Appendix

Theoretical Model

In the analysis of our article, we test whether there are increasing returns in U.S. manufacturing and what is driving these returns. In the first step, we estimate overall returns to scale by regressing growth of industry output on growth of total industry input. In the second step, we estimate each of the output elasticities separately to distinguish between market power and hoarding (input utilization) as potential explanations for increasing returns. This Appendix illustrates the theoretical background of our market power vs. hoarding hypotheses. We closely follow Basu and Fernald,[1] who provide a more extensive discussion of these issues and show how the results follow from first principles of a dynamic cost-minimization problem. The firm production function is

$$Y = F\left(\tilde{K}, \tilde{L}, M, Z\right) \tag{A1}$$

where Y is output, $\tilde{K}$ is effective capital input, $\tilde{L}$ is effective labor input, M are intermediate inputs and Z is technology. The production function F is differentiable and homogenous of degree γ in inputs. This parameter indicates the returns to scale, so $\gamma = 1$ corresponds to constant returns to scale. In general, returns to scale can be written as the sum of output elasticities

$$\gamma = \frac{F_{\tilde{K}}\tilde{K}}{Y} + \frac{F_{\tilde{L}}\tilde{L}}{Y} + \frac{F_M M}{Y} \tag{A2}$$

where F_x is the marginal product of that input. If firms are assumed to minimize costs, the returns to scale based on the cost function $C\left(Y\right)$[2] can be expressed as the inverse of the elasticity of the cost function with respect to output

$$\gamma = \frac{C\left(Y\right)}{Y}\frac{1}{C\left(Y\right)'} = \frac{AC\left(Y\right)}{MC\left(Y\right)} \tag{A3}$$

where, $C\left(Y\right)'$ is the derivative of the cost function with respect to output, AC denotes average costs and MC denotes marginal costs. This expression is useful because it relates returns to scale to costs of the firm, though it will only hold at the cost-minimizing level of output. Next, firms may charge a price P that is a markup μ over marginal cost: $\mu \equiv P/MC$. Equation A3 can be rewritten as

[1] Basu and Fernald, "Procyclical."

[2] In general, the cost function will also depend on input prices and quasi-fixed inputs such as the number of employees or the capital stock. These are omitted for simplicity.

$$\gamma = \frac{C(Y)}{Y}\frac{1}{C(Y)'} = \frac{C(Y)}{PY}\frac{P}{C(Y)'} = \frac{C(Y)}{PY}\frac{P}{MC} = (1 - s_\pi)\mu \qquad \text{(A4)}$$

where s_π is the share of pure economic profit in gross revenue.

Cost-minimizing firms who are price takers in input markets will use inputs up to the point where the marginal revenue product is equal to the marginal cost of each input. The marginal revenue product of each input x is given by

$$\frac{\partial R}{\partial x} = \frac{\partial R}{\partial Y}\frac{\partial Y}{\partial x} = \frac{P}{\mu}F_x \qquad \text{(A5)}$$

Equation A5 is then set equal to the marginal cost of input x:

$$\frac{P}{\mu}F_x = w_x \Rightarrow F_x = \mu\frac{w_x}{P} \qquad \text{(A6)}$$

where w_x is the price of input x and is equal to the marginal cost to the firm. Equation A6 shows how output elasticities are related to cost shares when firms have market power.

Following Solow,[3] take logs of both sides of equation A1 and differentiate with respect to time:[4]

$$dy = \frac{F_{\tilde{K}}\tilde{K}}{Y}d\tilde{k} + \frac{F_{\tilde{L}}\tilde{L}}{Y}d\tilde{l} + \frac{F_M M}{Y}dm + dz \qquad \text{(A7)}$$

where small letters denote growth rates, so dy is the growth rate of Y. This equation shows the familiar growth accounting decomposition of output growth into contributions from input growth and technological change. The weight of each input is given by its output elasticity, which Solow showed to be equal to input revenue shares under perfect competition. To see how this changes under imperfect competition, rewrite equation A6 so that the output elasticity of, for example, capital is

$$\frac{F_{\tilde{K}}\tilde{K}}{Y} = \mu\frac{w_{\tilde{K}}\tilde{K}}{PY} = \mu\frac{C(Y)}{PY}\frac{w_{\tilde{K}}\tilde{K}}{C(Y)} = \gamma c_{\tilde{K}} \qquad \text{(A8)}$$

Equation A8 shows that the output elasticity of capital is equal to the markup of price over marginal cost times the share of capital costs in revenue. Using equation A4, it can be shown that this is equivalent to the returns to scale times the cost share of capital.

This is a result we use in formulating our market power hypothesis. If increasing returns to scale are due to market power such that the ratio of price over marginal cost is

[3] Solow, “Technical.”
[4] Normalizing the output elasticity with respect to technology to one for simplicity.

larger than one, the estimated output elasticity for each of the inputs should be larger than the cost share by the same factor γ.

Now turn to the alternative hypothesis, namely unmeasured input utilization, or input hoarding. In equation A1, capital and labor was defined as *effective* capital and labor input. To be precise, assume that firms face adjustment costs when changing the capital stock or workforce. In the short run, however, firms may vary the degree to which they utilize the capital stock and workforce, which leads to

$$\tilde{K} = CK \tag{A9}$$

$$\tilde{L} = EHN \tag{A10}$$

Effective capital input $\tilde{K}$ is equal to the capital stock K times the length of the workweek of the capital stock C. Effective labor input $\tilde{L}$ is equal to the number of employees N times the average number of hours paid per worker H times the average effort per worker E. In practice, we do not observe the workweek of capital or worker effort. In our article, worker effort also includes the gap between hours paid and hours worked. So when estimating output elasticities based on a measure of capital stock (horsepower installed) and total hours paid, we face an omitted variable problem. Equation 4 in the main text gives the estimating equation for individual output elasticities. But based on equations A9 and A10, the true relationship is:[5]

$$dy = \varphi_L d\left(hn\right) + \varphi_K dk + \varphi_M dm + \left(\varphi_L de + \varphi_K dc\right) + dz \tag{A11}$$

where the terms in brackets are not observed. However, the key insight exploited by Basu et al. is that while unobserved, these utilization terms are correlated with flexible inputs, which can be freely adjusted.[6] If a firm faces a particular shock, it will not just change one input but will change all flexible inputs in the same direction. In our setting, average hours paid, dh, could be a flexible input, but its stand-alone explanatory power turns out to be very limited. Intermediate inputs, dm, is another flexible input therefore, in the spirit of Basu,[7] we use it here to also infer changes in unmeasured input utilization.

This lays out the foundations of our approach to distinguishing market power from hoarding (unmeasured input utilization). If increasing returns to scale are due to market power, equation A8 shows that all estimated output elasticities should exceed their cost shares by the same factor, such that $\hat{\varphi}_x = \gamma c_x$ for each input x (where a hat over a variable denotes an estimate). If increasing returns to scale are instead due to unmeasured input utilization, only the estimated output elasticity of the flexible input should exceed its cost share: $\hat{\varphi}_M > c_M$. Of course, market power and hoarding are not mutually exclusive hypotheses, so if both were relevant, $\hat{\varphi}_x = \gamma c_x$ for labor and capital and $\hat{\varphi}_M > \gamma c_M$ for intermediate inputs.

[5] For simplicity, we assume one type of labor instead of the two in the article. For consistency, we refer to the growth in hours paid by dhn and horsepower installed by dk instead of the dhp in the main text.

[6] Basu, Fernald, and Kimball, "Technology."

[7] Basu, "Procyclical."

Robustness Analysis

APPENDIX TABLE 1
RETURNS TO SCALE ESTIMATES USING DIFFERENT INPUT DATA

Input Combination (labor, capital, intermediates)	(1) *N*H, HP, I*	(2) *N*H, HP, O*	(3) *N, HP, I*	(4) *N*H, K, I*
Weighted average input growth	1.181**	1.258***	1.214***	1.202***
	(0.0646)	(0.0576)	(0.0722)	(0.0655)
Observations	190	190	190	190
R-squared	0.823	0.943	0.817	0.839

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
The null hypothesis is that the parameter is equal to 1.
Notes: Robust standard errors, clustered by industry, in parentheses. The dependent variable is biennial growth of gross output in each of 19 manufacturing industries between 1919 and 1939. In column 1, weighted average input growth is calculated using total hours worked (*N*H*), horsepower installed (*HP*) and input-deflated intermediate inputs (*I*). In column 2, output-deflated intermediate inputs (*O*) are used. In column 3, the number of workers (*N*) is used. In column 4, capital stock (*K*) is used. All regressions include industry fixed effects (not shown).
Sources: See the main text.

APPENDIX TABLE 2
RETURNS TO SCALE BASED ON ALTERNATIVE OUTPUT CONCEPTS

	Gross Output	Value Added	
	(1)	(2) Double-Deflated	(3) Single-Deflated
Weighted average input growth	1.181**	1.531**	1.675***
	(0.0646)	(0.204)	(0.133)
Implied value added RTS	1.520		
Observations	190	190	190
R-squared	0.823	0.388	0.695

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
The null hypothesis is that the parameter is equal to 1.
Notes: Robust standard errors, clustered by industry, in parentheses. The dependent variable in column 1 is biennial growth of gross output in each of 19 manufacturing industries between 1919 and 1939. The dependent variable in column 2 is double-deflated value added growth; in column 3 it is single-deflated value added growth. In column 1, weighted average input growth includes total hours worked, horsepower installed and input-deflated intermediate inputs. In columns 2 and 3, it only includes total hours worked and horsepower installed. The weights used to calculate the weighted average sum to one in both of the cases. The implied value added RTS is calculated based on the share of value added in gross output and is drawn from Basu and Fernald "Returns." All regressions include industry fixed effects (not shown).
Sources: See the main text.

APPENDIX TABLE 3
RETURNS TO SCALE FOR DIFFERENT INDUSTRY GROUPS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Industry Set	All Industries	Non-BP	BP	Non-CI	CI	Non-Durable	Durable
Weighted average input growth	1.181** (0.0646)	1.224 (0.195)	1.163*** (0.0466)	1.089 (0.101)	1.253** (0.0930)	1.132 (0.122)	1.211** (0.0705)
Difference in returns to scale (compared to industry set in previous column)			–0.0604 (0.195)		0.164 (0.133)		0.0798 (0.138)
Observations	190	90	100	100	90	120	70
R-squared	0.823	0.665	0.925	0.843	0.818	0.696	0.915

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors, clustered by industry, are in parentheses. The null hypothesis is that the parameter is equal to 1 for weighted average input growth and equal to 0 for difference in returns to scale. The dependent variable is biennial growth of gross output in each of 19 manufacturing industries between 1919 and 1939. The independent variable is weighted average input growth based on total hours worked, horsepower installed, and input-deflated intermediate inputs. BP denotes industries covered in the data of Bernanke and Parkinson, "Procyclical"; non-BP are the other industries. CI indicates the nine industries that were in the top of the capital-output distribution; non-CI indicates industries at the bottom. Durable indicates the seven industries that are considered durable manufacturing in the current GDP by Industry accounts of the BEA; Non-durable indicates the remaining 12 industries. See Appendix 1, Appendix Table 1 for the full classifications. The first line shows the results for regressions including only the industries listed at the top of each column. The second line shows the results of a separate regression: $dy_{it} = b_i + \gamma_1 dx_{it} + \gamma_2 D dx_{it} + \varepsilon_{it}$, where D is equal to one if an industry is BP (column 3), CI (column 5) or Durable (column 7) and zero otherwise. The line "Difference in returns to scale" reports coefficient γ_2, while the corresponding γ_1 is shown in the previous column as "weighted average input growth." All regressions include industry fixed effects (not shown).
Sources: See the main text.

APPENDIX TABLE 4
PERIOD-AVERAGE TECHNOLOGICAL AND TFP CHANGE

	Technology Change	Standard Error	Solow Residual TFP Change
Animal products	–0.10	(0.0160)	–0.04
Vegetable products except beverages, total	1.37	(0.0214)	1.27
Beverages and ice, total	9.69	(0.120)	10.16
Textiles and their products	3.82	(0.0274)	3.82
Forest products	1.90	(0.0230)	1.57
Paper and allied products	0.67	(0.0226)	1.59
Printing, publishing, and allied industries	0.94	(0.0206)	1.42
Chemicals and allied products	2.13	(0.0278)	2.59
Products of petroleum and coal	3.03	(0.0370)	4.05
Rubber products	4.92	(0.0435)	5.04
Leather and its manufactures, total	3.69	(0.0313)	2.44
Finished products of leather, total	2.07	(0.0297)	1.82
Stone, clay, and glass products	2.58	(0.0257)	2.90
Iron and steel and their products	0.68	(0.0350)	0.82
Nonferrous metals and their products	–0.46	(0.0259)	–0.15
Machinery, not including transportation equipment	0.23	(0.0321)	0.37
Transportation equipment, air, land, and water	3.41	(0.0422)	3.06
Tobacco manufactures	–0.74	(0.0371)	0.17
Miscellaneous industries	9.57	(0.0656)	8.75

Notes: Parameters shown under "Technological Change" are the b_i coefficients of equation 1 with corresponding standard errors and correspond to the average over the period of $dy_{it} - \gamma dx_{it}$ for each industry. "Solow Residual TFP Change" is the period average of the growth of output minus the growth of inputs.
Sources: See the main text.

APPENDIX TABLE 5
FIRST-STAGE REGRESSION RESULTS

Dependent Variable	Weighted Average Input Growth
Oil price	0.382***
	(0.0635)
Real government spending	0.100***
	(0.0314)
Lagged real government spending	–0.159***
	(0.0327)
Currency-deposit ratio	–0.140**
	(0.0525)
Deposits at failed banks	–0.0205***
	(0.00474)
Observations	190
R-squared	0.592
F-statistic	15.48

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors, are in parentheses. Shown is the first-stage regression underlying the IV estimates in Table 1, column 2, where instruments are used to explain biennial industry input growth. All instruments are taken as log changes from the last period.
Sources: See the main text.

APPENDIX TABLE 6
DYNAMIC EFFECTS OF TECHNOLOGY AND TFP CHANGES ON INPUTS AND OUTPUT

Explanatory Variable:	Technology			Solow Residual TFP		
	Current	Lagged 2Y	Lagged 4Y	Current	Lagged 2Y	Lagged 4Y
Dependent variable:						
Total inputs	0.158	0.193*	–0.107	0.535*	0.0942	–0.127*
	(0.215)	(0.0952)	(0.0795)	(0.297)	(0.0883)	(0.0677)
Total hours	0.156	0.259**	–0.277***	0.531	0.145	–0.226***
	(0.272)	(0.113)	(0.0872)	(0.323)	(0.111)	(0.0626)

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors, clustered by industry, are in parentheses. The dependent variables are either total inputs (weighted average growth of inputs) or growth of total hours. The explanatory variables are either technology change, the residual from the IV regression in Table 1 of the main text; or Solow residual TFP change, which is growth of output minus weighted average growth of inputs, with two lags. For both technology and Solow residual TFP, the current effect and two lags are included.
Sources: See the main text.

APPENDIX TABLE 7
OUTPUT ELASTICITIES FOR INDIVIDUAL PERIODS

	(1)	(2)	(3)	(4)	(5)	(6)
Period	1919–1927	1919–1927	1929–1933	1929–1933	1935–1939	1935–1939
Intermediate Input Deflation	Input-Deflated	Output-Deflated	Input-Deflated	Output-Deflated	Input-Deflated	Output-Deflated
Growth of hours worked by wage earners	0.132	0.258**	–0.0258	–0.0735*	0.0272	0.144*
	(0.164)	(0.0981)	(0.205)	(0.116)	(0.0823)	(0.0723)
Growth of hours worked by salary earners	–0.09	0.043	0.053	0.110	0.197	0.001
	(0.0993)	(0.0654)	(0.153)	(0.0795)	(0.144)	(0.0594)
Growth of horsepower installed	0.198	0.106	0.317	0.351	0.244	0.472
	(0.111)	(0.0702)	(0.373)	(0.193)	(0.746)	(0.356)
Growth of intermediate inputs	0.732**	0.715**	0.813**	0.849***	0.865**	0.737***
	(0.0667)	(0.0611)	(0.113)	(0.0550)	(0.113)	(0.0247)
Returns to scale	0.965	1.123*	1.158	1.237	1.333	1.354
Observations	76	76	57	57	57	57
R-squared	0.921	0.963	0.899	0.976	0.829	0.985

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

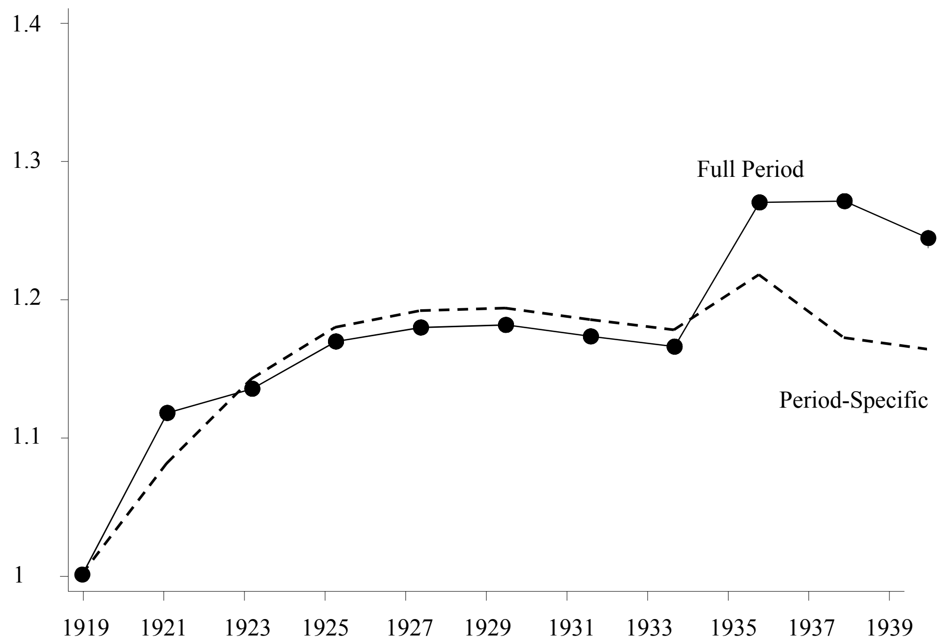
Notes: Robust standard errors, clustered by industry, are in parentheses. Returns to scale is the sum of the input coefficients and the null hypothesis is that returns to scale are equal to one. For other variables, the null hypothesis is that the parameter is equal to its cost share, averaged across industries for the period shown at the top of the column (they are approximately similar to the cost shares shown in Table 4, column 4). Dependent variable is biennial growth of gross output in each of 19 manufacturing industries between 1919 and 1939. Explanatory variables are the biennial growth of individual inputs, with input-price deflated and output-price deflated intermediate inputs. All regressions include industry fixed effects (not shown).

APPENDIX TABLE 8
OUTPUT ELASTICITIES AND COST SHARES BASED ON VALUE ADDED PRODUCTION FUNCTION

	(1)	(2)	(3)
Intermediate Input Deflation	Double-Deflated	Single-Deflated	Cost Share
Growth of hours worked by wage earners	0.479	0.756	0.378
	(0.194)	(0.159)	
Growth of hours worked by salary earners	0.346	0.174	0.114
	(0.165)	(0.121)	
Growth of horsepower installed	0.810	0.482	0.508
	(0.311)	(0.158)	
Returns to scale	1.635**	1.412***	1.000

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors, clustered by industry, are in parentheses. For returns to scale, the null hypothesis is that returns to scale are equal to one. For the inputs, the null hypothesis is that the output elasticities are equal to the cost share. Columns 1 and 2 show regression estimates where growth of value added is the dependent variable and the growth in wage earner hours, salary earner hours, and horsepower are explanatory variables. In column 1, double-deflated value added is the dependent variable; in column 2, single-deflated value added is the dependent variable. Column 3 shows the cost share of each of the inputs in total value added, averaged across industries, and years. All regressions include industry fixed effects (not shown).



APPENDIX FIGURE 2
TECHNOLOGY INDEX BASED ON FULL PERIOD RETURNS TO SCALE AND PERIOD-SPECIFIC RETURNS TO SCALE

Notes: The series are an index with 1919 = 1 and growth rates based on two measures of industry technology change. Industry technology change is calculated as the growth of industry gross output minus returns to scale times cost-share-weighted growth of inputs: intermediate inputs (input-price deflated), growth of hours worked by wage and salary earners, and growth of horsepower installed. Industry technology change is weighted using industry value added shares. Returns to scale for the "Full period" series are estimated as equal to 1.181 in Table 1 in the main text; returns to scale for the "Period-specific" series are estimated as 0.934 for 1919–1927, 1.128 for 1929–1933, and 1.518 for 1935–1939 in Table 3 in the main text.
Sources: See the text.

Data Tables on Output and Inputs in U.S. Manufacturing, 1919 –1939
(see Data tables in pdf or excel format)

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