hj} + \mu_{\gamma hj} s) \frac{p_h p_j}{p_1^2} - \bar{K}(\kappa_1 + s\mu_{\kappa 1}) - \tau_{11} t - \tau_{21} t^2 \right\} + \\ &(\theta_1 + \mu_{\theta,1} s) \bar{Q}^2 + \beta_{11} D_{m,n} + \beta_{12} s D_{m,n} + v_1 \end{aligned}$$

$$(8) \quad \begin{aligned} \bar{X}_n &= \alpha_n + \mu_{\alpha,n} s + \tau_{\alpha n} t + \\ \bar{Q} &\left\{ \sum_{h=2}^6 \sum_{j=2}^6 (\gamma_{hj} + \mu_{\gamma hj} s) \frac{p_j}{p_1} + \bar{K}(\kappa_n + \mu_{\kappa n} s) + \tau_{1n} t + \tau_{2n} t^2 \right\} + \\ &(\theta_n + s\mu_{\theta,n}) \bar{Q}^2 + \beta_{n1} D_{m,n} + \beta_{n2} s D_{m,n} + v_n, \end{aligned}$$

where  $\bar{Q}$  and  $\bar{K}$  are the (industry-specific) average output and capital per plant, respectively. The variable  $s$  is the share of unionized plants (estimated by the unionization rate). Note that the structural parameters ( $\alpha s$ ,  $\gamma s$ ,  $\kappa s$ ,  $\tau s$ ,  $\theta s$ , and  $\mu s$ ) are all identifiable. The only reduced form parameters in these equations are the betas on the industry dummies and union-

ization rates.<sup>4</sup> Once we have estimates of the parameters of these equations, we can construct the own- and cross-price elasticities of demand and therefore the Morishima elasticities of substitution.

### Data and Estimation Strategy

As no single U.S. dataset reports both industry unionization rates and the price and quantity data required for input demand equations, we construct such a dataset by aggregating and reconciling data from four sources. The unionization data are collected from the Current Population Survey, and the other industry data are collected mainly from the NBER-CES Manufacturing Industry Database (described in Bartelsman and Gray 1996), Employment and Earnings (Bureau of Labor Statistics, various), and County Business Patterns (U.S. Census Bureau). Because these different sources use different industry classification schemes that change over time, we construct a single encompassing 3-digit classification—the Extended Census Industry Classification Scheme (ECIC). Using concordances that are compatible with the ECIC, yielding an unbalanced panel of 1,458 observations for U.S. manufacturing ECIC industries observed annually from 1973 to 1996. For all years except two, there are between 59 and 68 industries per year. (For a published introduction to this dataset with a listing of the ECIC, see Magnani and Prentice [2003], and for a more detailed account see Magnani and Prentice [2001].)

However, using industry-level data makes it difficult to address potential sample selection problems. For instance, U.S. manufacturing declined over the sample period. The surviving firms in these industries at the end of the period may not be representative of the sample at the start of the period. If unions organize less flexible plants and a shock (such as increased competition

due to globalization) results in the closure of less flexible plants, exit of unionized and rigid firms will lead to a negative correlation between unionization and input flexibility. This means that it is important that we allow for endogenous unionization and control for technological differences across industries and over time. Furthermore, it limits the conditions under which we can infer causality from unionization to changes in flexibility. We address these issues further below.

### Definitions and Sources of the Main Variables

The definitions and sources of each of the dependent and explanatory variables and summary statistics are reported in Table 1. All variables are taken, with at most minor adjustments, directly from the sources except for overtime hours, the three wage rates, and unionization, which are transformed as described below.

*Overtime hours and wage per overtime hour.* Because the wage per overtime hour is per hour, the dependent variable must be number of hours, which is calculated by multiplying the number of overtime hours per production worker by the number of production workers. The wage per overtime hour is calculated by multiplying a standard hourly rate by the minimum legally required 1.5. The standard hourly rate is calculated by dividing average weekly earnings by the sum of the reported weekly average hours and 0.5 times weekly overtime hours. This effectively deflates the estimated hourly earnings for overtime payments.

*Wage per production worker.* This is calculated as the product of the average weekly standard hours (average weekly hours less average overtime hours) and the wage per standard hour.

*Wage per non-production worker.* While this is not reported directly in the NBER-CES database, it is estimated using variables in the this dataset. We compute the wage per non-production worker as the ratio of non-production worker payroll to employment, where non-production worker payroll is

<sup>4</sup>Because of their likely collinearity,  $\beta_{12}$  and  $\beta_{n2}$  are not estimated.

Table 1. Summary Statistics, Definitions, and Sources.

Variable	Definition (Source)	Mean	Std. Dev.	Min.	Max.
<b>Dependent Variables:</b>					
Energy (millions of dollars/10)	Expenditure on energy <sup>a</sup> (NBER)	674.87	1,020.53	14.13	8,053.17
Production Worker Employment (thousands)	Annual average production workers employed (EEH)	187.30	182.38	15.5	1,064.7
Overtime Hours	Average weekly overtime hours multiplied by production worker employment (EEH)	663.75	662.01	20.04	5,349.64
Raw Materials (millions of dollars/100)	Expenditure on materials <sup>a</sup> (NBER)	171.86	228.55	5.28	1,990.17
Inventories (millions of dollars/10)	End of year inventories (NBER)	445.54	506.88	29.43	4,296
Non-Production Worker Employment (thousands)	Difference between all employees and production worker employment (NBER)	70.50	78.54	3	426.3
<b>Explanatory Variables:</b>					
Price of Energy	1987 = 1 <sup>a</sup> (NBER)	0.91	0.28	0.19	1.59
Wage per Standard Hour	Average weekly hours multiplied by average hourly earnings divided by the sum of average weekly hours plus overtime hours multiplied by 0.5 (EEH)				
Wage per Production Worker (dollars/10)	Average weekly hours multiplied by Wage per standard hour (EEH)	31.41	6.91	16.21	56.13
Wage per Overtime Hour	Wage per standard hour multiplied by 1.5 (EEH)	12.63	2.59	6.92	20.74
Price of Raw Materials	1987 = 1 <sup>a</sup> (NBER)	0.93	0.24	0.26	1.61
Price of Inventories	Price of shipments deflator: 1987 = 1 (NBER)	0.92	0.26	0.27	1.82
Wage per Non-Production Worker (hundreds of dollars)	Annual payroll for non-production workers (NBER-CES) divided by non-production worker employment	2.76	0.42	1.68	4.16
Shipments (millions of dollars/10)	Value (NBER)	3,300.21	3,626.61	179.10	46,021.25
Capital (millions of dollars/10)	Value (NBER)	1,495.09	1,581.57	47.62	8,869.11
Union	Share of employed workers covered by a union agreement (CPS)	0.31	0.16	0.02	1.00
Number of Plants	Number of plants (CBP)	4,723.96	6,620.22	79	51,742
Time Trend	(1973 = 3)				
<b>Instrumental Variables:</b>					
Share Black	Share of employees that are black (CPS)	0.11	0.06	0	0.45
Average Age	Average age of all employees (CPS)	38.43	1.99	31.02	48.54
Share of Women	Share of female employees (CPS)	0.29	0.15	0	0.83
Share Young	Share of employees with age < 30 (CPS)	0.20	0.08	0.03	0.66
Share Old	Share of employees with age > 40 (CPS)	0.20	0.05	0	0.62
Share College	Share of employees with a college degree (CPS)	0.29	0.13	0	0.82
Share <High School	Share of employees with less than a high school degree (CPS)	0.26	0.13	0.02	0.69
Real Oil Price	Producer price index for crude petroleum (deflated) (SA)	58.65	22.11	31.78	120.57
Defense Outlays	National defense outlays (SA)	273.15	39.28	217.4	338.4
Procurement	Total military prime contracts (SA)	148.80	27.39	113.02	198.29
Republican	Equals 1 if Republican president	0.66	0.47	0	1
First Years Rep.	Equals 1 if first two years of Republican administration	0.32	0.46	0	1
First Years Dem.	Equals 1 if first two years of Democrat administration	0.17	0.37	0	1

Notes: All values are in 1987 dollars. All dependent variables, shipments, and capital are divided by the number of plants. NBER = NBER-CES manufacturing industry database; EEH = Employment and Earnings; CBP = County Business Patterns; CPS = Current Population Survey; SA = Statistical Abstract of the United States.

<sup>a</sup>Calculated following Barrelsman and Gray (1996).

calculated by subtracting production worker payroll from total payroll, while non-production worker employment is the difference between total employment and production worker employment.<sup>5</sup>

*Union.* Unionization is measured in the standard way as the ratio of number of workers covered by a trade union agreement to the total industry work force. This is calculated from the outgoing rotations of the CPS for 1983 to 1996 and the May CPS, from the NBER, for 1973 to 1980. Because a union status question is asked only of a quarter of the May CPS sample in 1981 and is not asked at all in 1982, there is no direct estimate for these years. Industry estimates are compiled by aggregating individual records using CPS individual weights. Where compatible estimates exist for 1980 and 1983, we interpolate estimates for the missing years. The NBER May CPS sample does not include the coverage variable for 1973 to 1977 (Gray 1999). To estimate coverage for these years, we scale union membership rates for these years by the ratio of union coverage to union membership for 1978.

Measures of other input quantities are obtained by dividing the expenditure by the corresponding input price. Finally, because the nature of some ECIC industries changes when there are major changes in the underlying Standard Industrial Classifications, the series from 1973 to 1982 and 1983 on, for example, may not be compatible. Incompatibilities are noted. If, for an ECIC, the statistics across two (or more) periods are not compatible, different fixed effects are used for different periods (104 in total).

<sup>5</sup>A caveat also applies to the frequency of collection of our industry data. Year-end employment measures may underestimate the extent of job "churning," arguably a widespread by-product of corporate restructuring, particularly in the 1980s and 1990s. (See Osterman [2000] and Davis, Haltiwanger, and Schuh [1997] for evidence at the firm level, and Mishel et al. [2001] for evidence at the household level.)

### Estimation Strategy and Causation Issues

There are three sets of variables that we consider potentially endogenous. Shipments is potentially endogenous because unobserved shocks to input demands, such as strikes, are also likely to be correlated with actual shipments. Furthermore, unionization may be endogenous. For example, unobservable shocks to production worker demand may well influence the extent of unionization. Also, as discussed above, technological aspects of industries are possible influences on the industry-specific unionization rate: entry and exit of plants, which will differ by industry, can systematically alter the share of plants with a given level of flexibility and unionization.

This last argument has important implications for our study. In the first place, it suggests that we need to conceptually distinguish between the *contemporaneous* relationship between unionization at time  $t$  and flexibility at time  $t$ , and the *lagged* link between unionization at time  $t$  and input flexibility at time  $t + n$ , where  $n$  is the number of periods it takes for rigid plants to exit the market. Note that the argument above relies on the hypothesis that there is a *causal relationship* between *high unionization* at time  $t$  and *low flexibility* at time  $t$ , but it also implies that high unionization (and low flexibility) at time  $t$  will cause high flexibility (and low unionization) at time  $t + n$  after the closures of rigid (and unionized) plants have taken place. While our specification clearly focuses on the issue of whether there is a causal contemporaneous relationship between unionization and input flexibility, further study, possibly with a dataset more suitable for capturing entry and exit of plants, is necessary to test for the existence of a lagged causal link between flexibility and unionization.

The third set of variables that may be endogenous is the input prices themselves, for the standard reasons. The efficient contracts literature suggests this problem is particularly acute for wage rates negotiated between unions and firms (see McDonald and Solow 1985). Hausman tests for

endogeneity supported instrumenting for all of these variables.

Unless we solve these endogeneity problems, we cannot properly address the questions at hand—whether unionization significantly affects input flexibility, and whether the decline in unionization has led to the increase in input flexibility that is celebrated as one important factor in manufacturing's response to the challenges of the new economic environment of the 1980s and 1990s. We obtain consistent estimates for the set of equations (7) and (8) using Three-Stage-Instrumental-Variables methodology. In particular, as instruments for unionization, we use industry-specific work force characteristics such as average age, education, the proportion of workers older than 40, the proportion of workers younger than 30, and the proportion of female and black employees, all compiled from the CPS. Although we cannot claim that the profound changes in the structure of the work force observed in the past few decades are totally exogenous with respect to input demands, a number of supply-side factors and economy-wide phenomena clearly exogenous to the parameters being studied (for example, the "feminization" of the work force, population aging, technological change, and the related greater demand for educated workers) have contributed to such changes. We use the Ramey (1989) instruments for shipments (measures of defense expenditure, price of crude oil, and political dummies) as they are incontrovertibly exogenous. In order to further control for exogenous industry-specific variations over time, we include (once) lagged values of the input prices, shipments, capital, and plant numbers. These instruments are combined in the same form as in equations (7) and (8), effectively creating lagged values of these variables. A lag length of one was chosen because of the difficulties of creating compatible lagged values when industry classifications changed.

Table 1 reports the definitions and summary statistics for the Ramey (1989) and worker characteristics instrumental variables. To assess the performance of the

instruments, we follow Shea (1997) in calculating the partial  $R^2$ s for each endogenous explanatory variable. These vary between 7% and 74%, with the bulk between 30% and 70%, which suggests that in most cases our instruments are relevant (but not too relevant) as well as exogenous. The partial  $R^2$ s are summarized in Table A.1 in Appendix 2.

Our use of panel data opens up two additional strategies to control for unobservable determinants of input demands. One way is to include a set of explanatory variables that control for technological differences across industries and time.<sup>6</sup> For this purpose, we also include a time trend that captures both technological shocks common to industries over time and, through interactions with average industry output, their industry-specific impact. A second way is to include industry fixed effects in our structural equations, which will also control for any unobservable determinants of input demands that are constant over time—for example, aspects of technology that do not change over time.

The availability of these methods is particularly important given that during our sample period there were substantial declines in unionization. Note, however, that the trends and fixed effects control for effects on the levels and trends in input demands. The trend and fixed effect coefficients are not used to calculate the elasticities that are used to measure flexibility. However, by controlling for these other influences, it is more likely we will have better estimates of the elasticities. If there was a technological shock that affected firms of different flexibility levels differently and it affected different industries at different times (as reflected by changes in unionization), we will still have an endogeneity and causality problem. Using a dataset similar

<sup>6</sup>Note that although controlling for changes in employee benefits, such as health insurance, would be highly desirable, the industry-level data needed for that purpose do not exist.

Table 2. Regression Results of Input Demand Equations.

<i>Selected Explanatory Variables</i>	<i>Production Worker Employment</i>	<i>Raw Materials</i>	<i>Overtime Hours</i>	<i>Inventories</i>	<i>Non-Production Worker Employment</i>
<b>Input Prices:</b>					
Production Worker Employment	-0.0015*** (-4.76)	0.0018* (1.92)	0.0042*** (5.00)	-0.0008 (-0.58)	-0.0023*** (-3.92)
Raw Materials	0.0018* (1.92)	-0.0303*** (-2.73)	-0.0038 (-1.37)	0.0456*** (4.97)	-0.0024 (-0.64)
Overtime Hours	0.0042*** (5.00)	-0.0038 (-1.37)	-0.0122*** (-5.18)	-0.0010 (-0.26)	0.0068*** (3.74)
Inventories	-0.0008 (-0.58)	0.0456** (4.97)	-0.0010 (-0.26)	-0.0446*** (-3.38)	0.0113*** (2.75)
Non-Production Worker Employment	-0.0023*** (-3.92)	-0.0024 (-0.64)	0.0068*** (3.74)	0.0113*** (2.75)	-0.0063** (-2.21)
<b>Scale Variables:</b>					
Capital	0.0002 (0.37)	0.0073*** (6.28)	-0.0165*** (-9.71)	0.0043* (1.67)	-0.0025*** (-3.62)
Shipments <sup>2</sup>	0.0002 (0.80)	-0.0026*** (-4.45)	0.0077*** (9.54)	0.0017 (1.34)	0.0015*** (4.40)
<b>Unionization:</b>					
Union	0.1863*** (8.37)	0.2789*** (4.76)	0.3929*** (4.26)	0.4995*** (3.78)	0.0896*** (2.77)
Union*(Wage per Production Worker)	0.0033*** (4.71)	-0.0075*** (-3.33)	-0.0093*** (-4.90)	0.0061* (1.86)	0.0048*** (3.42)
Union*(Price of Raw Materials)	-0.0075*** (-3.33)	-0.0693** (-2.42)	0.0163** (2.47)	0.0014 (0.06)	0.0072 (0.76)
Union*(Wage per Overtime Hour)	-0.0093*** (-4.90)	0.0163** (2.47)	0.0264*** (5.00)	-0.0100 (-1.10)	-0.0140*** (-3.19)
Union*(Price of Inventories)	0.0061* (1.86)	0.0014 (0.06)	-0.0100 (-1.10)	0.0190 (0.59)	-0.0180* (-1.81)
Union*(Wage per Non-Production Worker)	0.0048*** (3.42)	0.0072 (0.76)	-0.0140*** (-3.19)	-0.0180* (-1.81)	0.0124* (1.72)
Union*Capital	-0.0008 (0.58)	-0.0229*** (-6.43)	0.0350*** (6.35)	-0.0309*** (-3.85)	0.0053*** (2.59)
Union*Shipments <sup>2</sup>	-0.0001 (-0.17)	0.0138*** (8.69)	-0.0147*** (-6.32)	0.0032 (0.89)	-0.0034*** (-3.70)
<b>Trend and Cycle:</b>					
Time	0.0014*** (4.43)	0.0039*** (5.07)	0.0027** (2.12)	0.0063*** (3.51)	0.0012*** (2.69)
Shipments*Time	0.0010*** (6.61)	-0.0011*** (-2.68)	-0.0003 (-0.49)	0.0087*** (9.35)	0.0007*** (2.68)
Shipments <sup>2</sup> *Time	-0.00004*** (-8.79)	-0.00001 (-0.52)	0.00006*** (3.09)	-0.0004*** (-11.90)	-0.00004*** (-4.95)
R <sup>2</sup>	0.96	0.99	0.92	0.96	0.96
Observations	1,458	1,458	1,458	1,458	1,458

Notes: t values in parentheses. All input prices are relative to the price of energy.

\*Statistically significant at the .10 level; \*\*at the .05 level; \*\*\*at the .01 level.

to the one used in this study, however, in Magnani and Prentice (2003) we demonstrated that neither technological change

nor increased domestic or global competition was a statistically significant contemporaneous determinant of the decline in

Table 3. Input Demand Elasticities (High Unionization).

Input Demand	Prices							
	Energy	Production Worker Employment	Overtime Hours	Non-Production Worker Employment	Raw Materials	Inventories	Other Variables	
							Shipments	Union
Energy	-0.05*** (0.01)	-0.06 (0.04)	0.10** (0.05)	-0.03*** (0.01)	0.08*** (0.01)	-0.05*** (0.01)	0.10*** (0.03)	0.53*** (0.11)
Production Worker Employment	-0.03 (0.03)	0.05 (0.06)	-0.04 (0.07)	-0.004 (0.01)	-0.05*** (0.01)	0.06*** (0.01)	0.16*** (0.03)	1.06*** (0.13)
Overtime Hours	0.02** (0.01)	-0.02 (0.05)	0.02 (0.05)	0.004 (0.01)	0.03*** (0.01)	-0.04*** (0.01)	0.06* (0.03)	0.66*** (0.14)
Non-Production Worker Employment	-0.22*** (0.07)	-0.11 (0.32)	0.15 (0.40)	-0.06 (0.13)	0.06 (0.09)	0.18* (0.10)	0.27* (0.14)	1.08** (0.44)
Raw Materials	0.34*** (0.04)	-0.71*** (0.14)	0.64*** (0.17)	0.04 (0.05)	-1.13*** (0.08)	0.83*** (0.06)	-0.42*** (0.07)	0.51** (0.21)
Inventories	-0.08*** (0.02)	0.32*** (0.08)	-0.35*** (0.09)	0.04* (0.02)	0.31*** (0.02)	-0.24*** (0.03)	0.44*** (0.05)	0.75*** (0.19)

Notes: Standard errors in parentheses. All elasticities are evaluated at variable sample averages except Union, which is set equal to 0.47.

\*Statistically significant at the .10 level; \*\*at the .05 level; \*\*\*at the .01 level.

unionization in U.S. manufacturing. That finding suggests that the present study, because it controls for technological factors that have complex effects on unionization, has a greater chance of inferring causation between unionization and flexibility.

Finally, in estimating the model of input demand equations (7)–(8), the only restrictions we impose are those required for symmetry across equations.

### Estimation Results

Table 2 reports 3SLS estimates of the system of input demand equations (7)–(8). Because most coefficients are for variables that are products of two or three prices, output, and often unionization, it is hard to assess their general reasonableness. Coefficients on relative prices along the diagonal of the input prices section are negative, consistent with theory. However, the relative prices terms interacting with unionization are largely positive, leaving the net effect dependent on the unionization level. Importantly, at the sample average (union mean = 0.31), all the direct price effects are

negative, implying well-behaved input demand functions. Capital is negatively correlated with non-production worker employment, which casts some doubt on the ability of this variable to measure skilled labor. Also worth noting is that if we ignore the time trend variables by setting  $t$  equal to 0, the net effect of  $Shipments^2$  on the demand for inputs is consistently positive. Interestingly, when we consider the impact of  $Shipments^2$  interacted with a time trend for the demand for production workers, the effect of output diminishes, suggesting a decreasing trend in the responsiveness to output changes.

### Estimates of the Effect of Unionization on Input Flexibility

We now focus on the cross- and own-price elasticities and the Morishima elasticities of substitution. To assess the effect of declining unionization on input flexibility, we consider the results of the following experiment. As average unionization varies from 0.47 in 1973 to 0.19 in 1996, we recalculate the elasticities with these differ-

Table 4. Input Demand Elasticities (Low Unionization).

<i>Input Demand</i>	<i>Prices</i>							
	<i>Energy</i>	<i>Production Worker Employment</i>	<i>Overtime Hours</i>	<i>Non-Production Worker Employment</i>	<i>Raw Materials</i>	<i>Inventories</i>	<i>Other Variables</i>	
							<i>Shipments</i>	<i>Union</i>
Energy	-0.03 (0.02)	-0.10 (0.07)	0.19*** (0.07)	-0.04*** (0.02)	-0.01 (0.01)	-0.01 (0.02)	0.11*** (0.03)	0.22*** (0.04)
Production Worker Employment	-0.03 (0.02)	-0.53*** (0.12)	0.62*** (0.13)	-0.08*** (0.02)	0.01 (0.02)	0.01 (0.02)	0.18*** (0.03)	0.43*** (0.05)
Overtime Hours	0.03*** (0.01)	0.41*** (0.09)	-0.48*** (0.10)	0.06*** (0.02)	-0.01 (0.01)	-0.02 (0.02)	0.10*** (0.03)	0.27*** (0.06)
Non-Production Worker Employment	-0.30*** (0.11)	-2.14*** (0.53)	2.52*** (0.64)	-0.52** (0.21)	-0.07 (0.14)	0.51*** (0.15)	0.52*** (0.13)	0.44** (0.18)
Raw Materials	-0.04 (0.05)	0.17 (0.23)	-0.12 (0.28)	-0.04 (0.08)	-0.79*** (0.11)	0.82*** (0.09)	-0.21*** (0.06)	0.20** (0.09)
Inventories	-0.02 (0.03)	0.05 (0.13)	-0.18 (0.14)	0.11*** (0.03)	0.31*** (0.03)	-0.27*** (0.05)	0.42*** (0.05)	0.30*** (0.08)

*Notes:* Standard errors in parentheses. All elasticities are evaluated at variable sample averages except Union, which is set equal to 0.19.

\*Statistically significant at the .10 level; \*\*at the .05 level; \*\*\*at the .01 level.

ent values of unionization. This is a relatively crude experiment, as wages (at the very least) would also change with such a change in unionization. However, since we do not observe wages for all industries at these points in time, it seems preferable to consider one change, without also estimating union effects on wages. The results of this experiment are reported in Tables 3 and 5 for “high” unionization rates and in Tables 4 and 6 for “low” unionization.<sup>7</sup>

<sup>7</sup>At average values for all variables, the own-price elasticities are all negatively signed and statistically significant at the 1% level, and the patterns of substitutability are plausible, suggesting complementarity between production and non-production workers, and substitutability between overtime and both employment types. All statistically significant Morishima elasticities are positive except between non-production workers and both production workers and energy. When instruments are not used, the signs and statistical significance of the elasticities are similar (results of this exercise available upon request). However, the own-price elasticities for all inputs except energy and inventories tend to be lower (though not when unionization is high). Also, the output elasticities tend to be higher and the unionization elasticities lower. Similarly, the Morishima elasticities tend to be lower with low unionization. Finally,

The own- and cross-price elasticities under high unionization are reported in Table 3 and under low unionization in Table 4. All own-price elasticities on labor inputs are substantially smaller under high unionization. The own-price elasticities on production worker employment and overtime are positive at high unionization but do not differ from zero at statistically significant levels. The own-price elasticity on raw materials is lower if unionization is low, but the other own-price elasticities are largely the same. There is an interesting change in the statistical significance and size of the cross-price elasticities between high and low unionization. If unionization is high, the cross-price elasticities between the three labor margins are all not significantly different from zero, whereas the elasticities with respect to other prices are mostly statistically significant (if not usually large). At low levels of unionization, the reverse

when unionization is high, more Morishima elasticities for labor inputs are statistically significantly different from zero. In total, this would have suggested too low an impact of unionization on flexibility.

Table 5. Morishima Elasticities of Substitution (High Unionization).

<i>Inputs(j)</i>	<i>Inputs(i)</i>					
	<i>Energy</i>	<i>Production Worker Employment</i>	<i>Overtime Hours</i>	<i>Non-Production Worker Employment</i>	<i>Raw Materials</i>	<i>Inventories</i>
Energy		0.03* (0.02)	0.07*** (0.02)	-0.17** (0.08)	0.39*** (0.04)	-0.03 (0.03)
Production Worker Employment	-0.10 (0.08)		-0.07 (0.11)	-0.16 (0.30)	-0.75*** (0.15)	0.27*** (0.10)
Overtime Hours	0.08 (0.07)	-0.05 (0.12)		0.13 (0.43)	0.62*** (0.18)	-0.37*** (0.10)
Non-Production Worker Employment	0.03 (0.14)	0.06 (0.13)	0.07 (0.14)		0.10 (0.15)	0.10 (0.14)
Raw Materials	1.22*** (0.08)	1.09*** (0.08)	1.17*** (0.08)	1.20*** (0.13)		1.45*** (0.10)
Inventories	0.19*** (0.04)	0.29*** (0.04)	0.20*** (0.04)	0.42*** (0.10)	1.07*** (0.08)	

*Notes:* Standard errors are in parentheses. The  $i^{\text{th}}$  inputs are listed horizontally. These are the inputs in the ratio which are considered to be affected by a change in the price of the  $j^{\text{th}}$  input (in the first column). All elasticities are evaluated at variable sample averages except Union, which is set equal to 0.47.

\*Statistically significant at the .10 level; \*\*at the .05 level; \*\*\*at the .01 level.

occurs, with statistically significant (and larger) elasticities for the labor inputs but not between the labor and non-labor inputs. The output elasticities remain roughly the same except for raw materials (lower elasticities under low unionization) and non-production workers (higher elasticities under low unionization). The input demand elasticities with respect to unionization are all lower under low unionization, though they remain statistically significant. This is consistent with unionization having the greatest direct impact on the use of labor. An implication is that at high levels of unionization greater adjustments in the use of other inputs will be required in response to changes in the price of labor. Conversely, at low levels of unionization, quantities of labor inputs can be adjusted in response to price changes, and less adjustment in the use of other inputs is necessary.

The Morishima elasticities of substitution under high and low unionization are reported in Tables 5 and 6, respectively. We use these results to address one of our key concerns, whether our estimates over-

all support the hypothesis of an inverse relationship between input flexibility and unionization. The elasticities are interpreted as follows. The  $j^{\text{th}}$  inputs are listed in the first column. These are the inputs for which the price changes or, alternatively, the input for which the own-price elasticity is subtracted from each cross-price elasticity across the top row. The  $i^{\text{th}}$  inputs are listed along the top row. Hence the Morishima elasticity of substitution measures the change in the relative use of the  $i^{\text{th}}$  and  $j^{\text{th}}$  inputs as a result of a change in the price of the  $j^{\text{th}}$  input. Thus, for example, in Table 5, the Morishima elasticity of substitution between energy and overtime in response to change in energy prices is 0.07, while the Morishima elasticity of substitution between energy and overtime in response to a change in the price of overtime is 0.08.

The effects of falling unionization on the Morishima elasticities are listed and classified according to their effects on flexibility in Table 7. Flexibility unambiguously increases if a positive elasticity of substitution becomes more positive as we

Table 6. Morishima Elasticities of Substitution (Low Unionization).

<i>Inputs(j)</i>	<i>Inputs(i)</i>					
	<i>Energy</i>	<i>Production Worker Employment</i>	<i>Overtime Hours</i>	<i>Non-Production Worker Employment</i>	<i>Raw Materials</i>	<i>Inventories</i>
Energy		-0.003 (0.03)	0.06*** (0.02)	-0.27*** (0.12)	-0.01 (0.06)	0.01 (0.05)
Production Worker Employment	0.43*** (0.14)		0.94*** (0.20)	-1.61*** (0.51)	0.70*** (0.26)	0.58*** (0.16)
Overtime Hours	0.67*** (0.12)	1.09*** (0.22)		2.99*** (0.70)	0.35 (0.30)	0.30 (0.19)
Non-Production Worker Employment	0.48** (0.21)	0.44** (0.20)	0.58*** (0.22)		0.48** (0.23)	0.63*** (0.21)
Raw Materials	0.78*** (0.12)	0.80** (0.11)	0.78** (0.11)	0.72*** (0.20)		1.10*** (0.14)
Inventories	0.26*** (0.07)	0.28** (0.05)	0.25*** (0.16)	0.78*** (0.06)	1.10*** (0.13)	

*Notes:* Standard errors are in parentheses. The  $i^{th}$  inputs are listed horizontally. These are the inputs in the ratio which are considered to be affected by a change in the price of the  $j^{th}$  input (in the first column). All elasticities are evaluated at variable sample averages except Union, which is set equal to 0.19.

\*Statistically significant at the .10 level; \*\*at the .05 level; \*\*\*at the .01 level.

go from high to low unionization. This happens in five cases, as listed in the first row of Table 7. Reported in the second and third rows are another eleven cases in which the elasticity of substitution changes from being not statistically significantly different from zero or significantly negative to being significantly positive. Noteworthy is the fact that all of the intra-labor Morishima elasticities except one are included in this group. One case,  $\sigma_{inventories, overtime}$ , is less straightforward. This goes from being statistically significantly negative to not statistically significantly different from zero. Inspection of the underlying elasticities reveals that this is a result of overtime changing from being not significantly different from zero to significantly negative and the cross-price elasticity between inventories and overtime changing from being negative to not statistically significantly different from zero, which is suggestive of increased flexibility.

In twelve cases, listed in the second section of Table 7, flexibility has undoubtedly decreased, with either falling Morishima substitutability (ten cases), a

change from statistical insignificance to Morishima-complementarity (one case), or increased Morishima-complementarity (one case). Only one Morishima elasticity is not statistically significantly different from zero at high and low levels of unionization.

It is important to stress that consideration of which cases feature increased flexibility reveals the same general pattern as in the own- and cross-price elasticities. There is increased flexibility in response to labor price changes. In particular, of the fifteen Morishima elasticities in response to changes in the price of labor inputs, eleven reveal increased flexibility at low levels of unionization. The results on the flexibility in input use in response to price changes are more mixed. Only seven of fifteen elasticities on the relative use of labor inputs, in response to all price changes, reveal increased flexibility. While there is, in general, increased flexibility in the use of labor in response to labor and inventory price changes, there is less flexibility in response to changes in the price of raw materials and energy. This is consistent

Table 7. Summary of Effects of Falling Unionization on Morishima Elasticities.

<i>Sign of Morishima Elasticity If High Unionization</i>	<i>Sign of Morishima Elasticity If Low Unionization</i>	<i>Change in Elasticity Value from High to Low Unionization</i>	<i>Elasticities</i>
<b>Increased Flexibility</b>			
Positive	Positive	Increases	$\sigma_{iv,pu}, \sigma_{en,iv}, \sigma_{ot,iv}, \sigma_{np,iv}, \sigma_{rm,iv}$
Zero	Positive	Increases	$\sigma_{en,pu}, \sigma_{ot,pu}, \sigma_{en,ot}, \sigma_{pu,ot}, \sigma_{np,ot}, \sigma_{en,np}, \sigma_{pu,np}, \sigma_{ot,np}, \sigma_{rm,np}, \sigma_{iv,np}$
Negative	Positive	Increases	$\sigma_{rm,pu}$
Negative	Zero	Decreases	$\sigma_{iv,ot}$
<b>Decreased Flexibility</b>			
Positive	Positive	Decreases	$\sigma_{ot,en}, \sigma_{en,rm}, \sigma_{pu,rm}, \sigma_{ot,rm}, \sigma_{np,rm}, \sigma_{iv,rm}, \sigma_{pu,iv}$
Positive	Zero	Decreases	$\sigma_{pu,en}, \sigma_{rm,en}, \sigma_{rm,ot}$
Zero	Negative	Decreases	$\sigma_{np,pu}$
Negative	Negative	Decreases	$\sigma_{np,en}$
<b>No Change</b>			
Zero	Zero	Zero	$\sigma_{iv,en}$

Notes: The first column states the sign of the Morishima elasticity if Union is set equal to 0.47; the second column, if it is set equal to 0.19. All elasticities are classified as positive or negative if they are statistically significantly different from zero; otherwise they are classified as zero.

with the general hypothesis, discussed earlier in this section, that the decline of unionization has led to greater flexibility in the use of labor inputs but less reported flexibility in the use of other inputs as labor inputs become the low-cost margins to adjust in response to price changes.

Our results are consistent with those of Freeman and Medoff (1982) and Maki and Meredith (1987), who found that higher unionization is associated with less flexibility in the use of labor inputs. Hence, the findings of Freeman and Medoff (1982) survive outside of the period they considered and when extending the analysis to a different set of factors. However, our inclusion of a broad set of inputs yields a more complex result: lower unionization, we find, was associated with greater flexibility in the use of labor inputs but less flexibility in the use of other inputs.

As discussed above, previous studies, constrained by the potential endogeneity of unionization, could not go beyond infer-

ring a correlation between unionization and flexibility. For instance, the extent of unionization could result from union organizers' decisions on the allocation of organizing activities, which are driven by consideration of input flexibility, among other factors. Alternatively, there is a possibility that the relationship between unionization and input flexibility is driven by rigid, more unionized firms exiting the market while flexible and less unionized firms enter it. The combination of instrumental variable estimation with the use of panel data enables us to suggest more strongly that the decline in unionization has caused an increase in flexibility. Instrumental variable techniques enable consistent estimation of the parameters of interest. Fixed effects control for unobserved differences that are constant over time, such as technology differences across industries. Trends control for common differences over time. It is still possible that falling unionization did not cause greater flexibility.

While it is possible that we still have an endogenous unionization problem, our earlier work (Magnani and Prentice 2003) rules out some of the possible candidates. Conclusive results require analyzing a cross-industry plant-level dataset, which does not exist for this period.

### Conclusion

While a substantial literature in empirical labor economics has examined unionization's effects on particular margins, and the industrial relations literature has discussed unionization and flexibility at considerable length, very few studies have joined these two strands together. In this paper we have drawn on several literatures to estimate the effect of unionization on input flexibility as measured by price elasticities of demand and Morishima elasticities of substitution. For this purpose, we used a newly compiled dataset on U.S. manufacturing from 1973 to 1996, a period that witnessed a sharp decline in unionization rates, together with widespread changes in the internal organization of the firm, in the system of industrial relations, and in the broad macroeconomic environment.

The main results can be summarized as follows. First, our results show that, other things equal, the transition from high to low union density in the U.S. manufacturing sector increased the flexibility of labor inputs such as production workers' employment, non-production workers' employment, and overtime. This result is consistent with the conclusions of Freeman and Medoff (1982) and Maki and Meredith

(1987), who for the most part focused on labor factors of production. However, the claim that unionization decreases flexibility does not generalize to a fuller set of inputs. Our inclusion of a broader set of demand equations and treatment of unionization, input prices, and shipments as endogenous yields the finding that the decline in union density led to less estimated flexibility in the use of other non-labor inputs. Finally, while Freeman and Medoff (1982) and Maki and Meredith (1987) could not infer the direction of causality between unionization and flexibility, instrumental variables techniques on panel data adopted in this study allow us to suggest more strongly that the decline in unionization caused the increase in labor flexibility, through either management acting without unions or unions and management working together to increase flexibility and ensure survival.

There is much to do in future work. The ideal would be to analyze these questions empirically using plant-level rather than industry-level datasets. Although we have been able, by extending the earlier work of Ramey (1989), to generate input demand equations that permit identification of the structural parameters capturing the effects of unionization, plant-level data would be preferable. Such datasets are, at the moment, not easily available, especially those combining detailed input data with detailed unionization data. In addition, estimation under a suitable natural experiment could result in more insights into the direction of causation between input flexibility and unionization, which is of central concern to both practitioners and policy-makers.

**Appendix 1**  
**Assumptions Required for Aggregation**

Ramey (1989) showed that if assumptions (A.1) to (A.4) stated below hold, then plant input demand equations, derived from a Generalized McFadden cost function, can be estimated using aggregate industry data.

(A.1) The plant-specific component of the error term is distributed independently across plants. The average of the error term across plants is thus equal to an industry-specific error component.

(A.2) Firms face identical input prices.

(A.3) The variance of output  $\sigma_Q^2$  is constant across firms within each industry.

(A.4) The covariance of output and capital across firms  $\sigma_{QK}$  is constant within each industry.

Because we aggregate across two types of plants, unionized and nonunionized, the additional assumptions (A.5)–(A.7) are required to estimate unionized and nonunionized plant demand functions from industry data.

(A.5) The variance of output and the covariance of output and capital in the unionized sector of the

industry,  $\sigma_{Q_U}$  and  $\sigma_{Q_U K_U}$ , respectively, are constant within each industry.

(A.6)  $Q_U = sQ$ ,  $K_U = sK$ , and  $N_U = sN$ , where  $s$  is the share of employment in unionized firms where  $Q$  is industry output,  $K$  is industry capital, and  $N$  is the number of plants in the industry, and  $Q_U$ ,  $K_U$ , and  $N_U$  are the relevant aggregates across unionized plants.

(A.7)  $s_N = s$ , where  $s_N$  is the share of unionized plants in the industry and  $s$  is the share of unionized workers in the industry. This is necessary as we do not have separate estimates for  $s_N$  and  $s$ .

If there is too much heterogeneity in the industry, these assumptions may not hold. For instance, if the industry is dominated by a few large establishments, the “average” plant will not properly represent the behavior of larger firms in terms of input demands. In this case, assumptions such as A.2 and A.3 above are less likely to hold. Similarly, using the share of workers within an industry as a measure of unionization masks the possibility that union workers are concentrated in a small number of plants within an industry.

**Appendix 2**  
**Results of Instrumental Variable Analysis**

Table A1 summarizes the partial R<sup>2</sup>s for the two sets of endogenous explanatory variables used in estimating input demand equations (7)–(8). The variables reported in the first section of the table, constructed from relative prices, vary significantly across the energy and non-energy demand equations. The variables in the second set, reported in the second section of the table, do not vary substantially across equations.

The non-energy demand equations (summarized by equation 8) use a common set of explanatory

variables, listed in the first column, and the partial R<sup>2</sup>s are listed in the second column. The energy input demand equation includes a set of variables constructed from the products of relative input prices. The remaining five columns report the partial R<sup>2</sup>s for each of these products. Each statistic is for a variable constructed from the variable listed in the vertical column and the relative price listed for the column. For example, the partial R<sup>2</sup> for the variable that is a product of *Wage* per production worker and *Wage* per overtime hour (both relative to *Price* of energy) is 0.55.

**Table A1**  
**Explanatory Power of Instrumental Variables**

*Explanatory Variables:*

	<i>Equations</i>					
	<i>Non-Energy</i>	<i>Energy</i>				<i>Non-Production Worker Employment</i>
		<i>Production Worker Employment</i>	<i>Raw Materials</i>	<i>Overtime Hours</i>	<i>Inventories</i>	
Input Prices						
Production Worker Employment	0.74	0.58	0.52	0.55	0.53	0.38
Raw Materials	0.14		0.25	0.53	0.31	0.54
Overtime Hours	0.70			0.52	0.54	0.48
Inventories	0.08				0.41	0.62
Non-Production Worker Employment	0.68					0.51
Union*(Wage per Production Worker)	0.71	0.57	0.49	0.55	0.48	0.36
Union*(Price of Raw Materials)	0.14		0.24	0.50	0.32	0.47
Union*(Wage per Overtime Hour)	0.68			0.52	0.50	0.43
Union*(Price of Inventories)	0.10				0.41	0.52
Union*(Wage per Non-Production Worker)	0.64					0.44

*Other Variables:*

	<i>Equations</i>	
	<i>Non-Energy</i>	<i>Energy</i>
Capital	0.52	0.34
Shipments <sup>2</sup>	0.53	0.34
Union	0.21	0.20
Union*Capital	0.48	0.30
Union*Shipments <sup>2</sup>	0.52	0.29
Shipments*Time	0.66	0.51
Shipments <sup>2</sup> *Time	0.68	0.51

*Note:* Table reports the partial R<sup>2</sup>s for each endogenous variable following Shea (1997).

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