

# ARE SUPPLY CURVES CONVEX?

## IMPLICATIONS FOR STATE-DEPENDENT RESPONSES TO SHOCKS

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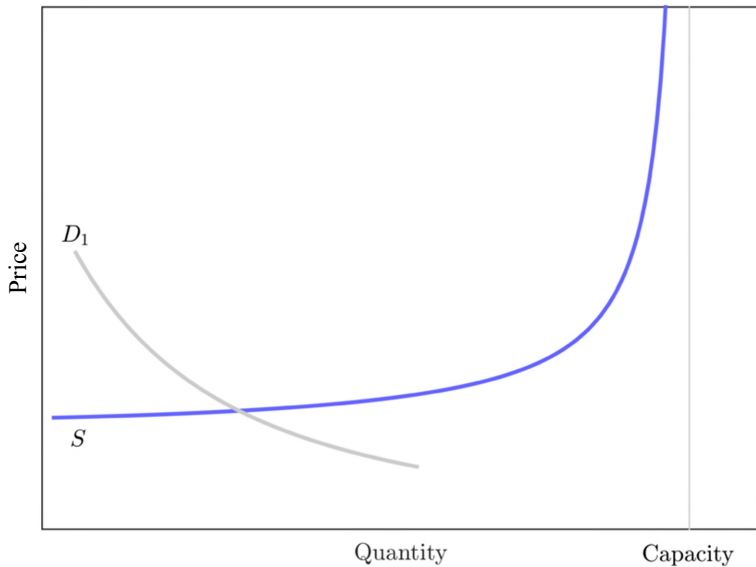
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- **Concerns:**
  - Robustness, e.g. Ramey and Zubairy (14), Santoro et al. (14)
  - Little to no structure
  - Identification

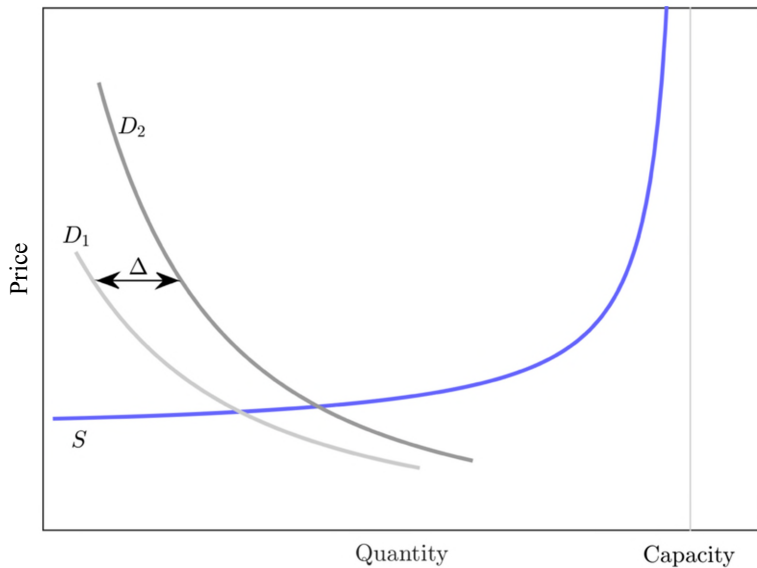
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- **Concerns:**
  - Robustness, e.g. Ramey and Zubairy (14), Santoro et al. (14)
  - Little to no structure
  - Identification
- **Our approach:**
  - Commit to one mechanism: convex supply curves

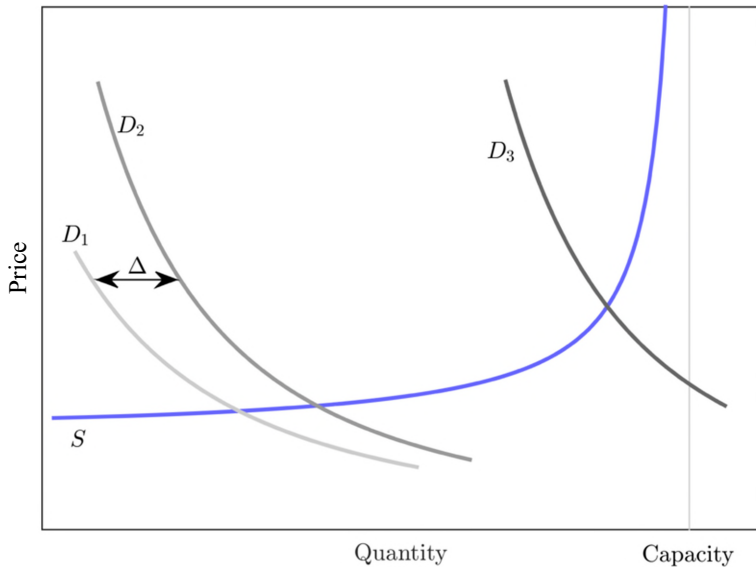
## MOTIVATION



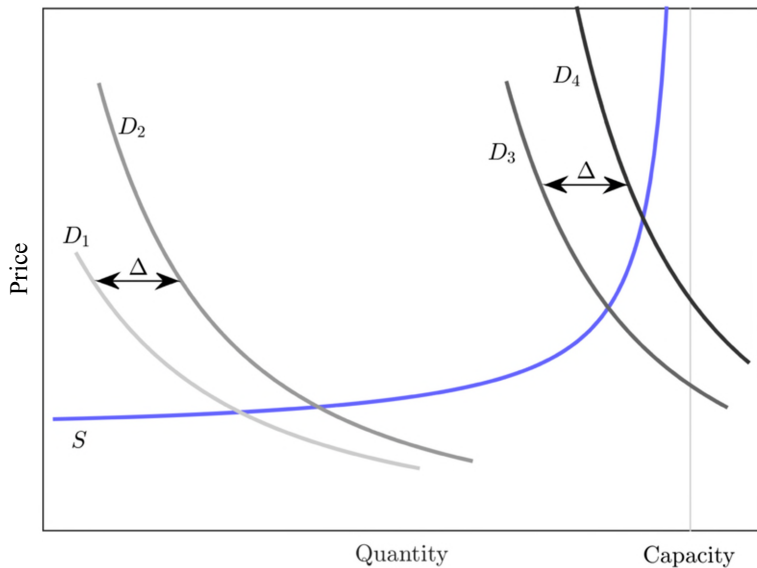
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## RELATED LITERATURE

- **State-dependent effects of stabilization policy**

Auerbach and Gorodnichenko (12, 13a, 13b), Michaillat (14), Owyang, Rainey, and Zubairy (13), Rainey and Zubairy (forthcoming), Santoro et al. (14), Tenreyro and Thwaites (16), Jorda, Schularick, and Taylor (17)

- **Capacity/capital utilization**

- Theory: Greenwood, Hercovitz, and Huffman (88), Cooley, Hansen, and Prescott (95), Fagnart, Licandro, and Portier (97)
- Empirics: Morin and Stevens (04), Bansak, Morin, and Starr (07), Lein and Koeberl (09, 11), Lein (10), Shapiro (89), Stock and Watson (99)

- **Exchange rate shocks**

Gopinatti and Rigobon (08), Amiti, Itskhoki and Konings (14)

# OUTLINE

1. Motivation
2. Model
3. Estimation
4. Direct evidence on rationing
5. Conclusion

## MODEL

- Main assumption: Putty clay capacity limit  $Q_{it}$

▶ Evidence ◀

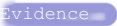
## MODEL

- Main assumption: Putty clay capacity limit  $Q_{i,t}$  
- Convexity: markup adjustments, rationing, shift premia, etc.

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## MODEL

- Main assumption: Putty clay capacity limit  $Q_{iyt}$  Clestone)
- Convexity: markup adjustments, rationing, shift premia, etc.
- Observable concept of capacity utilization  $U_{it} = I$
- Sufficient statistics estimating equation
- Object of analysis: Industry

# EQUILIBRIUM

- Supply of industry  $i$

$$\ln P_{it} = (u_j z_t) + \ln \frac{w_{it} l_{it}}{X_{it}}, t$$

# EQUILIBRIUM

- Supply of industry  $i$

$$\ln \bar{X}_{i,t} = \ln \bar{X}_{i,t} + \ln \frac{W_{i,t} L_{i,t}}{X_{i,t}}$$

- Demand from country  $n$

$$\bar{T}_{i,n,t} = W_{i,n,t} A_{n,t} \left[ \frac{P_{i,n,t}^*}{P_{n,t}^*} \right]^{-\sigma}$$

# EQUILIBRIUM

- Supply of industry  $i$

$$\ln P_{it} = E(U_{it}) + \ln \frac{w_{i,t} L_{i,t}}{X_{it}}$$

- Demand from country  $n$

$$X_{i,n,t} = W_{i,n,t} A_{n,t} \left[ \frac{P_{i,n,t}^*}{P_{n,t}^*} \right]^{-\sigma}$$

- Exchange rate

$$P_{i,n,t} = \frac{C}{e_{nt}} P_{i,n,t}^*$$

# EQUILIBRIUM

- Supply of industry  $i$

$$\ln P_t = \ln(0) + \ln i + \ln X_{i,t}$$

- Demand from country  $n$

$$T_{int} = W_{i,n,t} A_{n,t} \left[ \frac{P_i}{P_{n,t}^*} \right]^{-\sigma}$$

- Exchange rate

$$P_{i,n,t} = e_{int} P_{ii,n,t}^*$$

- Market clearing

$$X_{i,t} = G_{i,t} + \sum_n X_{i,n,t}$$

## SHOCKS

- Effective exchange rate depreciation of industry  $i$

$$A_{ei,t} := \frac{S_{i,n,t-14}}{n} \text{ in } Ent$$

- $S_{i,n,t}$ : sales share to country  $n$
- $n = 0$  is the U.S. (with  $A_{in,0,t} = 0$ )

## SHOCKS

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- $S_{i,n,t}$ : sales share to country  $n$
  - $n = 0$  is the U.S. (with  $A_{in,t} = 0$ )
- Defense spending shock

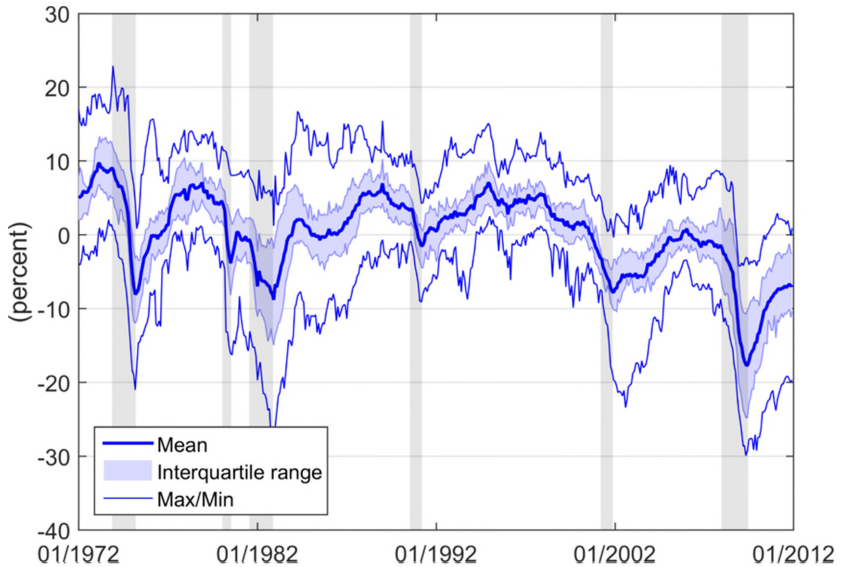
$$A_{git} := \frac{G_{it} - G_{i,t-1}}{X_{it-1}}$$

- Use Bartik-type instrument with aggregate defense spending

# OUTLINE

1. Motivation
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## DEMEANED UTILIZATION



## ESTIMATION

### Baseline specification

$$\ln X_{i,t} = \beta_{Aeit} + \beta_{eudeit} \cdot U_{i,t-1} + \beta_{ulit-1} \\ + \text{controls} + wzt$$

## ESTIMATION

### Baseline specification

$$\ln X_{i,t} = \beta_{meit} + \beta_{euAeit} \blacksquare U_{i,t-1} + \beta_{uui,t-1} \\ + \text{controls} + wzt$$

- If  $\beta_{eu} < 0$  the supply curve is convex

## ESTIMATION

### Baseline specification

$$\ln X_{i,t} = \beta_{meit} + \beta_{ueit} \blacksquare U_{i,t-1} + \beta_{uui,t-1} \\ + \text{controls} + wzt$$

- If  $\beta_{ue} < 0$  the supply curve is convex
- Controls include
  1. Market size and prices
  2. Unit costs
  3. Capacity
  4. Interactions with utilization

## ESTIMATION

### Baseline specification

$$A \ln X_{i,t} = B.Aeit + Beudeit + U_{i,t-1} + Buuit-1 \\ + \text{controls} + wzt$$

- If  $Beu < 0$  the supply curve is convex
- Controls include
  1. Market size and prices
  2. Unit costs
  3. Capacity
  4. Interactions with utilization
- Identification
  - $Bu$  will in general be biased,  $Beu$  won't
  - Next turn to  $Aeit$

## IDENTIFICATION

Purification of  $Ae^{\wedge}$

1. Control for cost changes (Amiti et al., 14)

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Purification of  $\Delta e^{\wedge}$

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2. Decomposition ( $R^2$  of 28.3 percent)

$$\Delta \ln \delta_{nt} = \Delta \ln \delta_{nt}^{TM} + \Delta \ln \delta_{nt}^{op\ ec}$$

## IDENTIFICATION

Purification of  $\Delta e^{\wedge}$

1. Control for cost changes (Amiti et al., 14)
2. Decomposition ( $R^2$  of 28.3 percent)

$$\Delta \ln \delta_{nt} = \Delta \ln \delta_t^{TM} + \Delta \ln \delta_{nt}^{pec}$$

Then

$$\Delta e_{i,t} = \underbrace{\Delta \ln \delta_t^{pec} \times (1 - 810.1 - 1)}_{\text{time FE} \times (1 - St, 0, t-1)}$$

## IDENTIFICATION

Purification of  $\hat{Ae}$

1. Control for cost changes (Amiti et al., 14)
2. Decomposition ( $R^2$  of 28.3 percent)

$$\ln \delta_{nt} = \alpha \ln \delta_t^{TM} + \alpha \ln \delta_{nt}^{pec}$$

Then

$$\underbrace{\hat{A} = \frac{\ln \hat{x} (1 - \frac{N}{sw})}{\ln \hat{x} (1 - \frac{N}{sw})}}_{\text{time FE} \times (1 - \text{Si}_{0,t-1})} - \frac{\ln \hat{x} (1 - \frac{N}{sw})}{\ln \hat{x} (1 - \frac{N}{sw})} \quad \text{time FE}$$

# IDENTIFICATION

## Purification of $\Delta \ln \hat{A}_t$

1. Control for cost changes (Amiti et al., 14)
2. Decomposition ( $R^2$  of 28.3 percent)

$$\Delta \ln \hat{A}_{nt} = \Delta \ln \hat{A}_t^{\text{TM}} + \Delta \ln \hat{A}_{nt}^{\text{pec}}$$

Then

$$\begin{aligned} \Delta \ln \hat{A}_{nt} = & \underbrace{\Delta \ln \hat{A}_t^{\text{TM}} \times (1 - \text{sw}_{t-1}) - \sum_{i=1}^N \Delta \ln \hat{A}_{nt}^{\text{pec}}}_{\text{time FE} \times (1 - \text{Si}_{o,t-1})} + \underbrace{\sum_{n=1}^N \Delta \ln \hat{A}_{nt}^{\text{pec}}}_{\text{our shock}} \\ & + \underbrace{\sum_{n=1}^N \Delta \ln \hat{A}_{nt}^{\text{pec}}}_{\text{our shock}} \end{aligned}$$

## RESULTS: QUANTITIES

Dependent variable A In  $X_{i,t}$

|                                 | (1)      | (2) | (3) | (4) | (5) |
|---------------------------------|----------|-----|-----|-----|-----|
| $\hat{\epsilon}_{i,t}$          | 2.79***  |     |     |     |     |
|                                 | (0.75)   |     |     |     |     |
| $\Delta \hat{\epsilon}_{i,t-1}$ | -22.30** |     |     |     |     |
|                                 | (9.43)   |     |     |     |     |
| $U_{it-1}$                      | -0.04    |     |     |     |     |
|                                 | (0.09)   |     |     |     |     |
| Baseline controls               | yes      |     |     |     |     |
| Observations                    | 819      |     |     |     |     |
| R-squared                       | 0.554    |     |     |     |     |
| Industry FE                     | no       |     |     |     |     |
| Time FE                         | no       |     |     |     |     |
| Time FE x (1 - St,0,t-1)        | no       |     |     |     |     |
| Higher order controls           | no       |     |     |     |     |

Note: Driscoll-Kraay standard errors. Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

## INTERPRETING OF THE INTERACTION TERM

| Dependent Variable: A in $X_{i,t}$                       |        |      |
|----------------------------------------------------------|--------|------|
| Percentile Utilization rate Elasticity w.r.t. $A_{ei,t}$ |        |      |
| 10th                                                     | -0.085 | 4.69 |
| 25th                                                     | -0.032 | 3.50 |
| 50th                                                     | 0.012  | 2.52 |
| 75 <sup>th</sup>                                         | 0.046  | 1.76 |
| 90th                                                     | 0.075  | 1.12 |

## RESULTS: QUANTITIES

Dependent variable A In  $X_{i,t}$

|                               | (1)                | (2)                 | (3) | (4) | (5) |
|-------------------------------|--------------------|---------------------|-----|-----|-----|
| $\hat{\alpha}_{i,t}$          | 2.79***<br>(0.75)  | 2.85***<br>(0.72)   |     |     |     |
| $\Delta \hat{\alpha}_{i,t-1}$ | -22.30**<br>(9.43) | -25.44***<br>(7.88) |     |     |     |
| $U_{it-1}$                    | -0.04<br>(0.09)    | -0.09<br>(0.08)     |     |     |     |
| Baseline controls             | yes                | yes                 |     |     |     |
| Observations                  | 819                | 819                 |     |     |     |
| R-squared                     | 0.554              | 0.569               |     |     |     |
| Industry FE                   | no                 | yes                 |     |     |     |
| Time FE                       | no                 | no                  |     |     |     |
| Time FE x (1 - St,0,t-1)      | no                 | no                  |     |     |     |
| Higher order controls         | no                 | no                  |     |     |     |

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## RESULTS: QUANTITIES

Dependent variable A In  $X_{i,t}$

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|---------------------------------|--------------------|---------------------|---------------------|-----|-----|
| $A_{ei,t}$                      | 2.79***<br>(0.75)  | 2.85***<br>(0.72)   | 1.27<br>(0.90)      |     |     |
| $Leit \times uist-1$            | -22.30**<br>(9.43) | -25.44***<br>(7.88) | -24.40***<br>(7.38) |     |     |
| $Uit-1$                         | -0.04<br>(0.09)    | -0.09<br>(0.08)     | -0.16<br>(0.10)     |     |     |
| Baseline controls               | yes                | yes                 | yes                 |     |     |
| Observations                    | 819                | 819                 | 819                 |     |     |
| R-squared                       | 0.554              | 0.569               | 0.679               |     |     |
| Industry FE                     | no                 | yes                 | yes                 |     |     |
| Time FE                         | no                 | no                  | yes                 |     |     |
| Time FE x (1 — $si_{i,0,t-1}$ ) | no                 | no                  | no                  |     |     |
| Higher order controls           | no                 | no                  | no                  |     |     |

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## RESULTS: QUANTITIES

Dependent variable A In  $X_{i,t}$

|                          | (1)                | (2)                 | (3)                 | (4)                 | (5) |
|--------------------------|--------------------|---------------------|---------------------|---------------------|-----|
| $A_{ei,t}$               | 2.79***<br>(0.75)  | 2.85***<br>(0.72)   | 1.27<br>(0.90)      | 2.02**<br>(0.85)    |     |
| $Lett_{x\ U_{i,t-1}}$    | -22.30**<br>(9.43) | -25.44***<br>(7.88) | -24.40***<br>(7.38) | -31.35***<br>(6.34) |     |
| $U_{it-1}$               | -0.04<br>(0.09)    | -0.09<br>(0.08)     | -0.16<br>(0.10)     | -0.18**<br>(0.09)   |     |
| Baseline controls        | yes                | yes                 | yes                 | yes                 |     |
| Observations             | 819                | 819                 | 819                 | 819                 |     |
| R-squared                | 0.554              | 0.569               | 0.679               | 0.714               |     |
| Industry FE              | no                 | yes                 | yes                 | yes                 |     |
| Time FE                  | no                 | no                  | yes                 | yes                 |     |
| Time FE x (1 - St,0,t-1) | no                 | no                  | no                  | yes                 |     |
| Higher order controls    | no                 | no                  | no                  | no                  |     |

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## RESULTS: QUANTITIES

Dependent variable A In  $X_{i,t}$

|                          | (1)                | (2)                 | (3)                 | (4)                 | (5)                 |
|--------------------------|--------------------|---------------------|---------------------|---------------------|---------------------|
| $A_{ei,t}$               | 2.79***<br>(0.75)  | 2.85***<br>(0.72)   | 1.27<br>(0.90)      | 2.02**<br>(0.85)    | 1.87<br>(2.07)      |
| $Lett_{x\ U_{i,t-1}}$    | -22.30**<br>(9.43) | -25.44***<br>(7.88) | -24.40***<br>(7.38) | -31.35***<br>(6.34) | -30.00***<br>(7.19) |
| $U_{it-1}$               | -0.04<br>(0.09)    | -0.09<br>(0.08)     | -0.16<br>(0.10)     | -0.18**<br>(0.09)   | -0.23**<br>(0.08)   |
| Baseline controls        | yes                | yes                 | yes                 | yes                 | yes                 |
| Observations             | 819                | 819                 | 819                 | 819                 | 819                 |
| R-squared                | 0.554              | 0.569               | 0.679               | 0.714               | 0.735               |
| Industry FE              | no                 | yes                 | yes                 | yes                 | yes                 |
| Time FE                  | no                 | no                  | yes                 | yes                 | yes                 |
| Time FE x (1 - St,0,t-1) | no                 | no                  | no                  | yes                 | yes                 |
| Higher order controls    | no                 | no                  | no                  | no                  | yes                 |

Note: Driscoll-Kraay standard errors. Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

# RESULTS: PRICES

|                           | Dependent variable | In $P_{it}$ |     |     |     |
|---------------------------|--------------------|-------------|-----|-----|-----|
|                           | (1)                | (2)         | (3) | (4) | (5) |
| $\hat{e}_{i,t}$           | -0.12<br>(0.24)    |             |     |     |     |
| $Ae^t \times U_i^I$       | 4.89**<br>(1.74)   |             |     |     |     |
| $U_{i,t-I}$               | -0.06*<br>(0.03)   |             |     |     |     |
| Baseline controls         | yes                |             |     |     |     |
| Observations              | 819                |             |     |     |     |
| R-squared                 | 0.906              |             |     |     |     |
| Industry FE               | no                 |             |     |     |     |
| Time FE                   | no                 |             |     |     |     |
| Time FE x $(1 - s^{o^i})$ | no                 |             |     |     |     |
| Higher order controls     | no                 |             |     |     |     |

Note: Driscoll-Kraay standard errors. Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

## RESULTS: PRICES

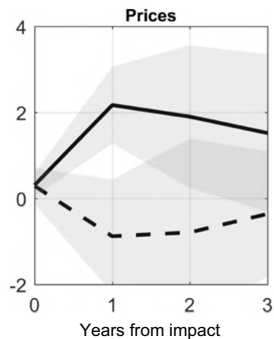
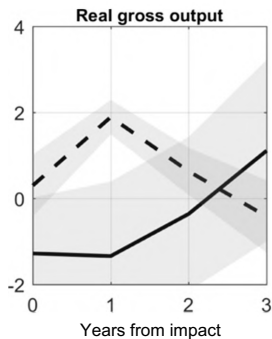
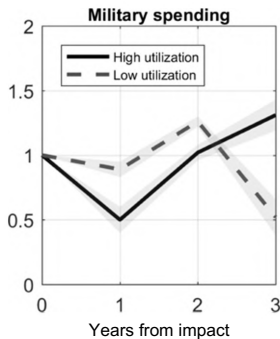
|                                     | Dependent variable |                   | In $P_{it}$       |                   |                  |
|-------------------------------------|--------------------|-------------------|-------------------|-------------------|------------------|
|                                     | (1)                | (2)               | (3)               | (4)               | (5)              |
| $\hat{\epsilon}_{i,t}$              | -0.12<br>(0.24)    | -0.13<br>(0.23)   | -0.13<br>(0.21)   | 0.25<br>(0.74)    | -1.69*<br>(0.93) |
| $\hat{\epsilon}_i \times U_{i,t-1}$ | 4.89**<br>(1.74)   | 4.53**<br>(1.78)  | 5.99***<br>(1.97) | 5.66***<br>(1.66) | 5.10**<br>(1.93) |
| $U_{i,t-1}$                         | -0.06*<br>(0.03)   | -0.07**<br>(0.03) | -0.04<br>(0.04)   | -0.04<br>(0.04)   | -0.01<br>(0.04)  |
| Baseline controls                   | yes                | yes               | yes               | yes               | yes              |
| Observations                        | 819                | 819               | 819               | 819               | 819              |
| R-squared                           | 0.906              | 0.908             | 0.921             | 0.927             | 0.932            |
| Industry FE                         | no                 | yes               | yes               | yes               | yes              |
| Time FE                             | no                 | no                | yes               | yes               | yes              |
| Time FE x (1 - s/o.t-i)             | no                 | no                | no                | yes               | yes              |
| Higher order controls               | no                 | no                | no                | no                | yes              |

Note: Driscoll-Kraay standard errors. Significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

# OUTLINE

1. Motivation
2. Model
3. Data and Estimation: Extension to defense spending
4. Conclusion

## RESULTS



Note: Shaded areas are one standard error bands, clustered by industry

## CONCLUSION

- Structural model with capacity constraints

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- Sufficient statistics approach to estimation

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- Structural model with capacity constraints
- Sufficient statistics approach to estimation
- Responses to demand shocks are highly state dependent
- Evidence consistent with convex supply curves
- Implications for stabilization policy?

# SURVEY FORM

## Item 2 VALUE OF PRODUCTION

A. Report market value of **actual production** for the quarter.

**ACTUAL PRODUCTION**.....

|  |
|--|
|  |
|  |

| \$Bil.               | Mil.                 | Thou.                |
|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |

B. Estimate the market value of production of this plant as if it had been operating at **full production capability** for the quarter.

Assume:

- only machinery and equipment in place and ready to operate.
- normal downtime.
- labor, materials, utilities, etc. **ARE FULLY AVAILABLE.**
- the number of shifts, hours of operation and overtime pay that can be **sustained** under **normal** conditions and a **realistic** work schedule in the long run.
- the **same product mix** as the actual production.

**FULL PRODUCTION CAPABILITY**.....

|  |
|--|
|  |
|  |

| \$Bil.               | Mil.                 | Thou.                |
|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> |
| <input type="text"/> | <input type="text"/> | <input type="text"/> |

C. Divide your **actual production** estimate by your **full production estimate**. Multiply this ratio by 100 to get a percentage.....

|  |
|--|
|  |
|  |

**Capacity Utilization**

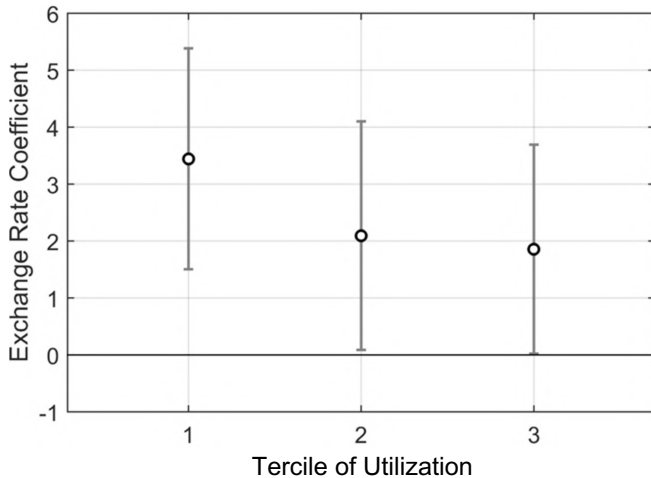
|                      |                      |                      |                      |   |
|----------------------|----------------------|----------------------|----------------------|---|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | % |
| <input type="text"/> |                      |                      |                      |   |

Is this a reasonable estimate of your utilization rate for this quarter?

☐

Yes • No — Review item 2A and 2B

## NONPARAMETRIC ESTIMATION: QUANTITIES



## RESULTS: QUANTITIES

| RHS Variable                                                 | Dependent Variable: A In X2t |                     |                     |                     |
|--------------------------------------------------------------|------------------------------|---------------------|---------------------|---------------------|
|                                                              | (1)                          | (2)                 | (3)                 | (4)                 |
| $\Delta \ln Si_{i,n,t-1}$                                    | 2.22***<br>(0.60)            | 0.48<br>(0.80)      | 0.83<br>(0.80)      | 2.20***<br>(0.57)   |
| $\Delta \ln Sin_{i,t-14} \ln \Delta n_{i,t} \cdot U_{i,t-1}$ | -16.32***<br>(5.48)          | -32.12***<br>(5.70) | -30.08***<br>(5.40) | -17.32***<br>(5.43) |
| $\ln qi_{i,t}$                                               | 0.98***<br>(0.04)            |                     |                     | 0.99***<br>(0.05)   |
| $\ln Qi_{i,t} \cdot ui_{i,t-1}$                              | -0.54<br>(0.57)              |                     |                     | -0.38<br>(0.55)     |
| A In $mci_{i,t}$                                             | -0.03<br>(0.04)              |                     | -0.17***<br>(0.05)  |                     |
| Annett $\cdot$ Uit-1                                         | -0.55<br>(0.56)              |                     | -0.64<br>(0.86)     |                     |
| Other variables                                              | yes                          | yes                 | yes                 | yes                 |
| Observations                                                 | 819                          | 819                 | 819                 | 819                 |
| R-squared                                                    | 0.62                         | 0.37                | 0.39                | 0.62                |
| Industry FE                                                  | no                           | no                  | no                  | no                  |
| Time FE                                                      | no                           | no                  | no                  | no                  |

Driscoll-Kraay standard errors in

parentheses: \*\*\*

<sup>1</sup> p<0.01, \*\*

p<0.05, \* p<0.1.

**Cures**

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| RHS Variable                                                   | Dependent Variable: $\Delta \ln X_t$ |                     |                     |                     |
|----------------------------------------------------------------|--------------------------------------|---------------------|---------------------|---------------------|
|                                                                | (1)                                  | (2)                 | (3)                 | (4)                 |
| $\Delta \ln Si_{i,n,t-1}$                                      | 0.85<br>(0.81)                       | -0.16<br>(0.81)     | -0.15<br>(0.78)     | 0.89<br>(0.83)      |
| $\Delta \ln Sin_{i,t-1} \Delta \ln \&n_{i,t} \cdot Ui_{i,t-1}$ | -16.62***<br>(4.36)                  | -22.33***<br>(6.86) | -21.21***<br>(6.78) | -16.97***<br>(4.43) |
| $\ln qi_{i,t}$                                                 | 0.96***<br>(0.11)                    |                     |                     | 0.97***<br>(0.11)   |
| $\ln Qi_{i,t} \cdot ui_{i,t-1}$                                | -0.57<br>(0.71)                      |                     |                     | -0.48<br>(0.66)     |
| $\Delta \ln mci_{i,t}$                                         | -0.06**<br>(0.03)                    |                     | -0.11**<br>(0.04)   |                     |
| $\Delta \ln met_{i,t} \cdot uit_{i,t-1}$                       | -0.36<br>(0.45)                      |                     | -0.63<br>(0.64)     |                     |
| Other variables                                                | yes                                  | yes                 | yes                 | yes                 |
| Observations                                                   | 819                                  | 819                 | 819                 | 819                 |
| R-squared                                                      | 0.70                                 | 0.61                | 0.61                | 0.70                |
| Industry FE                                                    | yes                                  | yes                 | yes                 | yes                 |
| Time FE                                                        | yes                                  | yes                 | yes                 | yes                 |

Driscoll-Kraay standard errors in

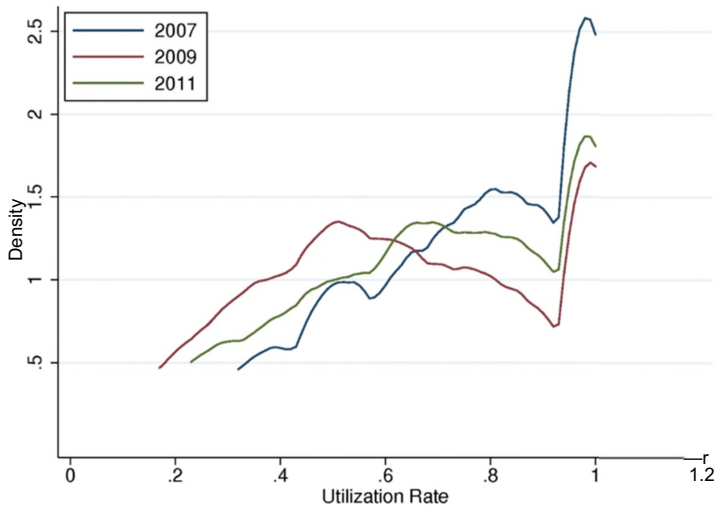
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# CROSS-SECTIONAL DISTRIBUTION OF UTILIZATION



## DATA

- Sample
  - Manufacturing 3-digit NAICS industries (21)
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  - 1972 - 2011

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$$\frac{wL}{X} = \frac{\text{Production Wages} + \text{Material Cost} - \text{Energy Cost}}{\text{Output}}$$

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- Peter Schott's website: exports