

Flexibility and Competition
in Food Manufacturing Industries

Christoph R. Weiss

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Address:

Department of Food Economics and Consumption Studies,
University of Kiel, Olshausenstr. 40, D-24118 Kiel.
Phone: +49/431 880 4425, Fax.: +49/431 880 7308,
e-mail: rstaehler@food-econ.uni-kiel.de
<http://www.uni-kiel.de/foodecon/ern-wirt.htm>

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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). More recently, this topic also found its way into the industrial organisation (Vives, 1986; Röller and Tombak, 1990) and the agricultural economics journals (Zeller and Robinson, 1992). 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 of the most significant advantages of flexibility is to provide the production process with the ability to modify itself in the face of exogenous shocks. *Ceteris paribus*, the ability to adjust quickly to exogenous changes should increase the profitability of firms in particular in industries facing significant fluctuations in their economic environment. Aiginger and Weiss (1998) actually find a "remarkably strong effect" (p. 551) of their measure of flexibility on industry profitability and conclude that it pays to be flexible. If flexibility is as important for profitability and international competitiveness of firms 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) investigate the determinants of flexibility empirically for a panel of 4-digit U.S. manufacturing industries and (d) specifically analyse 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 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 the firms simultaneously decide about quantities, they choose from a given set of alternative production technologies. The available technologies (indexed by $j = 1, \dots, J$) 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 will be 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 an inflexible one 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 to vary inversely with c_j : $f_j = f_j(c_j)$ with $\frac{\partial f_j}{\partial c_j} < 0$. For

simplicity of exposition, 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 $f_F = f$, whereas 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.

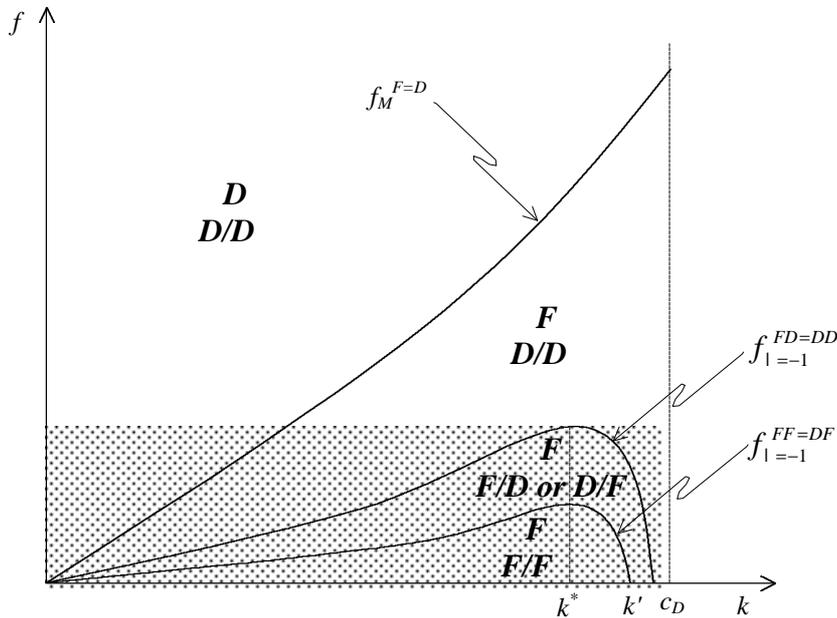
Let us first consider the monopoly situation. Profits are $\rho_M p(Q_M)Q_M - c_j Q_M^2 - f_j$. Choosing quantities so as to maximise profits in the second stage gives $\rho_M = \frac{a^2}{4(1+c_j)} - f_j$. A monopolist would choose the flexible technology in the first stage if profits ρ_M^F (with $c_j = c_F$ and $f_j = f$) exceed profits from choosing the inflexible technology ρ_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 ($p_M^F = p_M^D$) 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 . Also note that $f_M^{F=D}|_{k=0} = 0$. This is shown in Figure 1.

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 the size of the market (a smaller c_D and a larger a) increases the attractiveness of the flexible technology.

Consider now the flexibility decision in a competitive market. Suppose there are two firms ($i = 2$), both of which are identical before choosing technology in the first stage, they may, however, be different in the second stage when choosing optimal quantities. The profits

associated with the optimal quantity decisions are then used to choose production technologies in the first stage. This stage of the game is illustrated in Figure 2.

Figure 2: The payoff-matrix for the technology game.

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

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

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

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

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 realise profits p^{DD} . As fixed costs decline it may be profitable for one firm (but not for both firms) to choose a flexible technology. The flexible firm will earn profits p^{FD} , the inflexible one p^{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 $p_{\lambda=-1}^{FD} - p_{\lambda=-1}^{DD} = 0$ and solving for f . This gives

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

with $f_{\lambda=-1}^{FD=DD} \Big|_{k=0} = f_{\lambda=-1}^{FD=DD} \Big|_{k=k'}$, $k' = \frac{4c_D^2(1+c_D)}{(1+2c_D)^2}$ and $\frac{\partial f_{\lambda=-1}^{FS=SS}}{\partial k} > 0$. Similarly, we compute

the level of fixed costs for every k where the second firm would also switch to the flexible

technology. Solving $p_{1=-1}^{FF} - p_{1=-1}^{DF} = 0$ for f gives

$$f_{1=-1}^{FF=DF} = \frac{a^2(c_D - k)}{4(1 + c_D - k)^2} - \frac{a^2 c_D (c_D - k)^2}{[2c_D(1 + c_D - k) - k]^2} \text{ with } f_{1=-1}^{FF=DF} \Big|_{k=0} = 0 \text{ and } \frac{\partial f_{1=-1}^{FF=DF}}{\partial k} > 0.$$

Comparing $f_{1=-1}^{FF=DF}$ and $f_{1=-1}^{FD=DD}$ with the critical f in a monopoly market $f_M^{F=D}$ indicates that $f_M^{F=D} > f_{1=-1}^{FD=DD} > f_{1=-1}^{FF=DD} \quad \forall 0 < k \leq c_D$. 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) that it may be profitable for identical firms to choose a different production technology. 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

Let us finally consider the welfare implications of the firm's flexibility decisions. Are firms flexible enough? We define total welfare as the sum of consumer surplus and firm's profit $\Omega = \int_0^{Q^*} [p(Q) - 2cQ] - f$, where Q^* is 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:

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

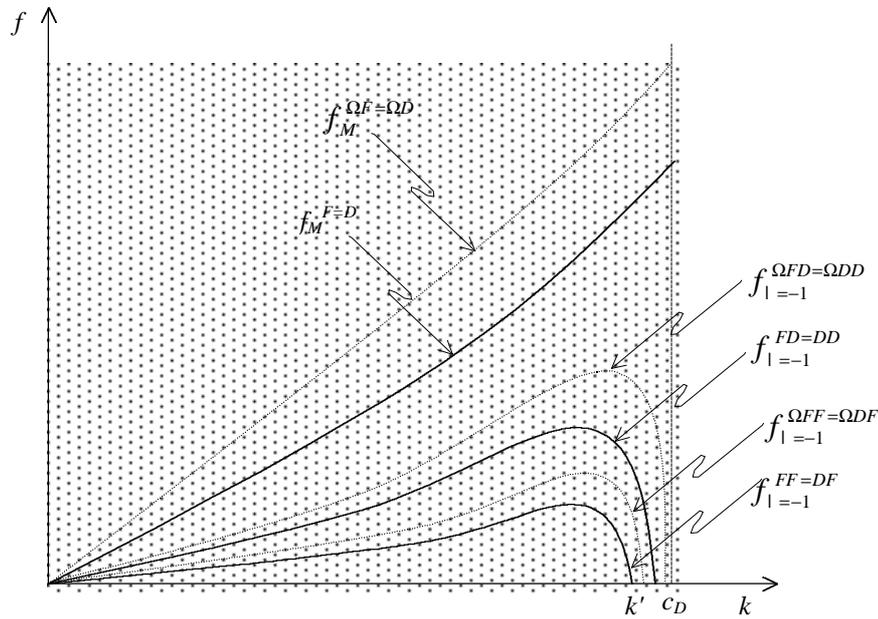
$$f_{l=-1}^{\Omega FD=\Omega DD} - f_{l=-1}^{FD-DD} = \frac{a^2 c_D k [2c_D(2+2c_D-k)-k]}{4(1+c_D)^2 [2c_D(1+c_D-k)-k]^2} > 0 \quad \text{and}$$

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

$$f_{l=-1}^{\Omega FF=\Omega DF} - f_{l=-1}^{FF=DF} = \frac{a^2 k (c_D - k) [(1+c_D-k)(4c_D-2k)-k]}{4(1+c_D-k)^2 [2c_D(1+c_D-k)-k]^2} > 0. \quad \text{Again, we can find}$$

combinations of f and k where 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

$$y_{i,t} = g_{q_{i,t}} + g_{p_{i,t}} - a_{l_{i,t}} (g_{w_{i,t}} + g_{l_{i,t}}) - a_{m_{i,t}} (g_{pm_{i,t}} + g_{m_{i,t}}) - (1 - a_{l_{i,t}} - a_{m_{i,t}}) (g_{r_{i,t}} + g_{k_{i,t}}),$$

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

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 a_l and a_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 $mc_{i,t}$ on output:

$mc_{i,t} = b + c_{i,t} q_{i,t} + e_{i,t}$. Whether flexibility differs between industries (as well as over time)

can be analysed by specifying $c_{i,t} = g + Xd$, where X is a matrix of industry characteristics (such as concentration), which then gives the following estimation equation:

$mc_{i,t} = b + g q_{i,t} + X d q_{i,t} + e_{i,t}$. 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 1.

Table 1.: Results of the random-effects model estimated on 299 U.S. manufacturing industries for 1962 to 1989.

Estimation model: $\ln(c_{i,t}) = a + b\ln(q_{i,t}) + g_1\ln(q_{i,t})CR4_{i,t} + g_2\ln(q_{i,t})COR_{i,t} + g_3\ln(q_{i,t})ASR_{i,t} + g_4\ln(q_{i,t})GR_{i,t} + g_5\ln(q_{i,t})FOOD_{i,t} + g_6\ln(q_{i,t})FOOD_{i,t} COR_{i,t} + g_7\ln(q_{i,t})FOOD_{i,t} ASR_{i,t} + e_{i,t} + u_i + v_t$							
Independent Variables	Symbol	Param.(t-value) [1]		Param. (t-value) [2]		Param. (t-value) [3]	
(1) <i>Intercept</i>		-0.255	(-3.96)	-0.380	(-6.31)	-0.428	(-7.45)
(2) <i>Output</i>	$\ln(q_{i,t})$	0.031	(3.68)	0.065	(7.35)	-0.084	(-9.87)
<i>Interaction-effects with output [$\ln(q_{i,t})$]:</i>							
(3) <i>Concentration</i>	$CR4/100$			-0.040	(-5.83)	-0.031	(-4.41)
(4) <i>Capital-Output-Ratio</i>	COR					-0.026	(-5.93)
(5) <i>Advertising-Sales-Ratio</i>	$ASR/100$					-0.222	(-4.86)
(6) <i>Growth Rate</i>	GR					-0.041	(-5.05)
(7) <i>Food Industry Dummy</i>	$FOOD$					-0.015	(-2.62)
(8) <i>Adv. in Food Ind.</i>	$FOOD*ASR$					0.003	(2.10)
(9) <i>Growth in Food Ind.</i>	$FOOD*GR$					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 $v_t = v$.

The first column of table 1 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 analyses the flexibility decision of firms both, theoretically and empirically. Four hypothesis can be derived from a 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) can be tested empirically for a panel of 299 4-digit US manufacturing industries with annual data 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 corresponds to hypothesis (a). Furthermore, we find a significant and positive impact of the capital-output ratio, the advertising to sales ratio as well as the industry growth rate suggesting that flexibility is higher in quickly growing markets with high entry barriers. Flexibility in food manufacturing industries is 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 of 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.