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Flexibility and Competition in U.S. Food Manufacturing Industries:

Are Firms too Inflexible?

by

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1. Introduction

The concept of flexibility has received a large amount of attention in the business literature. In reviewing this literature, Carlsson (1989) observes that "judging from the business literature, flexibility would seem to be as important a determinant of international competitiveness as costs" (p. 180). This topic also has found its way into both the industrial organisation (Röller and Tombak, 1990; Norman, Thisse, 1999; deVaal 2000) and the agricultural economics literature (Zeller and Robinson, 1992; Weiss, 2001). Focusing on the specific situation of the food industry, Martin et al. (1991) claim that "... it flies in the face of much current management thinking that ... suppliers will need to be increasingly flexible" (p. 1464).

One advantage of flexibility is that it provides producers the opportunity to modify the production process in response to exogenous shocks. Ceteris paribus, this ability to adjust quickly to changes should increase profitability, in particular in firms in industries facing significant fluctuations in their economic environment. Aiginger and Weiss (1998) found a "remarkably strong effect" (p. 551) of their measure of flexibility on industry profitability and concluded that it pays to be flexible. If flexibility is as important for profitability and international competitiveness as this literature seems to suggest, we have to ask why some firms do not choose a flexible production technology. What determines firms' flexibility decisions? Is there a need to become increasingly flexible, that is, are firms too inflexible? Are firms in the food industry particularly (in)flexible?

This paper analyses the flexibility decision of firms. In particular we (a) ask whether the flexibility choice is influenced by market structure (concentration, market growth, ...), (b) compare the firms' actual choices with welfare maximising flexibility decisions, (c) empirically investigate the determinants of flexibility using a panel of 4-digit U.S. manufacturing industries and (d) analyze the flexibility decision in the U.S. food manufacturing industries. The paper is organised as follows. The following section 2 analyses the flexibility decision of firms theoretically. Section 3 discusses the empirical results from random effects models estimated on a panel of 299 4-digit U.S. manufacturing firms whereby specific attention is given to the situation in the food industry. Section 4 concludes.

2. The model

Consider an industry where n firms each produce a homogenous product. Demand for this product is assumed to be given by a linear inverse demand curve $p = a - Q$, where a is a positive demand-scaling constant, p is the price of this good and $Q = \sum_{i=1}^{n} q_i$. Before firms simultaneously decide about production quantities, they choose from a given set of alternative production technologies. The available technologies (indexed by j = 1, ... J) are characterised by a quadratic cost function $C_{i,j} = f_j + c_j q_{i,j}^2$, where f_j are fixed costs and $q_{i,j}$ is the quantity produced by firm i employing technology j. Following Stigler (1939), the slope of the marginal cost curve was used as our measure of flexibility. If changes in output are associated with large cost changes (a steep marginal cost curve and a large c), this technology will be considered inflexible compared to a technology where changes in output do not lead to significant cost change (flat marginal cost curve and a low c). However, flexibility is not a free good: " a plant certain to operate at X units of output per week will surely have lower costs at that output than a plant designed to be passably efficient from $X/2$ to $2X$ units per week" (Stigler, 1939, p. 125). To capture this idea of lower average costs for an inflexible technology, we assume fixed costs f_j vary inversely with c_j: $f_j = f_j(c_j)$, with $\frac{\partial f_j}{\partial c_j} < 0$. For simplicity, we consider only two technologies (J = 2). The flexible technology (F) is characterised by a flat marginal cost curve (slope c_F) but involves fixed costs $f_F = f$. The inflexible technology (D) has no fixed costs $f_D = 0$ but has significant cost changes when deviating from a specific output level (steep marginal cost curve with slope c_D). Specifically we have, $c_F = c_D - k$ with $0 < k < c_D$.

Firms simultaneously choose among available technologies in the first stage. Given this choice, firms determine quantities in the second stage.

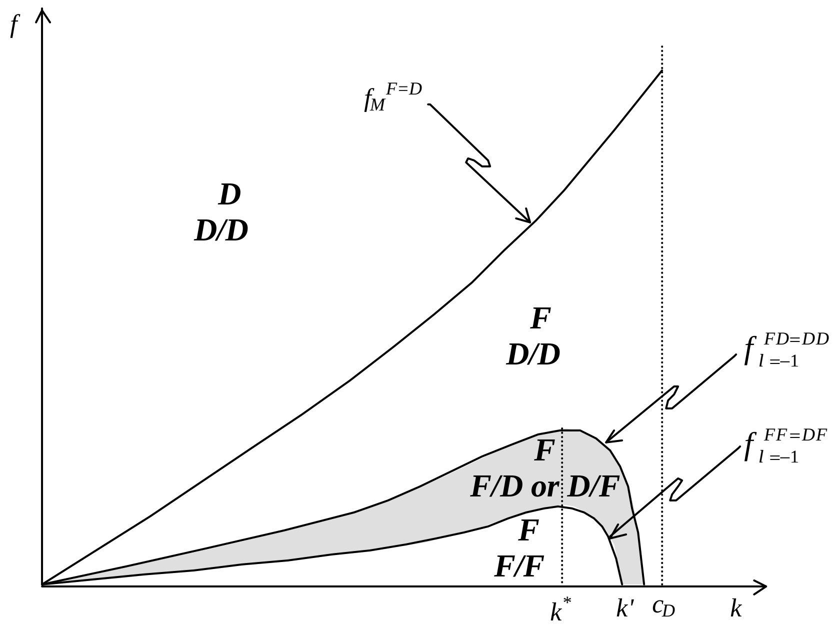
Let us first consider the monopoly situation. Profits are $\boldsymbol{p}_M\, p(Q_M)Q_M - c_j Q_M^2 - f_j$. Choosing quantities to maximise profits in the second stage gives $\boldsymbol{p}_M = \frac{a^2}{4(1+c_j)} - f_j$. A monopolist would choose the flexible technology in the first stage if profits $\boldsymbol{p}_M^F$ (with $c_j = c_F$ and $f_j = f$) exceed profits associated with the inflexible technology $\boldsymbol{p}_M^D$ (with $c_j = c_D$ and

$f_j = 0$). Computing the level of fixed costs $f_M^{F=D}$ which makes a monopolist indifferent between the two technologies ($\pi_M^F = \pi_M^D$) we get:

$$f_M^{F=D} = \frac{a^2 k}{4(1+c_D)(1+c_D-k)}.$$

We find that $f_M^{F=D}$ increases with k (Figure 1). Also note that $f_M^{F=D}\Big|_{k=0} = 0$.

Figure 1: Equilibrium regions in the (f, k)-space.



If, for a given k the fixed costs associated with the flexible production technology are above the boundary locus in the (f, k)-space, the monopolist will choose the inflexible technology (strategy D). If fixed costs decline and are lower than $f_M^{F=D}$, the monopolist will switch to the flexible technology (strategy F). Also note that the boundary locus $f_M^{F=D}$ depends on the parameters a and c_D. An increase in market size (a smaller c_D and a larger a) increases the attractiveness of the flexible technology.

Consider the flexibility decision in a competitive market. Suppose there are two firms (i = 2) which are identical before choosing technology in the first stage. They may be different in the second stage after choosing optimal quantities. The profits associated with the optimal quantity decisions are used to choose production technologies in the first stage. This stage of the game is illustrated in Table 1.

Table 1: The payoff-matrix for the technology game.

		Decision of firm *j*	
		Strategy *F*	Strategy *D*
Decision of firm *i*	Strategy *F*	π^{FF} / π^{FF}	π^{FD} / π^{DF}
	Strategy *D*	π^{DF} / π^{FD}	π^{DD} / π^{DD}

Considering the most aggressive behaviour in a quantity-setting duopoly game by assuming the parameter of conjectural variation λ = -1 allows us to compute profits associated with the various strategies:

$$\pi^{DD}_{\lambda=-1} = \frac{a^2 c_D}{4(1+c_D)^2}, \qquad \pi^{FD}_{\lambda=-1} = \frac{a^2 c_D^2 (c_D - k)}{[2c_D(1+c_D-k)-k]^2} - f,$$

$$\pi^{DF}_{\lambda=-1} = \frac{a^2 c_D (c_D - k)^2}{[2c_D(1+c_D-k)-k]^2} \quad \text{and} \quad \pi^{FF}_{\lambda=-1} = \frac{a^2 (c_D - k)}{4(1+c_D-k)^2} - f.$$

If, for a given *k*, the fixed costs associated with the flexible technology are very high, both firms will choose the inflexible strategy (strategy *D*) and realize profits π^{DD}. As fixed costs decline it may be profitable for one firm (but not for both firms) to change to a flexible technology. The flexible firm will earn profits π^{FD}, the inflexible one π^{DF}. This critical level of *f*, where one firm is indifferent between strategies *F* and *D* given that its rival chooses *D*, can be found by computing $\pi^{FD}_{\lambda=-1} - \pi^{DD}_{\lambda=-1} = 0$ and solving for *f*. This gives

$$f^{FD=DD}_{\lambda=-1} = \frac{a^2 c_D^2 (c_D - k)}{[2c_D(1+c_D-k)-k]^2} - \frac{a^2 c_D}{4(1+c_D)^2}$$

with $f^{FD=DD}_{\lambda=-1}\Big|_{k=0} = f^{FD=DD}_{\lambda=-1}\Big|_{k=k'} = 0$, $k' = \dfrac{4c_D^2(1+c_D)}{(1+2c_D)^2}$ and $\dfrac{\partial f^{FS=SS}_{\lambda=-1}}{\partial k} > 0$. Similarly, we compute the level of fixed costs for every *k* where the second firm would also switch to the flexible technology. Solving $\pi_{l=-1}^{FF} - \pi_{l=-1}^{DF} = 0$ for f gives $f_{l=-1}^{FF=DF} = \frac{a^2(c_D - k)}{4(1+c_D-k)^2} - \frac{a^2 c_D (c_D-k)^2}{[2c_D(1+c_D-k)-k]^2}$ with $f_{l=-1}^{FF=DF}\Big|_{k=0} = 0$ and $\frac{\partial f_{l=-1}^{FF=DF}}{\partial k} > 0$.

Comparing $f_{l=-1}^{FF=DF}$ and $f_{l=-1}^{FD=DD}$ with the critical f in a monopoly market $f_M^{F=D}$ indicates that $f_M^{F=D} > f_{l=-1}^{FD=DD} > f_{l=-1}^{FF=DD} \quad \forall\, 0 < k \le c_D$. This has two interesting implications: The first inequality implies:

(a) a higher attractiveness of the flexible strategy F in a monopoly compared to a competitive market. There are combinations of f and k where the monopolist would be choosing the flexible technology F whereas both firms in a duopoly market in the same situation would choose the inflexible one (technology D).

The second inequality implies:

(b) it may be profitable for identical firms to choose different production technologies. Thus, although the two duopolists are identical ex ante, they will be different ex post. The combinations of f and k where firms will choose different technologies is shown by the shaded area in Figure 1.[1]

Finally, consider the welfare implications of a firm's flexibility decisions. Are firms flexible enough? We define total welfare as the sum of consumer surplus and firm profits $\Omega = \int_0^{Q^*} [p(Q) - 2cQ] - f$, where Q^* is the total quantity supplied in the various market forms. In order to find combinations of f and k where total welfare associated with the flexible and the inflexible strategy is equal in the monopoly case, we compute $\Omega_M^F - \Omega_M^D$ and solve for f. This gives:

$$f_M^{\Omega F=\Omega D} = \frac{a^2[(1+c_D)^2 - (1+c_D-k)^2]}{8(1+c_D-k)^2(1+c_D)^2} + f_M^{F=D}$$

It is easy to see that $f_M^{\Omega F=\Omega D} > f_M^{F=D} \quad \forall\, c_D > 2k$. This implies that, for a specific $f_M^{\Omega F=\Omega D} > f > f_M^{F=D}$, the monopolist would not choose the flexible technology (since $f > f_M^{F=D}$) although choosing the flexible technology would have increased welfare (since

[1] A simple graphical illustration of this result is given in Appendix 1.

$f_M^{\Omega F=\Omega D} > f$). Thus a monopolist will be too inflexible. A similar conclusion can be derived for competitive firms. Solving $\Omega_{l=-1}^{FD} - \Omega_{l=-1}^{DD}$ and $\Omega_{l=-1}^{FF} - \Omega_{l=-1}^{DF}$ for f gives:

$$f_{l=-1}^{\Omega FD=\Omega DD} = \frac{a^2 c_D k}{2(1+c_D)[2c_D(1+c_D-k)-k]}, \text{ with}$$

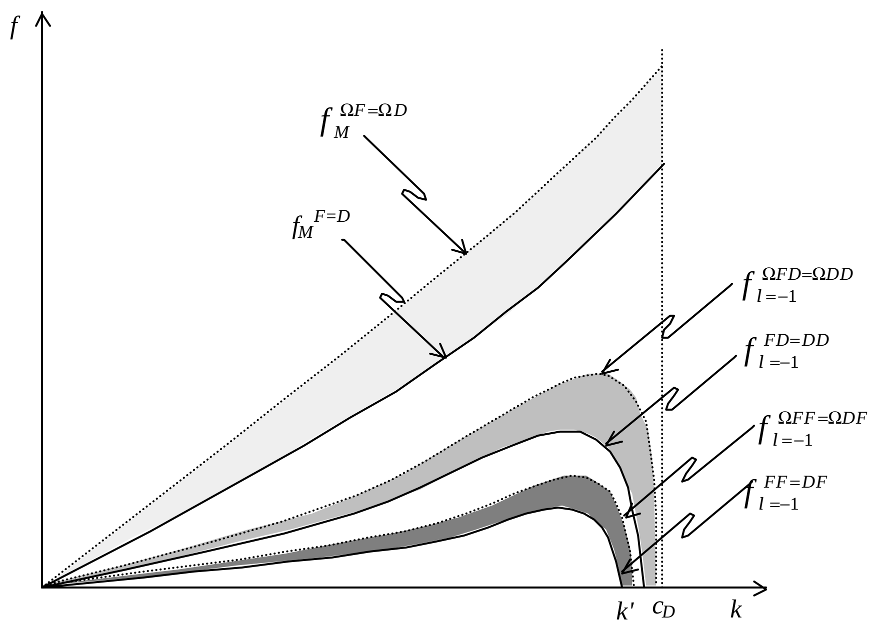
$$f_{l=-1}^{\Omega FD=\Omega DD} - f_{l=-1}^{FD-DD} = \frac{a^2 c_D k[2c_D(2+2c_D-k)-k]}{4(1+c_D)^2[2c_D(1+c_D-k)-k]^2} > 0 \text{ and}$$

$$f_{l=-1}^{\Omega FF=\Omega DF} = \frac{a^2 k(c_D-k)}{2(1+c_D-k)[2c_D(1+c_D-k)-k]} \text{ with}$$

$$f_{l=-1}^{\Omega FF=\Omega DF} - f_{l=-1}^{FF=DF} = \frac{a^2 k(c_D-k)[(1+c_D-k)(4c_D-2k)-k]}{4(1+c_D-k)^2[2c_D(1+c_D-k)-k]^2} > 0 .$$

Again, we can find combinations of f and k such that choosing the flexible strategy would increase welfare but firms choose the inflexible strategy instead. This situation is shown in Figure 2.

Figure 2: Socially optimal vs. equilibrium technology choices of firms.



Whether firms with market power as well as firms in large (or growing markets) are more likely to choose a flexible production technology will be tested empirically in the following section.

3. Empirical results

Following Roeger (1995) we compute the difference between the primal and dual measure of total factor productivity which yields an equation from which marginal costs can be determined: $mc_{i,t} = p_{i,t}(1-\frac{y_{i,t}}{x_{i,t}})$, where

$$\begin{aligned} y_{i,t} = {} & g_{q_{i,t}} + g_{p_{i,t}} - \boldsymbol{\alpha}_{l_{i,t}}(g_{w_{i,t}} + g_{l_{i,t}}) - \boldsymbol{\alpha}_{m_{i,t}}(g_{pm_{i,t}} + g_{m_{i,t}}) \\ & - (1-\boldsymbol{\alpha}_{l_{i,t}} - \boldsymbol{\alpha}_{m_{i,t}})(g_{r_{i,t}} + g_{k_{i,t}}) \end{aligned},$$

$$x_{i,t} = g_{q_{i,t}} + g_{p_{i,t}} - (g_{r_{i,t}} + g_{k_{i,t}}),$$

and g refers to the growth rate of a variable, q, p, w, l, pm, m, r, and k are output, the output-price-index, wages, labour, price index of materials, materials, factor price of capital and the capital stock respectively. The share of wage payments and materials in revenue is $\boldsymbol{\alpha}_l$ and $\boldsymbol{\alpha}_m$. Subscript *i* refers to an industry and *t* is time.

The slope of the marginal cost curve and thus our measure of flexibility can be obtained by regressing $m_{ci,t}$ on output: $mc_{i,t} = \boldsymbol{\beta} + c_{i,t} q_{i,t} + \boldsymbol{\varepsilon}_{i,t}$. Whether flexibility differs between industries (as well as over time) can be analysed by specifying $c_{i,t} = \boldsymbol{\gamma} + \boldsymbol{X\delta}$, where $\boldsymbol{X}$ is a matrix of industry characteristics (such as concentration), which then gives the following estimation equation: $mc_{i,t} = \boldsymbol{\beta} + \boldsymbol{\gamma} q_{i,t} + \boldsymbol{X\delta} q_{i,t} + \boldsymbol{\varepsilon}_{i,t}$. We estimate this equation in a double-logarithmic form for 299 4-digit US manufacturing industries with annual data for the period 1962 to 1989. The primary source of information is the US Annual Survey of Manufacturers and the Census of Manufacturers. The data are described in more detail in Appendix 2, the results of a random effects model are reported in Table 2.

Table 2.: Results of the random-effects model estimated on 299 U.S. manufacturing industries for 1962 to 1989.

Estimated model: $\ln(c_{i,t}) = a + b\ln(q_{i,t}) + g_1\ln(q_{i,t})CR4_{i,t} + g_2\ln(q_{i,t})COR_{i,t} + g_3\ln(q_{i,t})ASR_{i,t} + g_4\ln(q_{i,t})GR4_{i,t} + g_5\ln(q_{i,t})FOOD_{i,t} + g_6\ln(q_{i,t})FOOD_{i,t}\,COR_{i,t} + g_7\ln(q_{i,t})FOOD_{i,t}\,ASR_{i,t} + e_{i,t} + u_i + v_t$

Independent Variables	Symbol	Param. [1]	(t-value) [1]	Param. [2]	(t-value) [2]	Param. [3]	(t-value) [3]
(1) Intercept		-0.255	(-3.96)	-0.380	(-6.31)	-0.428	(-7.45)
(2) Output	$\ln(q_{i,t})$	0.031	(3.68)	0.065	(7.35)	-0.084	(-9.87)
Interaction-effects with output [$\ln(q_{i,t})$]:							
(3) Concentration	*CR4/100*			-0.040	(-5.83)	-0.031	(-4.41)
(4) Capital-Output-Ratio	*COR*					-0.026	(-5.93)
(5) Advertising-Sales-Ratio	*ASR/100*					-0.222	(-4.86)
(6) Growth Rate	*GR*					-0.041	(-5.05)
(7) Food Industry Dummy	*FOOD*					-0.015	(-2.62)
(8) Advert. in Food Ind.	*FOOD*ASR*					0.003	(2.10)
(9) Growth in Food Ind.	*FOOD*GR*					0.069	(3.06)
N			8671		8671		8671
Hausman Test			2.49		0.79		24.68
LMT (DF)			43,887.18 (2)		41,952.88 (2)		25,567.63 (2)

Remarks: N is the number of observations. LMT symbolises the "Lagrange Multiplier Test" for the restriction $u_i = u$ and $v_t = v$.

Column [1] of table 2 assumes the slope of the marginal cost curve to be identical for all industries and constant over time. A parameter estimate of 0.03 indicates that an increase in output increases marginal costs by 3%. The significant parameter estimates of the interaction effects in columns [2] and [3] however reject the assumption of an identical slope of the marginal cost curve in all industries. The significant and negative parameter estimate of the interaction effect with the four-firm concentration ratio (CR_4) in column [2] indicates that the slope of the marginal cost curve $c_{i,t}$ decreases with market concentration. A standard deviation increase in concentration (19.5 percentage points) reduces $c_{i,t}$ and thus increases flexibility by 15.9%. The positive relationship between flexibility and market power corresponds to the theoretical model in section 2. This effect remains unchanged if additional explanatory variables are included in the empirical model. We find a significant and negative effect of the advertising to sales ratio and the market growth rate. A standard deviation increase in the advertising to sales ratio (2.99 percentage points) increases flexibility by 56.0%. Similarly, an increase in the industry growth rate by one standard deviation (15 percentage points) implies an increase in flexibility by 35.5%. Given that high values of *COR* and *ASR* are an indication of high entry barriers protecting the market position of incumbents, their positive impact on flexibility corresponds to the theoretical expectations. Furthermore, the negative parameter estimate of the dummy variable *FOOD* (which is set equal to 1 for food manufacturing industries and is 0 otherwise) suggests that firms in the food industry are significantly more flexible. The advertising and growth variable are less important in food manufacturing, the interaction effect of *FOOD* with CR_4 is not significantly different from zero and is thus not shown here. The higher flexibility of firms in the food sector could be contributed to the higher costs of storing (perishable) food products which increases the attractiveness of flexible production technologies to quickly meet demand fluctuations.

Conclusion

This paper presented research that analysed the flexibility decision of firms both, theoretically and empirically. Four hypothesis were derived from the theoretical model.

(a) The relative attractiveness of the flexible production technology increases with market power. Whereas a monopolist would choose the flexible technology in a specific environment, oligopolists in the same market would prefer the inflexible one.

(b) It may be profitable for identical firms in an oligopoly to choose different production technologies. Thus, although they are identical ex-ante, they will be different ex-post.

(c) The relative attractiveness of the flexible production technology increases with the size of the market.

(d) Firms will be too inflexible. Both, a monopolist as well as oligopolists are choosing inflexible technologies although the welfare maximising choice would call for employing the flexible production technology.

Hypothesis (a) and (c) were tested empirically using panel data for 299 4-digit US manufacturing industries for the period 1962 to 1989. The results of a random-effects model suggest a positive relationship between flexibility and market power (the four-firm concentration ratio), which supports hypothesis (a). Furthermore, we found a significant and positive impact of the capital-output ratio, the advertising to sales ratio, and the industry growth rate. This suggests that flexibility is greater in quickly growing markets with high entry barriers. Flexibility in food manufacturing industries was found to be significantly higher than in all other industries. The higher flexibility of firms in the food industry is explicable in terms of higher storage costs for (perishable) food products, which increases the attractiveness of a flexible technology.

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Appendix 1

to be prepared

Appendix 2

The data

The Census of Manufacturers (CM) and the Annual Survey of Manufacturers (ASM) are the primary sources of information for the panel data base. Census data assign individual establishments (plants), as opposed to whole companies, to their primary SIC industry. The full data set contains information on 450 4-digit manufacturing industries (according to the 1972 classification) over the period from 1958 to 1989.

Description of data: to be prepared.

Variables:

CR We use the Weiss-Pascoe adjusted four-firm concentration ratio for 1972 and 1977. The CM reports (non-adjusted) concentration ratios also for 1958, 1963, 1967, and 1982, the elements of these series have been adjusted by the difference between Weiss and Pascoe's estimate and the Census' counterpart for 1972. Concentration ratios in non-census years are estimated as weighted averages of the concentration ratios in the immediately preceding and succeeding censuses. Estimates for the 1983 to 1989 period are obtained by extrapolating from the 1977 and 1982 observations. Concentration ratios have been adjusted by the import-to-sales ratio (ASM).

K Real stock of capital at the start of the year (PCS).

P^C User cost of capital defined as $P^I * r$, where P^I is the price deflator for new investment (ASM) and r is the interest rate, in logs.

Q Real value of shipments (ASM) in logs.

UNION The unionisation data are taken from Kokkelenberg and Sockell (1985), who report the three-year moving averages of the of the percentage unionised for three-digit industries for the period 1973 to 1981. These three-digit estimates have been mapped to each of the corresponding four-digit industries in the sample. Estimates for the 1960 to 1972 and 1982 to 1989 period are obtained by extrapolating from the 1973 and 1981 observations by using the average growth rate of the last three periods.

W Real total payroll per employee, excluding social security or other legally mandated payments, or employer payments for some fringe benefits (ASM) in logs.

Sources:

1. ASM: U.S. Bureau if Census, Annual Survey of Manufacturing (GPO, Washington, DC, various issues).

2. PCS Data developed in a joint project by the University of Pennsylvania, the Bureau of the Census and the SRI.Inc.

3. CM Census of Manufacturers.