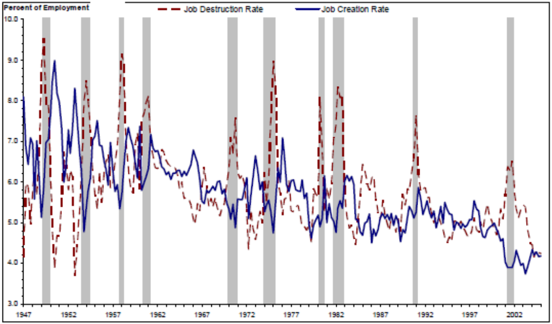
Four motivating facts

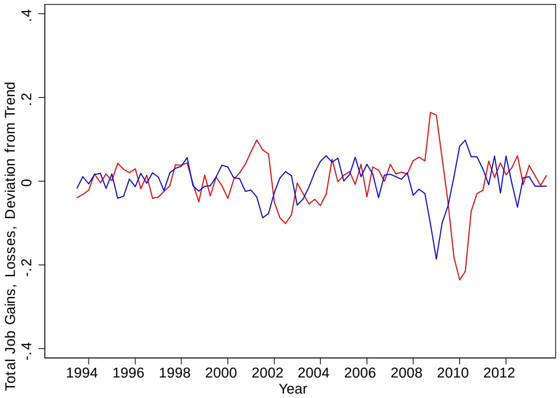
- In recessions:
  - Existing jobs are shed; new jobs are created less frequently Job destruction is almost twice as volatile as job creation.
  - Measured labor productivity decreases (perhaps less so in recent recessions)
- There is lot of variation, within industries, in measured productivity.
- At any given point in time, less productive firms are more likely to exit the industry.

In recessions: job creation goes down, job destruction goes up

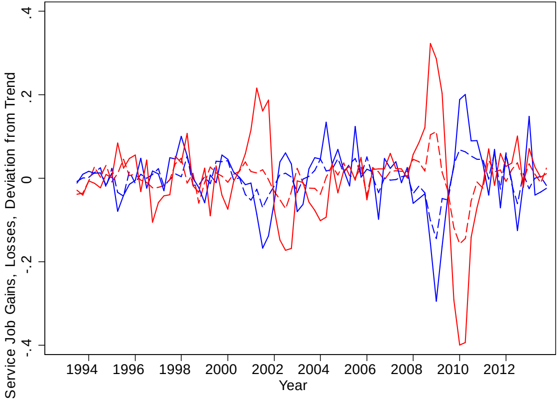


Source: Foster, Haltiwanger, Kim (2006)

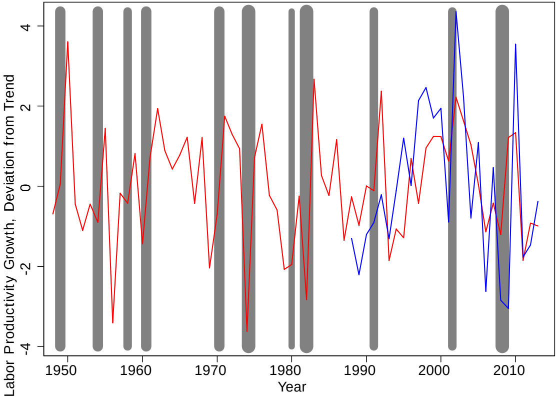
In recessions: job creation goes down, job destruction goes up



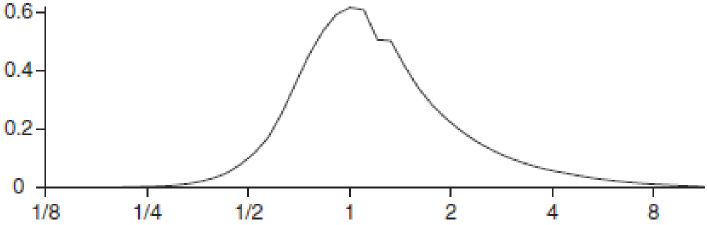
In recessions: job creation goes down, job destruction goes up



Measured labor productivity is lower in recessions



There is a lot of variation in productivity within industries.



Source: Hsieh and Klenow (2009)

Notes on Caballero and Hammour (1994): "The Cleansing Effect of Recessions"

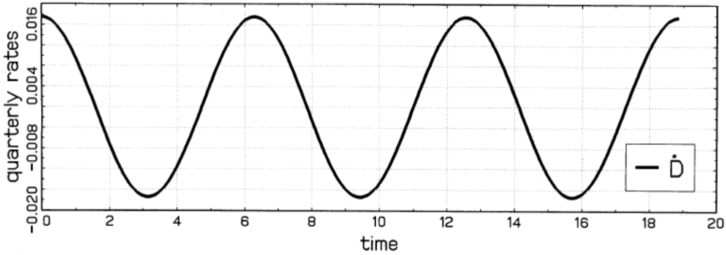
The question

- Firms have heterogeneous productivities. Least productive firms are less likely to survive.
- Suppose demand for an industry (or in the entire economy) falls:
  - Incumbent firms exit in response to lower demand.
  - But if lower demands reduces competition from entrants, then incumbent firms may be have less of an incentive to exit.
- Which margin (reduced entry vs. increased exit) is more important in industries' response to recessions?

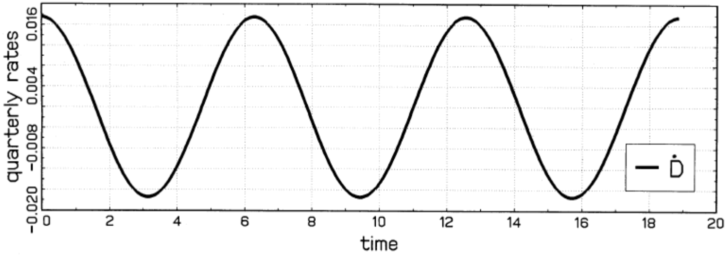
The quick answer and motivation

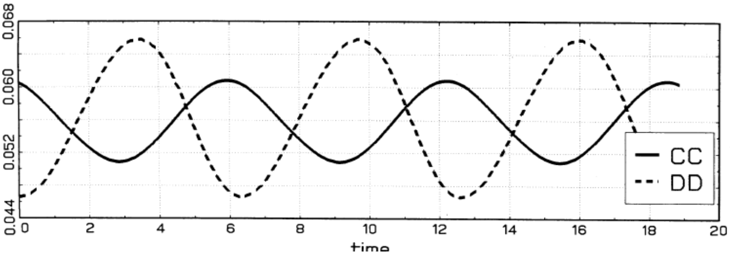
- Which margin (reduced entry vs. increased exit) is more important in industries' response to recessions?
- Answer: It depends on how easily entrants can enter.
  - If the N^{th} entrant can enter as easily as the 1^{st} entrant $\Rightarrow$All of the action is on the entry margin.
    - equilibrium condition: cost of entry = discounted profits over lifetime (from birth to exit).
    - if entry decision doesn't depend on how many other people is entering, so is the eventual decision of when to exit (doesn't depend on path of demand).
  - If the cost of entry increase the number of entrants$\Rightarrow$ both margins are important.
  - In the data, the destruction margin is important $\Rightarrow$ Adjustment costs are important.
- Why do we care: New firms embody new technologies. To the extent that recessions "weed out less productive firms," they can lead to long-term productivity growth.

Assume a periodic demand process



Assume a periodic demand process: What is the rate of firm creation/destruction?





Notes on Kehrig (2011) "The Cyclicality of Productivity Dispersion"

Introduction.

- Question : Are recessions "cleansing"?
- Quick answer No. Productivity dispersion goes *up* in recessions.
- Outline
  - How to estimate productivity
  - Results:
    - Correlation between productivity dispersion and output is negative, more-so in durable-goods-producing industries.
    - Estimated returns to scale are higher in durable-goods-producing industries.
  - A model that can fit these facts: Cost of staying in the industry can be changing in recessions vs booms. Can overcome Caballero and Hammour's "cleansing effect."

Industry definitions

Durable	Nondurable
321 Wood products	311 Food & kindred products
327 Nonmetalic mineral products	312 Beverage and tobacco
331 Primary metals	313 Textile mill products
332 Fabricated metal products	314 Other Textile products
333 Machinery	315 Apparel
334 Computer equipment.	316 Leather
335 Electrical equipment	322 Paper
336 Transportation equipment	323 Printing & publishing
337 Furniture	324 Petroleum & coal
339 Miscellaneous manufacturing	325 Chemicals
	326 Rubber & plastics

Industry definitions

3361 - Motor vehicle manufacturing

- 33611 - Automobile and light duty motor vehicle manufacturing
  - 336111 - Automobile manufacturing
  - 336112 - Light truck and utility vehicle manufacturing
- 33612 - Heavy duty truck manufacturing
  - 336120 - Heavy duty truck manufacturing

Olley and Pakes productivity estimation

Suppose plants (i) in industry j have C-D prod. functions:

$$y_{ijt} = \underbrace{\beta_0 + v_{ijt} + \epsilon_{ijt}}_{a_{ijt}} + \beta^k k_{ijt} + \beta^l l_{ijt} + \beta^e e_{ijt} + \beta^m m_{ijt}$$

Three issues when estimating β's:

1. Capital services (not capital stock) is what generates output.
2. Inputs will be correlated with (observed to firm but unobserved to us) productivity. $\rightarrow$ OLS would give upward biased estimates of β^l, β^m
3. Decision to stay in industry will depend on α_{ijt} and k_{ijt}.$\rightarrow$ OLS would give downward biased β^k

Solution to these issues.

1. Proxy for k_{ijt} using electricity usage..

2. and 3. Assume:

- Productivity follows first-order Markov process.
- $i_{ijt} = k_{ij,t+1} - (1-\delta)\, k_{ijt}$ is an increasing function of last period's capital stock (k_{ijt}) and productivity ($\beta_0 + v_{ijt}$).
- Idea: Investment is a proxy for unobserved productivity.

Olley and Pakes productivity estimation

$$y_{ijt} = \beta^k k_{ijt} + \beta^l l_{ijt} + \beta^e e_{ijt} + \beta^m m_{ijt} + \underbrace{\beta_0 + v_{ijt} + \epsilon_{ijt}}_{a_{ijt}}$$

Correlation between $\beta_0 + v_{ijt}$ and l, e, m, is nonzero, since input choices depend on productivity, and productivity level is correlated with survival and past investment choices.

Three step process:
Step 1: Estimate via OLS

$$y_{ijt} = \beta^l l_{ijt} + \beta^e e_{ijt} + \beta^m m_{ijt} + \phi\left(i_{ijt}, k_{ijt}\right) + \epsilon_{ijt}, \text{ where}$$
$$\phi\left(i_{ijt}, k_{ijt}\right) = \beta_0 + \beta^k k_{ijt} + h_t\left(i_{ijt}, k_{ijt}\right)$$

This gives us $\hat{\beta}^l, \hat{\beta}^e, \hat{\beta}^m$, and $\hat{\phi}$

Olley and Pakes productivity estimation

$$y_{ijt} = \beta^k k_{ijt} + \beta^l l_{ijt} + \beta^e e_{ijt} + \beta^m m_{ijt} + \underbrace{\beta_0 + v_{ijt} + \epsilon_{ijt}}_{a_{ijt}}$$

Write

$$v_{ijt} = \mathbb{E}\left[v_{ijt} | v_{ij,t-1}, \text{survival}\right] + \underbrace{v_{ijt} - \mathbb{E}\left[v_{ijt} | v_{ij,t-1}, \text{survival}\right]}_{\equiv \xi_{ijt}}$$

From step 1, we have

$$y_{ijt} - \hat{\beta}^l l_{ijt} - \hat{\beta}^e e_{it} - \hat{\beta}^m m_{it} = \beta^k k_{ijt} + \beta_0 + \mathbb{E}\left[v_{ijt} | v_{ij,t-1}, \text{survival}\right] + \xi_{ijt} + \epsilon_{ijt}$$

Step 2: Estimate the survival probability, $\hat{P}_{ijt}$, as a function of i_{ijt} and k_{ijt}

Step 3: Estimate via OLS

$$\begin{aligned} y_{ij,t+1} - \hat{\beta}^l l_{ij,t+1} - \hat{\beta}^e e_{ij,t+1} - \hat{\beta}^m m_{ij,t+1} &= \beta_0 + \beta^k k_{ij} + \xi_{it} + \epsilon_{ijt} \\ &\quad + g\left(\hat{P}_{ijt}, \hat{\phi}_{ij,t-1} - \beta_k k_{ij,t-1}\right) \end{aligned}$$

Parameter estimates and cost shares

	Olley-Pakes		Cost shares	
	Non-durables	Durables	Non-durables	Durables
Capital	0.101	0.053	0.17	0.14
	(0.002)	(0.010)		
Hours Worked	0.235	0.292	0.17	0.27
	(0.002)	(0.007)		
Materials	0.471	0.520	0.60	0.55
	(0.001)	(0.006)		
Energy	0.104	0.077	0.02	0.02
	(0.001)	(0.001)		
Returns-to-scale	0.911	0.942		

The dispersion measure

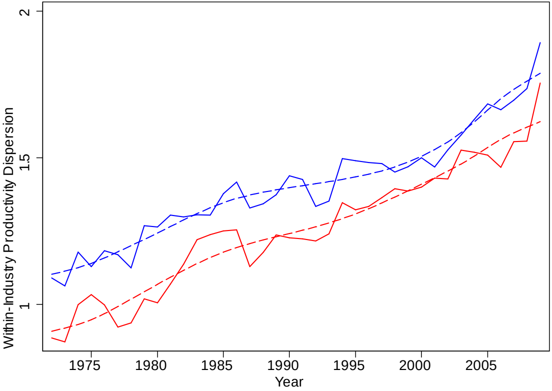
- From above, we have a_{ijt} for all plants in all 473 3-digit NAICS industries. Write z_{ijt} as the productivity measure relative to an industry-level trend.
- Define

$$\text{Var}_{jt} \equiv \left[\left(\frac{z_{ijt} - \bar{z}_j}{\sigma_j} \right) \right]^2$$

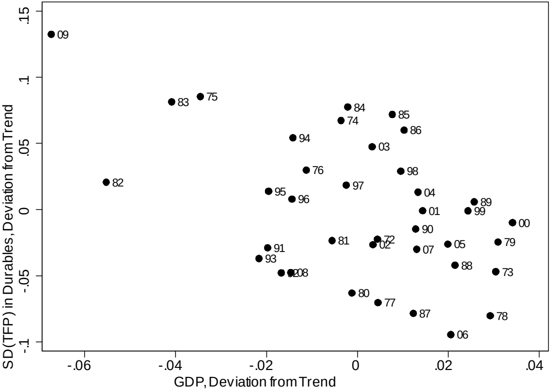
  - $\bar{z}_j$ (σ_j) is the average (standard deviation) de-trended productivity in industry j., and

$$\text{Disp}_t = \text{Median}_t \left[\text{Var}_{jt} \right]$$

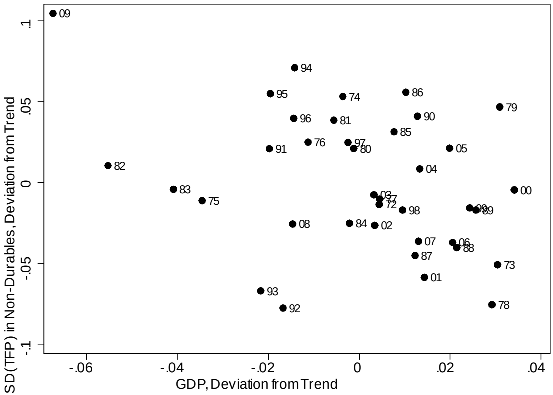
Productivity dispersion: trends



Productivity dispersion: cyclical components



Productivity dispersion: cyclical components



Model: Overview

- Heterogeneous-productivity industries
  - As in Caballero and Hammour: potential entrants weight cost of entry to discounted profits from entry. Exit is only of the exogeneous type.
  - Fixed cost of producing the durable good is proportional to the wage, which is pro-cyclical.
- Demand shocks $\Rightarrow$ Increased profits $\Rightarrow$ Increased entry
  - $\Rightarrow$Real wages increase $\Rightarrow$ Productivity cut-off increases in the durable industry.$\Rightarrow$ More compressed productivity distribution.
  - Negative correlation between productivity distribution and output.
- Key objects:
  - Parameters: Elasticities of substitution in preferences (σ, ϱ), productivity z_i, production cost c_f, and entry cost c_e
  - Endogeneous objects:
    - Cut-off productivity for production in durables (z^*)
    - Entrants (N^e), total firms (N), and firms producing durable goods $\left(N^d\right)$
    - Relative wage (w) and price of durables $\left(P^d\right)$

Final goods producers

The set of intermediate-input-producing firms is Ω_t., subset Ω_t^d of which produce durable goods. The production function of the (competitive) final goods producers are:

$$Y_t^n = \left[\int_{i \in \Omega_t} [y_{it}^n]^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \text{ and } Y_t^d = \left[\int_{i \in \Omega_t^d} \left[y_{it}^d \right]^{\frac{\varrho-1}{\varrho}} \right]^{\frac{\varrho}{\varrho-1}}$$

The demand curves for intermediate inputs are:

$$\frac{y_{it}^n}{Y_t^n} = \left[\frac{p_{it}^n}{P_t^n} \right]^{-\sigma} \text{ and } \frac{y_{it}^d}{Y_t^d} = \left[\frac{p_{it}^d}{P_t^d} \right]^{-\varrho}, \text{ where}$$

$$P_t^n = \left[\int_{i \in \Omega_t} (p_{it}^n)^{1-\sigma} \, di \right]^{1/(1-\sigma)} \text{ and } P_t^d = \left[\int_{i \in \Omega_t^d} \left(p_{it}^d \right)^{1-\sigma} \, di \right]^{1/(1-\sigma)}$$

Intermediate goods producers

For firm i, the production function for producing nondurables and durables is

$$y_{it}^{n} = z_{it} l_{it}^{n} \text{ and } y_{it}^{d} = z_{it}\left(l_{it}^{d} - c_f\right)$$

The price (marginal cost $\times$ markup) price for firm i is

$$p_{it}^{n} = \frac{\sigma}{\sigma - 1}\frac{w_t}{z_{it}} \text{ and } p_{it}^{d} = \frac{\varrho}{\varrho - 1}\frac{w_t}{z_{it}}$$

The profit function for firm for firm i is

$$\pi_{it}^{n} = \frac{1}{\sigma}\left(\frac{\sigma - 1}{\sigma}\frac{z_{it}}{w_t}\right)^{\sigma - 1} Y_t^{n}$$

$$\pi_{it}^{d} = \max\left\{0, \frac{1}{\varrho}\left(\frac{\varrho - 1}{\varrho}\frac{z_{it}}{w_t}\right)^{\varrho - 1} Y_t^{d}\left(P_t^{d}\right)^{\varrho} - w_t c_f\right\}$$

Firm i will produce durables if and only if

$$z_{it} > z_t^{*} \equiv \frac{1}{\varrho - 1}\left[\left(\varrho\frac{w_t}{P_t^{d}}\right)^{\varrho}\frac{c_f}{Y_t^{d}}\right]^{1/(\varrho - 1)}$$

Intermediate goods producers

Firm i will produce durables if and only if

$$z_{it} > z_t^* \equiv \frac{1}{\varrho - 1}\left[\left(\varrho \frac{w_t}{P_t^d}\right)^{\varrho} \frac{c_f}{Y_t^d}\right]^{1/(\varrho-1)}$$

Durable goods producers will survive if:

- The values of sales is high (Y_t^d or P_t^d) is high
- Wages are low.

Intermediate goods producers

Suppose nondurable goods producers' productivity follows a Pareto distribution with lower bound 1 and slope k.

A useful property of the Pareto distribution and CES preferences:

$$\bar{z}^n \equiv \left[\int_1^\infty z^{\sigma-1} dF(z)\right]^{\frac{1}{\sigma-1}}$$

$$= \left[k \int_1^\infty z^{\sigma-1-k+1} dz\right]^{\frac{1}{\sigma-1}} = \left[\frac{k}{k-\sigma+1}\right]^{1/(\sigma-1)}$$

Similarly, define:

$$\bar{z}^d \equiv \left[\frac{1}{1-F[z_t^*]} \int_{z_t^*}^\infty z^{\varrho-1} dF(z)\right]^{\frac{1}{\varrho-1}}$$

$$= \left[\frac{k}{k-\varrho+1}\right]^{1/(\varrho-1)} z_t^*$$

Average productivity in the two industries depends only on cut-offs, EoS, and shape of the productivity distribution.

Intermediate goods producers

Price indices:

$$
\begin{aligned}
P_t^n \equiv 1 &= \left[\int_{i\in\Omega_t} (p_{it}^n)^{1-\sigma}\, di\right]^{1/(1-\sigma)} \\
&= \left[\int_{i\in\Omega_t} \left[\frac{w_t}{z_{it}}\frac{\sigma}{\sigma-1}\right]^{1-\sigma} di\right]^{1/(1-\sigma)} \\
&= N^{\frac{1}{\sigma-1}}\frac{w_t\sigma}{\sigma-1}\left[\int_{i\in\Omega_t} z_{it}^{\sigma-1} di\right]^{1/(1-\sigma)} \\
&= \frac{w_t}{\bar{z}^n}\frac{\sigma}{\sigma-1}N_t^{\frac{1}{1-\sigma}}
\end{aligned}
$$

Similarly

$$
P_t^d = \frac{w_t}{\bar{z}^d}\frac{\varrho}{\varrho-1}\left[N_t^d\right]^{\frac{1}{1-\sigma}}
$$

Combining these equations, plus those from the past slide.

$$
\frac{P_t^d}{P_t^n} = \frac{\varrho}{\varrho-1}\frac{\sigma-1}{\sigma}\frac{\bar{z}^n}{\bar{z}^d} \propto [z_t^*]^{-1}
$$

Firm Entry

- Free entry condition: cost of entry and expected profits

$$c_e w_t = \mathbb{E}\left[\sum_{s=1}^{\infty} \beta^s \frac{\lambda_{t+s}}{\lambda_t} (1-\zeta)^s \pi_{t+s}\right]$$

  λ_t is the Lagrange multiplier on the household BC (next slide).

- Evolution of the number of firms

$$N_{t+1} = (1-\zeta)\left[N_t + N_t^e\right]$$

Household problem

Consumers care about consumption of nondurables (C_t), durables (D_t), and labor supply (L_t)

$$U = \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\theta} \left[C_t^{\alpha} \left(\eta D_t \right)^{\eta} \left(1 - \phi_t L_t \right)^{\psi} \right]^{1-\theta} \right]$$

Budget constraint:

$$\begin{aligned} C_t + P_t^d \left[D_{t+1} - (1-\delta) D_t \right] = {} & w_t L_t + s_t \pi_t N_t \\ & + v_t \left(s_{t+1} N_{t+1} - s_t N_t \right) \end{aligned}$$

Equilibrium conditions

- Market clearing conditions:
  - Shares: $\int s_t = 1$
  - Durable goods, nondurable goods: $\int Y_t^n = C_t$; $\int_t D_{t+1} - (1-\delta) D_t$.
  - Labor: $L_t = N_t l(\bar{z}^n) + N_t^d l(\bar{z}_t^d) + N_t^e c_e$
- Consumers choose share holdings, durable goods consumption, nondurable goods consumption, labor supply to maximize utility.
- Intermediate input suppliers choose
  - whether to enter by comparing $c_e w_t$ to discounted profits.
  - whether to produce durable goods if per period profits are positive
  - labor demand to maximize profits.

Suppose a demand shock hits...

- Remember:

$$N_{t+1} = (1-\zeta)\left[N_t + N_t^e\right]$$
$$P_t^n = 1 = \frac{w_t}{\bar{z}^n}\frac{\sigma}{\sigma-1}N_t^{\frac{1}{1-\sigma}}$$

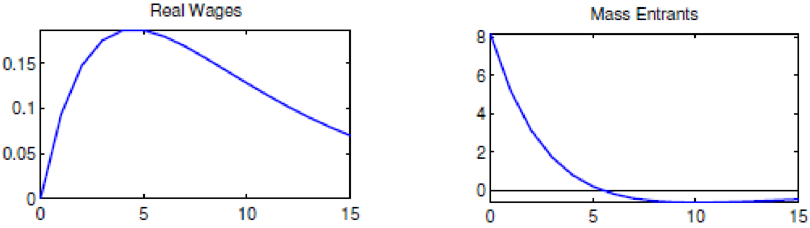
$\Rightarrow$ Real wage is fixed upon impact.

  - To meet increased demand potential entrants begin to enter and productivity cutoff (for durable production) decreases.
  - As more firms produce the durable good, the relative price of durables decreases.
  - Consistent with the last two bullet points, remember:

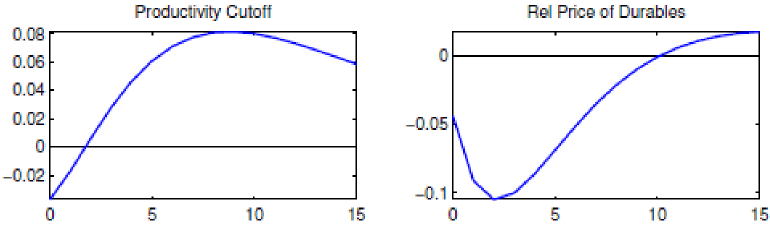
$$\frac{P_t^d}{P_t^n} \propto \left[z_t^*\right]^{-1}$$

- Over time, in response to the additional number of firms the real wage increases

Impulse responses from a demand shock



Impulse responses from a demand shock

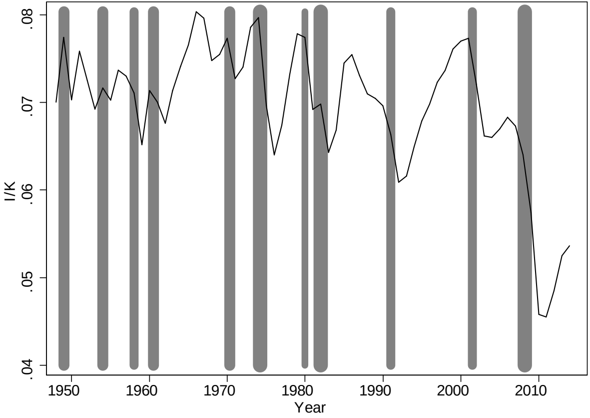


Notes on Caballero and Engel (1999): "Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach"

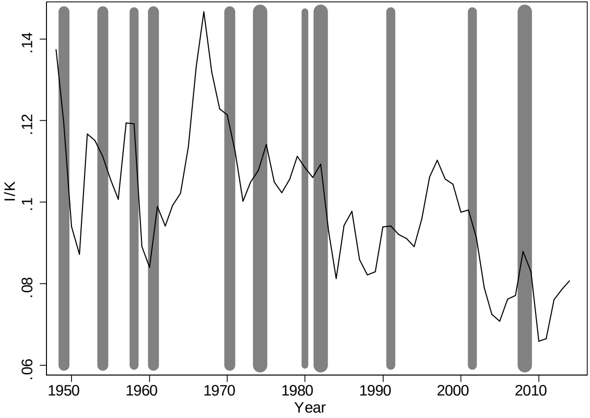
Motivation and Contribution

- In the aggregate (or sectoral) data, Changes in investment seem to be very sensitive to aggregate conditions. Investment rates are persistent.
  - Both of these facts are more pronounced for investment in structures than compared to investment in equipment
- In the micro data: In a given year many firms invest quite a lot and many others invest nothing.
- Contribution:
  - Method: A tractable way of introducing firm-level adjustment costs.
  - Empirically demonstrate: To fit the aggregate patterns, fixed adjustment costs are necessary.

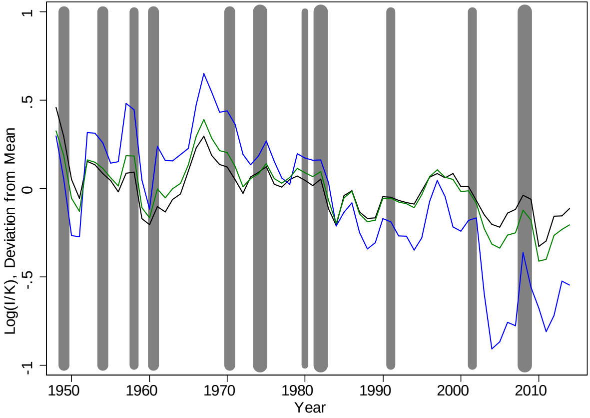
Investment rates in the private economy



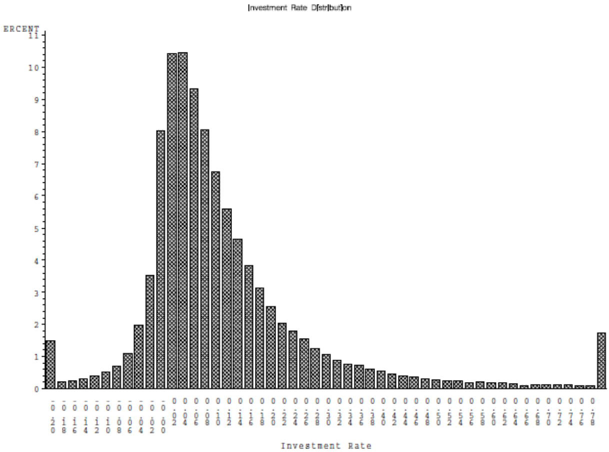
Investment rates in manufacturing



Investment rates in manufacturing



In a given year, many firms invest nothing



- Source: Cooper and Haltiwanger .

Model: Overview

- A heterogeneous-firm industry wherein the main decision is how much invest each period.
  - The marginal revenue product of capital is subject to aggregate and idiosyncratic shocks.
- Main trade-off: Invest today and pay a fixed cost or endure a capital stock that is away from the frictionless profit-maximizing level? Depends on:
  - How far (x) the firm is from the frictionless optimum (c).
  - The size of the adjustment cost (ω, which is random).
  - The distribution of adjustment costs in the future.

Review of notation

- $z \equiv \log\left(\frac{K}{K^*}\right)$
- foregone cost of adjusting capital: ω is drawn from a distribution G
- $\Omega(z)$ =cutoff ω for a which the firm decides to adjust its capital stock to $z = c$
- $\Lambda(z) = \int_0^{\Omega(x+c)} dG(\omega)$
- $\log\left(\frac{K_t^*}{K_{t-1}^*}\right) \equiv \mu_{it} = \epsilon_{it} + \nu_t$

Steps of period t

- Start: $f(x, t-1)$: Distribution of x at end of period $t-1$.
- Aggregate shocks (ν), depreciation (δ).
  - Because there are no new decisions c doesn't change.
  - $z' = z - \delta - \nu \Rightarrow x' = x - \delta - \nu$
  - $f(x + \delta + \nu, t-1) = \tilde{f}(x, t)$ =density of firms with imbalance x
- Firms decide whether to invest, how much to invest.
- Then idiosyncratic shocks ϵ.

$$f(x,t) = \left[\int \Lambda(y)\,\tilde{f}(y,t)\,dy\right] g_\epsilon(-x) + \int [1 - \Lambda(x+\epsilon)]\,\tilde{f}(x+\epsilon_t, t)\,g_\epsilon(-\epsilon)\,d\epsilon$$

- Combining equations:

$$f(x,t) = \left[\int \Lambda(y)\,f(y+\delta+\nu_t, t-1)\,dy\right] g_\epsilon(-x) + \int [1 - \Lambda(x+\epsilon)]\,f(x+\epsilon+\delta+\nu_t, t-1)\,g_\epsilon(-\epsilon)\,d\epsilon$$

Aggregate Investment

- Last time: A firm with x invests $\Lambda(x)\left(e^{-x}-1\right)K_t(x)$
- Average over all firms with x: $\Lambda(x)\left(e^{-x}-1\right)\overline{K_t(x)}$
- Integrating over all imbalances:

$$I_t^A = \int \left(e^{-x}-1\right)\Lambda(x)\,\overline{K_t(x)}\tilde{f}(x,t)\,dx$$

- Divide by K_t^A and do some re-arranging:

$$\begin{aligned}\frac{I_t^A}{K_t^A} &= \int \left(e^{-x}-1\right)\Lambda(x)\,\tilde{f}(x,t)\,dx \\ &\quad + \frac{1}{K_t^A}\int \left(e^{-x}-1\right)\Lambda(x)\,\tilde{f}(x,t)\left(\overline{K_t(x)}-K_t^A\right)dx\end{aligned}$$

- The authors argue, numerically, that the second term is small.

$$\begin{aligned}\frac{I_t^A}{K_t^A} &\approx \int \left(e^{-x}-1\right)\Lambda(x)\,\tilde{f}(x,t)\,dx \\ &\approx \int \left(e^{-x}-1\right)\Lambda(x)\,f(x+\delta+\nu_t, t-1)\,dx\end{aligned}$$

Aggregate Investment: Partial Adjustment Model

- Assume $\tilde{f}$ has most of its mass near $x = 0$ ($\Rightarrow e^{-x} - 1 \approx -x$) and that the hazard of adjustment does not depend on $x \Rightarrow \frac{I_t^A}{K_t^A} \approx -\Lambda_0 \tilde{X}_t$, where $\tilde{X}_t = \log\left(\frac{K_t^A}{K_t^*}\right)$
- Evolution of capital $\frac{K_t^A}{K_{t-1}^A} = 1 - \delta + \frac{I_{t-1}^A}{K_{t-1}^A}$
- Use definition of $\tilde{X}_t = \log\left(\frac{K_t^A}{K_{t-1}^A}\right) - \log\left(\frac{K_t^*}{K_{t-1}^*}\right) + \tilde{X}_{t-1}$
- Plug in last definition to the previous equation:

$$\tilde{X}_t - \tilde{X}_{t-1} = \log\left(\frac{K_t^A}{K_{t-1}^A}\right) - \log\left(\frac{K_t^*}{K_{t-1}^*}\right)$$

$$-\frac{1}{\Lambda_0}\left(\frac{I_t^A}{K_t^A} - \frac{I_{t-1}^A}{K_{t-1}^A}\right) \approx \frac{I_{t-1}^A}{K_{t-1}^A} - \delta - \log\left(\frac{K_t^*}{K_{t-1}^*}\right)$$

$$\frac{I_t^A}{K_t^A} = (1-\Lambda_0)\frac{I_{t-1}^A}{K_{t-1}^A} + \Lambda_0\left(\delta + \log\left(\frac{K_t^*}{K_{t-1}^*}\right)\right)$$

Estimation

- Data: $\frac{I_t^A}{K_t^A}$ from 1947 to 1992, for structures and equipment.
- Set most parameters to "reasonable" values: $r = 6\%$, $\delta_e = 10\%$, $\delta_s = 5\%$, $\beta \equiv \frac{\alpha(\eta-1)}{1+\alpha(\eta-1)} = 0.4$, $\sigma_\epsilon = 0.1$
- Method 1: Use model as it has been laid out. Estimate parameters of ω distribution.
- Method 2: Use a reduced form in which $\Lambda(x) \equiv 1 - e^{-\lambda_0 - \lambda_2 x^2}$ is specified. Estimate λ's.

Estimation

- Reminder:

$$\frac{I_t^A}{K_t^A} \approx \int \left(e^{-x} - 1\right) \Lambda\left(x\right) f\left(x + \delta + \nu_t, t - 1\right) dx$$

- Estimate via maximum likelihood.
  - Assume ν_t are $\mathcal{N}\left(\mu, c\right)$ distributed.
  - For a single data point, its log density is

$$\mathcal{L}\left(\frac{I_t^A}{K_t^A}; \mu, c, \lambda\right) = -\frac{1}{2}\log\left(2\pi\right) - \frac{1}{2}c - \frac{\left(\nu_t - \mu\right)^2}{2c} - \log\left|\frac{\partial\left(I_t^A \div K_t^A\right)}{\partial \nu_t}\right|$$

  - Remember: Change of variable formula for pdfs: $f_v\left(v\right) = \left|\frac{\partial x}{\partial v}\right| f_x\left(x\right)$

Estimation

From the last slide:

$$\mathcal{L}\left(\frac{I_t^A}{K_t^A}; \mu, c, \lambda\right) = -\frac{1}{2}\log(2\pi) - \frac{1}{2}c - \frac{(\nu_t - \mu)^2}{2c} - \log\left|\frac{\partial\left(I_t^A \div K_t^A\right)}{\partial \nu_t}\right|$$

Extend to multiple industries:

- V_i is shocks of sector i. $V = \begin{pmatrix} V_1 \\ \dots \\ V_I \end{pmatrix}$
- $\mu_V = \mathbb{E}[V]$
- C, the covariance matrix of productivity shocks: c_{ij} in entry i, j

The MLE estimate of C: $\frac{(V-\hat{\mu}_V)(V-\hat{\mu}_V)'}{T}$

Plug this result in:

$$\mathcal{L} = -\text{cons.} - \frac{T}{2}\log\left|\frac{(V - \hat{\mu}_V)(V - \hat{\mu}_V)'}{T}\right| - \sum_{i,t}\left|\frac{\partial\left(I_{it}^A \div K_{it}^A\right)}{\partial \nu_{it}}\right|$$

Estimation

- Problem: We never see the state variable, the distribution of imbalances $f(x, t-1)$. So how can we back out the ν_{it}s?

- Solution: Assume that the initial distribution $f(x, 0)$ is known, equal to the stationary distribution.
  - Given data on $\frac{I_{i1}^A}{K_{i1}^A}$ we will be able to back v_{i1}.
    - Only tricky point is to show that $\frac{\partial \left(I_{it}^A \div K_{it}^A \right)}{\partial \nu_{it}} > 0$ so that there is a one-to-one mapping between the aggregate shocks and investment rates
  - Since we f evolves according to:

$$f(x, t) = \left[\int \Lambda(y) f(y + \delta + \nu_t, t-1) \, dy \right] g_\epsilon(-x) + \int [1 - \Lambda(x + \epsilon)] f(x + \epsilon + \delta + \nu_t, t-1) \, g_\epsilon(-\epsilon) \, d\epsilon$$

we can now write out $f(x, 1)$.

Estimation

Parameters	Equipment		Structures	
λ_0	0.155		0.000	
λ_2	2.804		2.437	
constant	0.057	-0.006	0.013	0.019
μ_ω		0.166		0.228
cv_ω		0.327		0.066
$\mathcal{L}$	2430	2431	2612	2637
$\mathcal{L}$: $\lambda_2 = 0$	2387		2533	
$\mathcal{L}$: constant only	2315	2315	2497	2497

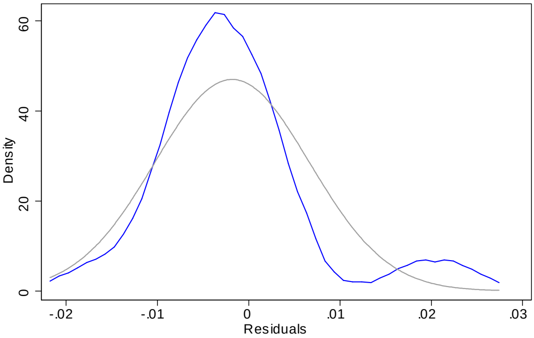
- Remember our reduced form for $\Lambda(x)$ was $1 - e^{-\lambda_0 - \lambda_2 x^2}$.
- $\lambda_2 > 0$ parameterizes the strength of the relationship between imbalance and probability of adjusting.

Where does the Partial Adjustment Model struggle?

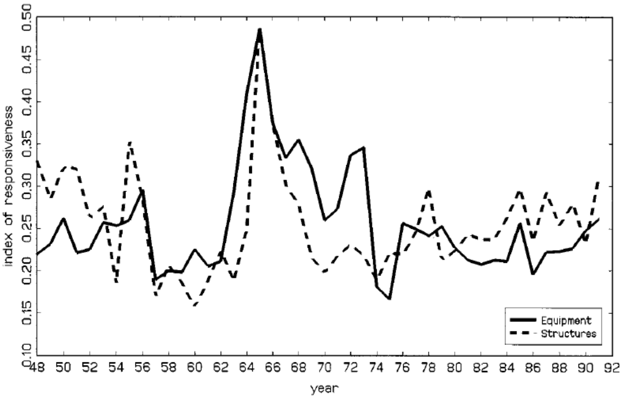
- Investment intensity of the Partial Adjustment Model:

$$\frac{I_t^A}{K_t^A} = (1 - \Lambda_0)\,\frac{I_{t-1}^A}{K_{t-1}^A} + \Lambda_0 \left(\delta + \log\left(\frac{K_t^*}{K_{t-1}^*} \right) \right)$$

$$= \varrho \frac{I_{t-1}^A}{K_{t-1}^A} + \nu_t$$



Aggregate Implications



- $\frac{\partial\left(I_{it}^{A} \div K_{it}^{A}\right)}{\partial \nu_{it}}$, i.e. the response of investment to shocks varies over the business cycle

Conclusion

- Model with fixed costs of investment helps fit both micro and macro data better.
- Firms' decisions are characterized by periods of inaction and lumpy investment.
- Many other economic problems fit this mold (see Caplin and Leahy, *A Celebration of the (S,s) Model*):
  - Do I change the price I charge my customers in response to a change in demand/marginal costs?
  - Do I change my house or durable good stock in response to a change in household finances?
  - Do I refinance my mortgage in response to a decline in the prevailing interest rate?
  - How quickly do I change my money holdings (Baumol-Tobin model of money demand)?

Notes on Cooper and Haltiwanger (2006): "On the Nature of Capital Adjustment Costs"

Question

- How important are adjustment costs in fitting micro investment data?
  - Convex adjustment costs
  - Non-convex adjustment costs
  - Transaction costs
- How important are adjustment costs' in fitting macro investment data?

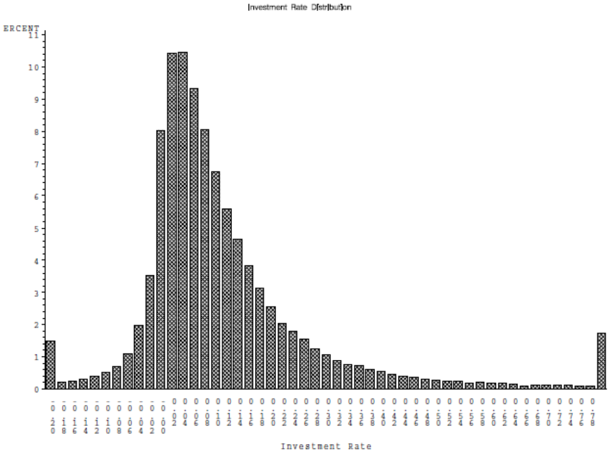
Outline

- Data and moments.
- Extreme cases
  - Convex adjustment costs
  - Fixed costs of adjusting capital
  - Transaction costs
- Estimation

Data

- From 1972-1988 the U.S. Census
  - 7000 plants that are in continuous operation
  - Investment expenditures minus retirements$\equiv I_t = K_{t+1} - (1-\delta) K_t$
  - Gross profits (sales $-$ payments to labor $-$ material inputs)

Data



Investment Rate Distribution
ERCENT
11
10
9
8
7
6
5
4
3
2
1
0
Investment Rate

Data

- Moments:
  - Average investment rate : 12%
  - Inaction rate ($\left|\frac{I_t}{K_t}\right| < 0.01$): 8%
  - Serial correlation of investment : 6%
  - Correlation of profit shocks and investment: 14%
  - Fraction of observations with... $\frac{I_t}{K_t} > 0.2$: 19%; $\frac{I_t}{K_t} < -0.2$: 2%

The general dynamic programming problem

$$V\left(A,K\right)=\max_{I}AK^{\theta}-C\left(I,A,K\right)-P\left(I\right)I+\beta\mathbb{E}_{A'|A}V\left(A',K'\right)$$

- Special cases:
  - Convex adjustment costs: $C\left(I,A,K\right),=\frac{\gamma K}{2}\left(I/K\right)^{2}$, $p_I=p_I$
  - Caballero and Engel: $C\left(I,A,K\right)=\left(1-\lambda\right)AK^{\theta}$, $P\left(I\right)=p_I$
  - Abel and Eberly transaction costs: $p\left(I\right)=\begin{cases}p_b \text{ if } I>0\\ p_s \text{ if } I<0\end{cases}$

Convex adjustment costs

$$V(A,K) = \max_I AK^\theta - p_I I - \frac{\gamma K}{2}(I/K)^2 + \beta \mathbb{E}_{A'|A} V(A',K')$$
$$K' = (1-\delta)K + I$$

First-order conditions (wrt I):

$$\gamma \frac{I}{K} = \mathbb{E}_{A'|A}\left[\beta \frac{\partial V(A',K')}{\partial K'} - p_I\right]$$

Special Case ($\theta = 1$)

$$V(A,K) = \max_I AK - p_I I - \frac{\gamma K}{2}\left(\frac{I}{K}\right)^2 + \beta \mathbb{E}_{A'|A} V(A',K')$$

Guess that $V(A,K) = v(A) \cdot K$

$$v(A) \cdot K = \max_I AK - p_I \frac{I}{K} K - \frac{\gamma K}{2}\left(\frac{I}{K}\right)^2 + \beta K \mathbb{E}\left[v(A')\right] K'$$

Convex adjustment costs: CRS Production (Detour)

Guess that $V(A,K) = v(A) \cdot K$

$$v(A) \cdot K = \max_I AK - p_I \frac{I}{K} K - \frac{\gamma K}{2} \left(\frac{I}{K}\right)^2 + \beta K \mathbb{E}\left[v(A')\right] K'$$

$$v(A) = \max_I -p_I \frac{I}{K} - \frac{\gamma}{2} \left(\frac{I}{K}\right)^2 + \beta \mathbb{E}\left[v(A')\right] \left[\frac{I}{K} - (1-\delta)\right]$$

$$= A - \beta(1-\delta) + \max_I -p_I \frac{I}{K} - \frac{\gamma}{2} \left(\frac{I}{K}\right)^2 + \beta \frac{I}{K} \mathbb{E}\left[v(A')\right]$$

Convex adjustment costs: CRS Production (Detour)

- From last slide:

$$v(A) = A - \beta(1-\delta) + \max_{I} -p_I \frac{I}{K} - \frac{\gamma}{2}\left(\frac{I}{K}\right)^2 + \beta \frac{I}{K}\mathbb{E}\left[v(A')\right]$$

- Take first order conditions:

$$\begin{aligned} p_I + \gamma \frac{I}{K} &= \beta \mathbb{E}\left[v(A')\right] \\ \gamma \frac{I}{K} &= p_I \left[\beta \frac{\mathbb{E}\left[v(A')\right]}{p_I} - 1\right] \\ &= p_I \left[\beta \frac{\mathbb{E}\left[\frac{V(A',K')}{K'}\right]}{p_I} - 1\right] \end{aligned}$$

  Investment rate is positive if and only if $\beta \mathbb{E}\left[\frac{V(A',K')}{K'}\right]$ is bigger than p_I.
- Marginal Q: $\frac{\text{Marginal discounted profits of extra unit of capital}}{\text{Marginal cost of extra unit of capital}}$
- Normally: In the data we see $\frac{V(A',K')}{K'}$. With CRS production: average=marginal.

Convex adjustment costs

- From the last slide:

$$\frac{I}{K} = \frac{1}{\gamma}\left[\beta \mathbb{E}\left[v\left(A'\right)\right] - p_I\right]$$

When $\theta < 1$:

$$\frac{I}{K} = \frac{1}{\gamma}\mathbb{E}\left[\beta \frac{\partial V\left(A', K'\right)}{\partial K'} - p_I\right]$$

- Investment rates inherit the expectation of future productivity.
- γ dampens response of investment
- When $\gamma = 0 \Rightarrow$

$$\beta \frac{\partial V\left(A', K'\right)}{\partial K'} = p_I$$

  Here, there can be "bursts" of investment activity. Less persistence in investment rates.

Non-convex adjustment costs.

Suppose $C(I, A, K) = (1-\lambda) AK^{\theta} + FK$
Then

$$\begin{aligned} V(A, K) &= \max\left\{V^{i}(A, K), V^{a}(A, K)\right\} \text{ where} \\ V^{i}(A, K) &= AK^{\theta} + \beta \mathbb{E} V\left(A', K(1-\delta)\right) \\ V^{a}(A, K) &= \max_{I} \lambda AK^{\theta} - FK - p_{I} I + \beta \mathbb{E} V\left(A', K(1-\delta) + I\right) \end{aligned}$$

Caballero and Engel has $F = 0$. Because of the K term that multiplies F, we can still do the trick of showing that the value function is homogenous of degree 1 in K.

Transaction costs

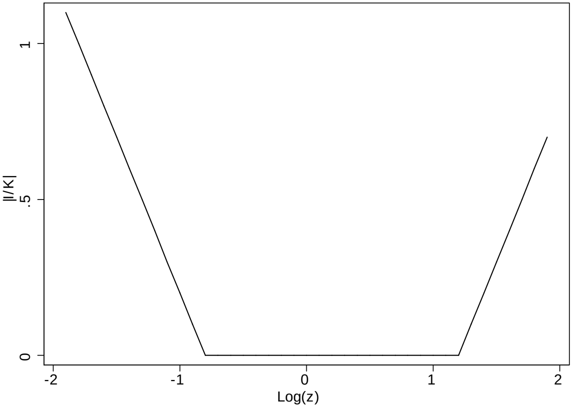
$$C(I, A, K) = 0 \text{ but } p_I = 1 \text{ if } I > 0 \text{ and } p_I = p_s < 1 \text{ if } I < 0$$

$$\begin{aligned}
V(A, K) &= \max\left\{V^b(A, K), V^s(A, K), V^i(A, K)\right\} \\
V^i(A, K) &= AK^\theta + \beta\mathbb{E}V\left(A', K(1-\delta)\right) \\
V^b(A, K) &= \max_I AK^\theta - I + \beta\mathbb{E}V\left(A', K(1-\delta) + I\right) \\
V^s(A, K) &= \max_I AK^\theta - p_s I + \beta\mathbb{E}V\left(A', K(1-\delta) + I\right)
\end{aligned}$$

We can write things more compactly:

$$\begin{aligned}
V(A, K) = \max_{K'} & AK^\theta - \left(K' - (1-\delta)K\right) \\
& + \mathbf{1}_{K'-(1-\delta)K<0}(1-p_s)\left(K' - (1-\delta)K\right) + \beta\mathbb{E}V\left(A', K'\right)
\end{aligned}$$

Transaction costs



- Compared to the fixed-cost-based non-convex adjustment cost model, investment will:
  - be more persistent
  - have fewer bursts

Estimation: Profit function parameters

Profit function:

$$\begin{aligned} \Pi\left(A_{it}, K_{it}\right) &= A_{it} K_{it}^{\theta}, \text{ where} \\ \log A_{it} &= b_t + \varepsilon_{it} \text{ and} \\ \varepsilon_{it} &= \rho_\varepsilon \varepsilon_{i,t-1} + \eta_{it} \end{aligned}$$

Taking logs of the profit function:

$$\begin{aligned} \pi_{it} &= b_t + \varepsilon_{it} + \theta k_{it}, \text{ also} \\ \rho_\varepsilon \pi_{i,t-1} &= \rho_\varepsilon b_{t-1} + \rho_\varepsilon \varepsilon_{i,t-1} + \rho_\varepsilon \theta k_{i,t-1} \end{aligned}$$

Combining equations:

$$\begin{aligned} \pi_{it} &= \rho_\varepsilon \pi_{i,t-1} + b_t + \theta k_{it} - \rho_\varepsilon b_{t-1} - \rho_\varepsilon \theta k_{i,t-1} + \varepsilon_{it} - \rho_\varepsilon \varepsilon_{i,t-1} \\ &= \rho_\varepsilon \pi_{i,t-1} + b_t - \rho_\varepsilon b_{t-1} + \theta k_{it} - \rho_\varepsilon \theta k_{i,t-1} + \eta_{it} \end{aligned}$$

Estimation: Profit Function Parameters

Profit function:

$$\pi_{it} = \rho_\varepsilon \pi_{i,t-1} + b_t - \rho_\varepsilon b_{t-1} + \theta k_{it} - \rho_\varepsilon \theta k_{i,t-1} + \eta_{it}$$

Estimate by GMM. Sample moments, $\hat{m}_{it}\left(b_t, \rho_\varepsilon, \sigma_\varepsilon, \theta\right) =$

$$\begin{pmatrix} \left[\pi_{it} - b_t - \theta k_{it} - \rho_\varepsilon \left(\pi_{i,t-1} - b_{t-1} - \theta k_{i,t-1}\right)\right] \pi_{i,t-2} \\ \left[\pi_{it} - b_t - \theta k_{it} - \rho_\varepsilon \left(\pi_{i,t-1} - b_{t-1} - \theta k_{i,t-1}\right)\right] k_{i,t-2} \end{pmatrix}$$

In second step: run OLS regression

$$\hat{b}_t = \rho_b \hat{b}_{t-1} + \eta_t^b$$

to get the parameters of the aggregate shocks.
Results: $(\theta, \rho_b, \rho_\varepsilon, \sigma_b, \sigma_\varepsilon) = (0.59, 0.76, 0.89, 0.08, 0.64)$

How do the extreme models fit the data?

Parameters :

	γ	λ	$\frac{p_s}{p_b}$
None	0	1	1
Convex	2	1	1
Non-convex	0	0.95	1
Transaction	0	1	0.75

Results:

	Prob $\frac{I}{K} > 0.2$	Prob $\frac{I}{K} < -0.2$	Prob $\left\lvert \frac{I}{K} \right\rvert < 0.01$	Correl. $\frac{I_t}{K_t}, \frac{I_{t-1}}{K_{t-1}}$
Data	0.180	0.018	0.081	0.058
None	0.298	0.203	0.000	-0.053
Convex	0.075	0.000	0.038	0.732
Non-conv.	0.213	0.198	0.588	-0.060
Transact.	0.120	0.024	0.690	0.110

Estimation of Adjustment Costs

- Estimate adjustment costs parameters $(\gamma,\ F,\ p_s)$ via simulated method of moments
- $\hat{\theta} = \arg min_\theta\ \mathcal{W}(\theta) = \left[\Psi^d - \Psi^s(\theta)\right]' W \left[\Psi^d - \Psi^s(\theta)\right]$

Estimation of Adjustment Costs, $\lambda = 1$

	Data	All	γ only	p_s only	F only
γ		0.049	0.455	0	1
F		0.039	0	0	0.070
p_s		0.975	1	0.795	1
Corr. (i_t, i_{t-1})	0.058	0.086	0.605	0.113	-0.004
Corr. (i_t, a_t)	0.143	0.310	0.540	0.338	0.213
P$(\frac{I}{K}) > 0.2$	0.186	0.127	0.230	0.132	0.105
P$(\frac{I}{K}) < -0.2$	0.018	0.030	0.028	0.033	0.033
$\mathcal{W}\left(\hat{\theta}\right)$		6400	53183	7674	7391

- Convex adjustment costs model fit data terribly
- Fixed costs and transaction costs, alone, each play a similar role.
- Ramey and Shapiro's aerospace study: $p_s = 0.75$.

Estimation of Adjustment Costs, $\lambda < 1$, $F = 0$

	Data	$\lambda = 0$	λ only	$F = 0$
γ		0.049	0	0.153
F		0.039	0	0
p_s		0.975	1	0.981
λ		1	0.796	0.796
Corr. (i_t, i_{t-1})	0.058	0.086	-0.009	0.148
Corr. (i_t, a_t)	0.143	0.310	0.060	0.156
$\mathrm{P}(\frac{I}{K}) > 0.2$	0.186	0.127	0.107	0.132
$\mathrm{P}(\frac{I}{K}) < -0.2$	0.018	0.030	0.042	0.023
$\mathcal{W}\left(\hat{\theta}\right)$		6400	9384	2730

- Fit of the model much better when $\lambda < 1$, even if F is fixed to 0.

How well do different models match aggregate facts?

	Data	All
Corr. (i_t, i_{t-1})	0.46	0.63
Corr. (i_t, a_t)	0.51	0.54

Punchline: Aggregate investment is much more serially correlated than micro investment.
Three caveats:

1. No general equilibrium effects; relative price of investment does not respond to shocks.
2. Use only investment data from manufacturing (represents less than a quarter of GDP).
3. The moments used by Caballero and Engel (on the heterogeneous sensitivity of investment rates to shocks) are not included, here. (λ is lower when they try to fit the skewness of investment rates)

Conclusion

Main results

- Both nonconvex and convex adjustment costs are necessary to fit the micro investment rate data.
- Convex adjustment costs suffice to fit the macro investment rate data.

Extensions:

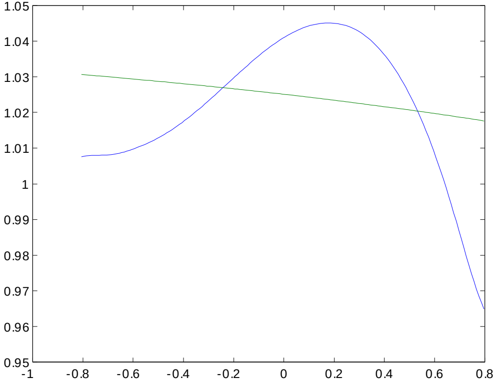
- Include more moments to try to match.
- Allowing for p_I to respond to the path of aggregate productivity shocks.

Notes on Bloom (2009): "The Impact of Uncertainty Shocks"

Question and Motivation

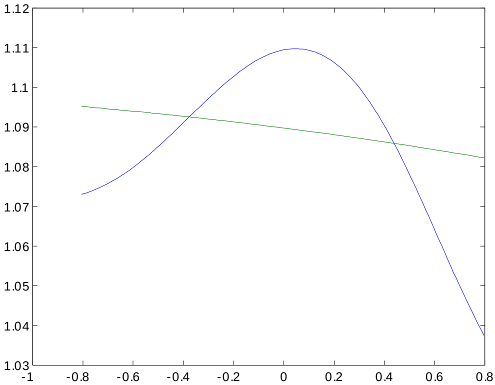
- How do temporary changes in uncertainty affect aggregate investment, output, hiring, etc... ?
- Uncertainty
  - In the model: standard deviation of shocks to individual firms' productivity/demand
  - Potential data counterparts: stock market volatility, standard deviation of firms' profit growth rates, dispersion of GDP forecasts
- These uncertainty measures move around *a lot.*
- Policy-makers seem to believe that uncertainty matters.

Problem 3 Value Functions: $\omega = 0.05$, $\sigma = 0.06$



- Length of inaction region $= 0.77$

Problem 3 Value Functions: $\omega = 0.05$, $\sigma = 0.20$



- Length of inaction region $= 0.82$

Contribution

- Last two slides
  - Range of inaction is wider when σ is big.
  - But the previous slides are not informative about the dynamic responses to temporary changes in σ.
- Bloom (2009)
  - Allow for σ to vary over time according to some Markov Process
  - Include convex and nonconvex adjustment costs to the hiring of labor.
  - Estimate these adjustment costs using firm-level data from Compustat.
  - With the estimated model, simulate the response to a temporary increase in uncertainty.

Preview of the main results

When σ increases

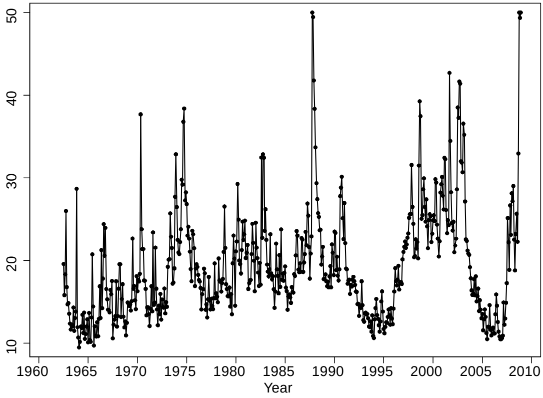
1. then the range of inaction widens, and more firms hold off on adjusting their capital/labor stock upward$\Rightarrow$ aggregate investment/output/etc... fall
   - Because more firms are in "wait-and-see" mode, there is less input reallocation from low$\rightarrow$high productivity firms$\Rightarrow$ aggregate productivity drops

2. After several months have passed, many firms are now at the edge of their inaction region. The patterns of step 1 quickly reverse themselves.
   - In fact, there is "over-shooting"

Outline

- Reduced-form evidence.
- Introducing the model.
- Simulations of the effect of an uncertainty shock.
- In the paper (but not today): Estimation of the adjustment costs and stochastic process for firm profitability.

Stock market volatility exhibits jumps

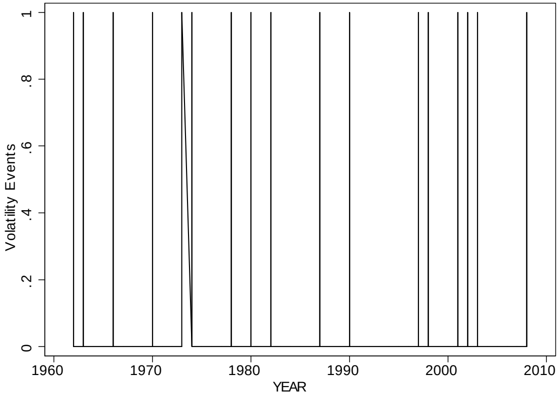


Stock market volatility is correlated with other measures of uncertainty

Firm profit growth	0.469			
	(0.115)			
Firm stock returns		0.570		
		(0.037)		
Industry TFP Growth			0.419	
			(0.125)	
GDP Forecasts				0.579
				(0.121)
R^2	0.238	0.373	0.284	0.381
Time span	62Q3-05Q1	62M7–06M12	62-96	62H2-98H2
Observations	171	534	35	63

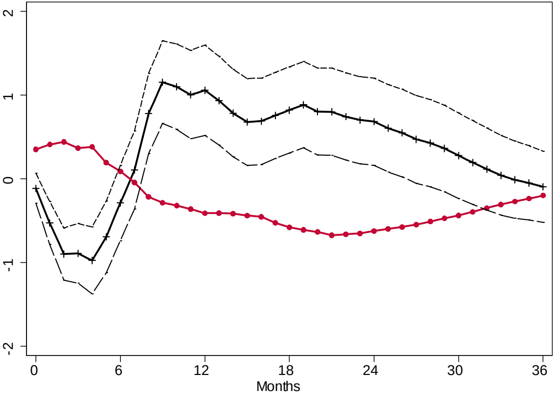
- Dispersion of profitability growth *rates* increases with uncertainty (~recessions). Similar result to Kehrig (2013), who talked about dispersion of productivity *levels* .

Volatility Events



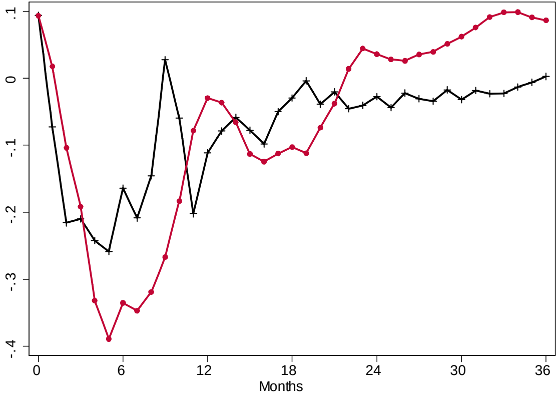
Volatility (and Fed Funds Rates) and Industrial Production

- Variables: log(S&P), stock-market volatility, fed funds rate, log(avg. early earnings), log(cpi), hours, employment, log(industrial production)



Volatility and Prices

- Variables: log(S&P), stock-market volatility, fed funds rate, log(avg. early earnings), log(cpi), hours, employment, log(industrial production)



Model: Overview

- Plants make investment decisions similar to those in Cooper and Haltiwanger:
  - Key addition adjustment costs to the number of workers
- Firms are comprised of multiple plants.
  - Plant-level productivity evolves over time.
  - The expected value and standard deviation of productivity growth changes over time.
  - Plant decisions are independent of one another, within firms.
- Optimal investment/hiring follows a 2-dimensional "zone" of inaction.
  - The inaction zone expands in periods in which the standard deviation is large

Model: Flow Profits

- Assume sales are a function of capital, workers, hours per worker:
$$S(A,K,L,H) = A^{1-a-b}K^{a}(LH)^{b}$$
- (Per hour) wages are a function of hours per worker:
$$w = w_1 + w_1 w_2 H^{\gamma},\ \gamma > 0$$
- Take first-order conditions w.r.t. H
$$bA^{1-a-b}K^{a}(LH)^{b} = w_1 H + \gamma w_1 w_2 H^{\gamma+1}$$
- Can solve for H as a function of A, K, L. Substitute this back in to get $\tilde{S}(A,K,L)$
    - Key feature of $\tilde{S}$: It is homogeneous of degree 1 in A, K, L.

Model: Evolution of profitability (A)

- For plant i in firm j at time t: $A_{ijt} = A_t^M A_{it}^F A_{ijt}^U$
- Each process is an augmented geometric random walk:

$$A_t^M = A_{t-1}^M \left(1 + \sigma_{t-1} W_t^M\right)$$
$$A_t^F = A_{t-1}^F \left(1 + \mu_{it} + \sigma_{t-1} W_t^F\right)$$
$$A_t^U = A_{t-1}^U \left(1 + \sigma_{t-1} W_t^U\right)$$

  The W's are i.i.d. standard normal random variables.
- μ_{it} and σ_{t-1} govern the mean and standard deviation of units' productivity Each evolves according to a 2-state Markov Process.
- $\sigma_t \in \{\sigma_L, \sigma_H\}$. $\mu_{it} \in \{\mu_L, \mu_H\}$. Transitions are governed by $\pi^{\sigma}_{s \to t}$ and $\pi^{\mu}_{s \to t}$

Model: Adjustment Costs

$$C(A,K,L,I,E) = wC_L^P L\left(\frac{E^+ + E^-}{L}\right) + K\left(\frac{I^+}{K} - \left(1 - C_K^P\right)\frac{I^-}{K}\right)$$
$$+ \left(C_L^F 1_{E\neq 0} + C_K^F 1_{I\neq 0}\right)\tilde{S}(A,K,L)$$
$$+ C_L^Q L\left(\frac{E}{L}\right)^2 + C_L^Q L\left(\frac{I}{K}\right)^2$$

- In these equations: E^+, I^+ are the positive components of hiring/inestment; E^-, I^- are the negative components.
- First row: partial irreversibilities to hiring and investment
- Second row: fixed disruption cost of hiring and investment
- Third row: convex adjustment costs.
- For next slide: assume that capital and labor stocks each depreciate, at rates δ_K, δ_L

Model: Value function for a plant

$$V(A,K,L,\sigma,\mu)=\max_{I,E}\{\tilde{S}(A,K,L)-C(A,K,L,I,E)-wL+\frac{1}{1+r}\times\mathbb{E}\left[V\left(A',K(1-\delta_K)+I,L(1-\delta_L)+E,\sigma',\mu'\right)\right]\}$$

One can guess and verify that V is homogenous of degree 1 in A,K,L (it follows from the homogeneity in $\tilde{S}$, and C)
Can define $a\equiv\frac{A}{K}$, $l\equiv\frac{L}{K}$, $e\equiv\frac{E}{K}$, $i=\frac{I}{K}$, $S^*(a,l)=\tilde{S}(a,1,l)$, and $Q(a,l,\sigma,\mu)=V(a,1,l,\sigma,\mu)$:

$$Q(a,l,\sigma,\mu)=\max_{i,e}S^*(a,l)-C^*(a,l,i,e)+\frac{1-\delta_K+i}{1+r}\mathbb{E}\left[Q\left(a',l',\sigma',\mu'\right)\right]$$

Simulations: Overview

- Calibration.
- Description of the simulations.
- Inaction regions.
- Model fit.

Calibration/Estimation

- Parameters governing profitability stochastic process
  - $\mu_H = \frac{1}{12}0.08$, $\mu_L = -\frac{1}{12}0.04$: Average growth rate $= 2\%$ per annum
  - $\sigma_H = \frac{1}{12}0.886$, $\mu_H = \frac{1}{2}\sigma_H$
  - $\pi^\sigma = \begin{pmatrix} 0.71 & 0.29 \\ 0.03 & 0.97 \end{pmatrix}$, $\pi^\mu = \begin{pmatrix} 1.00 & 0.00 \\ 0.00 & 1.00 \end{pmatrix}$
    - High uncertainty periods happen once every 3 years, last about 2 months.
- Each firm has $N = 250$ plants.
- Many other parameters: Adjustment cost parameters (to be estimated), $\delta_L = \delta_K = \frac{1}{12}10\%$, ε(markup)$= 4$, α (capital share)$=\frac{1}{3}$, $r = \frac{1}{12} \cdot 6\%$, w_1, w_2, γ

Description of the simulations

Do the following 25000 times

- Simulate 1000 units (four firms) for 15 years at an annual frequency.
- In year 11, fix $\sigma_t = \sigma_H$ for all plants
- In all other periods, for all other plants, shocks are allowed to hit according to the parameters given on the last slide.

Average over the 25000 simulations to

Simulated σ and A

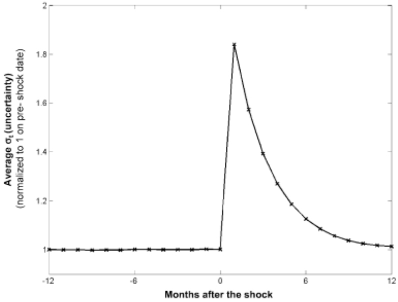
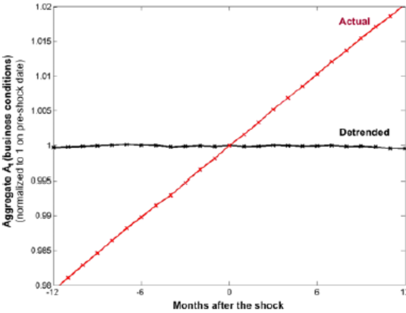
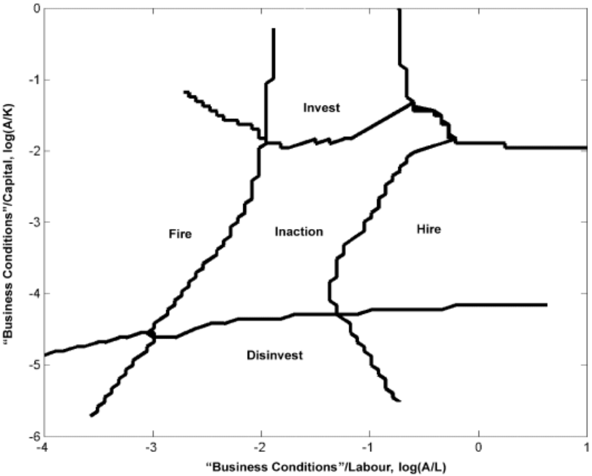


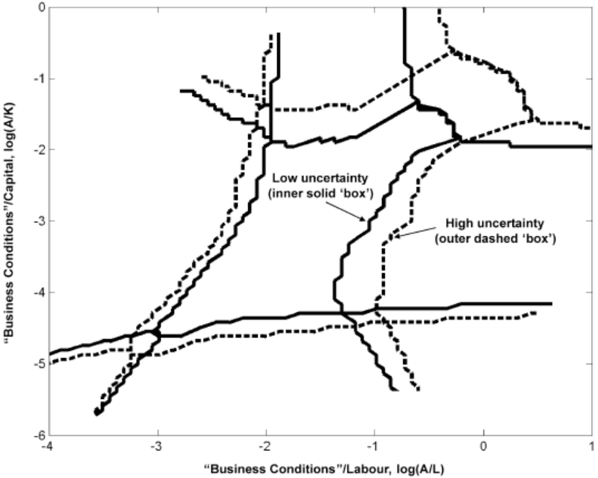
FIGURE 7A.—The simulation has a large second-moment shock.



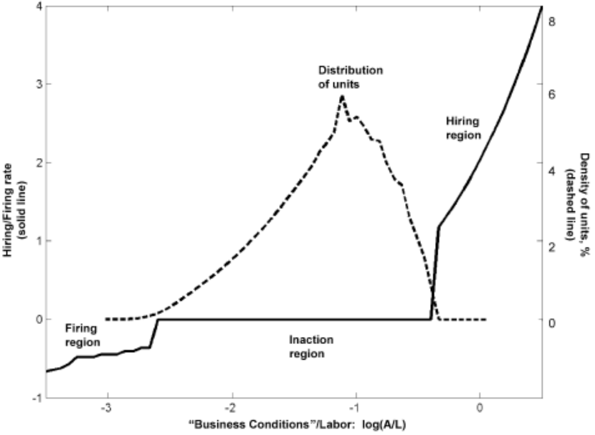
Inaction regions: $\sigma = \sigma_L$



Inaction regions: $\sigma = \sigma_H$



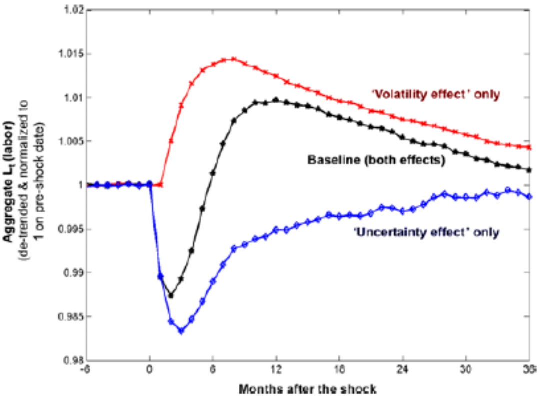
A cut of the inaction region: Constant K/L



Two opposing forces resulting from a change in σ

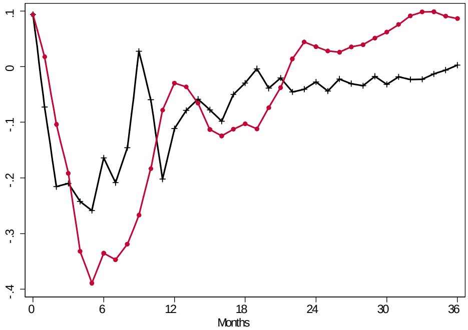
- Inaction regions widen ("Uncertainty effect")
  - Since more firms are closer to the hiring/investing side boundary, this depresses hiring/investment.
  - Occurs immediately after the uncertainty shock.
- σ is wider ("Volatility effect")
  - For a given size of the inaction region, more firms will hit one of the boundaries.
  - Takes some time for the effect of increased volatility to lead to more firms hitting the bounds.

Two opposing forces resulting from a change in σ



General equilibrium adjustments?

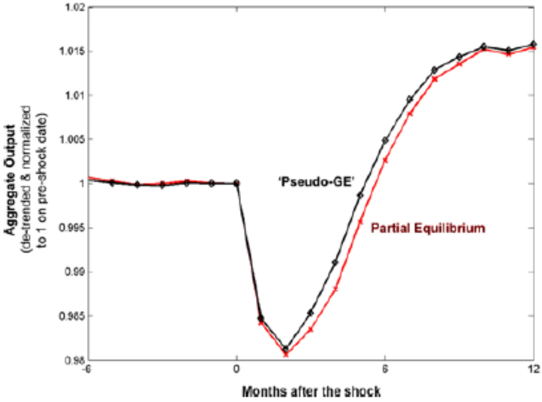
- So far, in the model, wages and the price of investment were fixed.
- But according to the VAR evidence, prices fall after an uncertainty shock.



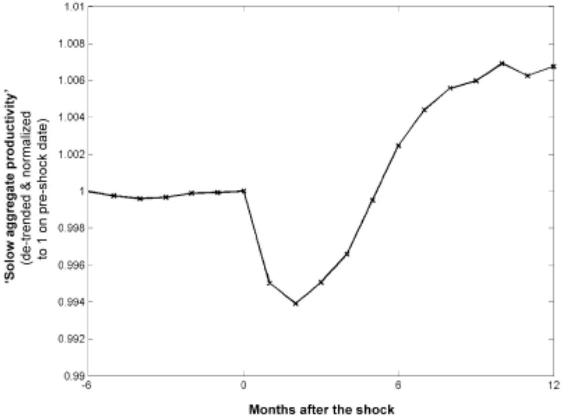
- Could the price drops counteract some of the initial decline in output/employment from increased uncertainty?

General equilibrium adjustments?

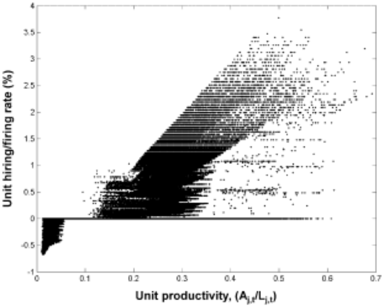
- In the simulation, feed in the price drops that we estimated in the VARs to generate (instead of fixing them at some constant values, as before).

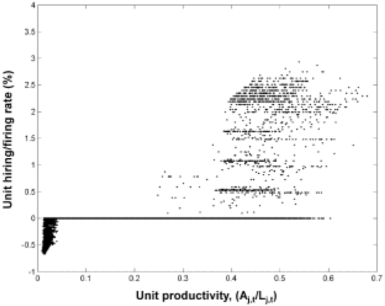


Measured aggregate productivity drops following the uncertainty shock



Measured aggregate productivity drops following the uncertainty shock... because reallocation declines





Estimation: Overview

- Similar idea to Cooper and Haltiwanger (2006): SMM estimation on moments describing plants' sales and input patterns
- Parameters we want to estimate: Those parameterizing the adjustment cost functions, those parameterizing the stochastic productivity processes.
- Some parameters we fix before estimation: $\frac{\sigma_H}{\sigma_L} = 2$, $\pi^\sigma = \begin{pmatrix} 0.71 & 0.29 \\ 0.03 & 0.97 \end{pmatrix}$, $\frac{1}{2}(\mu_L + \mu_H) = 2\%$, $\delta_L = \delta_K = 0.1$
- For a given set of parameters θ:
  - Draw a sample equal to the number or firms in the actual data (with 250 plants per firm), times some constant κN for $T + 10$ years.
  - Combine all plants within a firm, all months within a year.
  - Compute sample moments $\Psi^S(\theta)$
- $\hat{\theta} = \arg\min_\theta \left[\Psi^S(\theta) - \Psi^D\right]' W \left[\Psi^S(\theta) - \Psi^D\right]$

Estimation: Which moments to include?

- Suppose investment rates for a firm are not very volatile. Roughly speaking, this could be for one of two reasons
  - Productivity shocks are not that important (σ is, on average low)
  - Productivity shocks are important, but quadratic investment adjustment costs are large.
- Now bring in extra info (sales): If sales are volatile, one should infer that the latter reason is more salient.
- Upshot: To distinguish capital + labor adjustment costs from volatility of productivity shocks you need to use moments relating to firm sales, investment, *and* labor inputs.

Estimation: Which moments to include?

- Suppose investment rates, hiring, sales are similar from one year to the next. Roughly speaking, this could be for one of two reasons
  - Productivity growth is persistent
  - Productivity growth is not that persistent, but quadratic adjustment costs are large.
- We can distinguish these explanations by looking that the medium-to-long-run persistence of growth rates of firm-level variables.
  - If both sales and investment are highly persistence over many years $\Rightarrow$ productivity growth rates are persistent.
  - If sales is not all that persistent but investment is persistent $\Rightarrow$ investment adjustment costs are important.
- Upshot: We need moments that track firm-level variables over relatively long horizons.

Estimation: Data

- Data are from Compustat
  - 1981-2000. Annual data.
  - Keep only firms with 500 + firms and \$10 million in sales
  - 2548 firms with 22950 firm-year observations
- Sample statistics:
  - Median firm has 3450 employees and \$0.5 billion in sales
  - Mean firm has 13540 employees and \$2.3 billion in sales

Estimation: Parameter estimates

	All	Capital	Labor	Quad.
C_K^P: investment resale loss (%)	33.4	42.7		
C_K^F: investment fixed costs (%)	1.5	1.1		
C_K^Q: investment quad. adjust.	0.00	1.00		4.84
C_L^P: labor resale loss (%)	1.8		16.7	
C_L^F: labor fixed costs (%)	2.1		1.1	
C_L^Q: labor quad. adjustment	0.00		1.01	0.00
σ_L: baseline uncertainty	0.44	0.41	0.22	0.17
$\mu_H - \mu_L$: spread of avg. prod	0.12	0.12	0.26	0.08
$\pi_{H \to L}^{\mu}$: transition probability	0.00	0.00	0.02	0.00

Estimation: Model Fit

	Data	All	Capital	Labor	Quad.
Skewness Coef. of $\frac{\Delta(I/K)}{I/K}$	1.79	0.00	0.09	1.20	1.31
Correlation $(I/K)_t$, $(I/K)_{t-2}$	0.33	0.06	-0.02	0.05	-0.04
Correlation $(I/K)_t$, $\left(\frac{\Delta S}{S}\right)_{t-2}$	0.26	-0.02	-0.01	-0.04	-0.10
Skewness Coef. of $\frac{\Delta(L)}{L}$	0.45	-0.14	0.29	-0.01	0.40
Correl. $\left(\frac{\Delta L}{L}\right)_t$, $\left(\frac{\Delta L}{L}\right)_{t-2}$	0.10	-0.01	0.05	-0.03	0.05
Correl. $\left(\frac{\Delta L}{L}\right)_t$, $\left(\frac{\Delta S}{S}\right)_{t-2}$	0.15	0.00	0.09	-0.05	0.06
Skewness Coef. of $\frac{\Delta(S)}{S}$	0.34	-0.41	-0.08	-0.37	-0.18
Correl. $\left(\frac{\Delta S}{S}\right)_t$, $\left(\frac{\Delta S}{S}\right)_{t-2}$	0.21	-0.03	0.00	-0.19	-0.04
Criterion, $\Gamma(\theta)$		404	628	3618	2798

- Persistence of investment rates is between Cooper and Haltiwanger's estimate for plants and their estimate for all of manufacturing.

Conclusion

- VAR evidence: An increase in uncertainty is followed by an immediate drop in activity, followed by an overshoot (beginning after 6 months).
- Primary contribution: A model in which the distribution of productivity growth changes in dispersion over time.
- Both labor and capital adjustment costs are needed to fit firm-level dynamics.

Notes on Baker, Bloom, and Davis (2009): "Measuring Economic Policy Uncertainty"

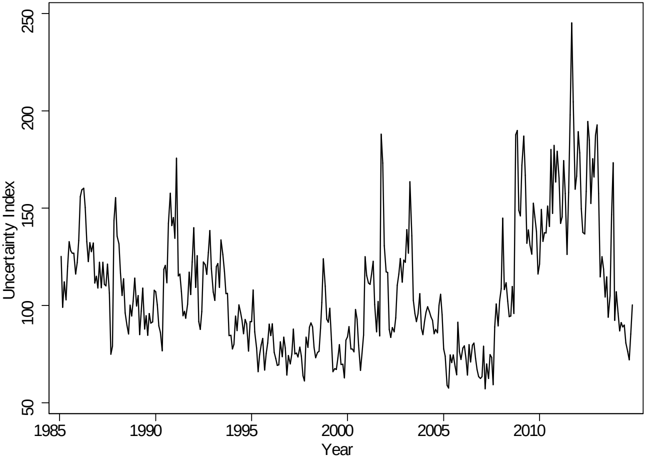
Question and Contribution

- Bloom (2009): Changes in firms' perceptions over the dispersion of future productivity play a potentially important role in generating countercyclical aggregate investment.
- What are the sources of uncertainty?
- Contribution:
  - Construct a new index of uncertainty from the ground up.
  - Compare this index of uncertainty (and its components) to other business cycle variables.

Outline

- Components of the uncertainty index
  - newspaper mentions
  - upcoming changes in taxes
  - disagreement among forecasters
- The relationship between the policy uncertainty index to other uncertainty measures.
- The relationship between the policy uncertainty index and measures of output.

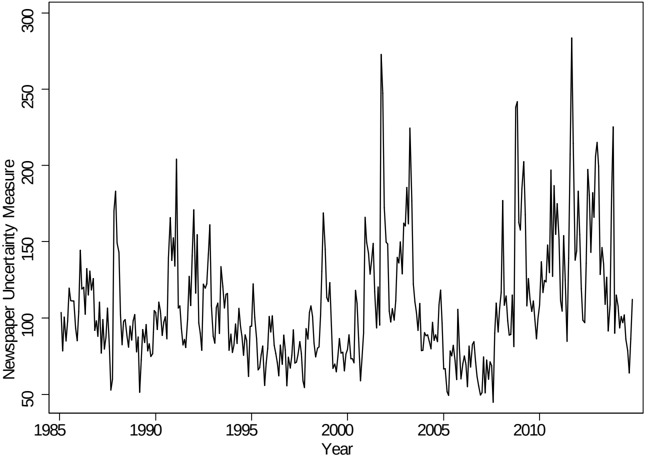
Uncertainty Index



Newspaper-based uncertainty measure

- Look at ten large newspapers from 1985 to the present: USA Today, Miami Herald, Chicago Tribune, Washington Post, Los Angeles Times, Boston Globe, San Francisco Chronicle, Dallas Morning News, (New York Times$\rightarrow$ Houston Chronicle)
- Count the number of articles with pairs of phrases
  - uncertainty or uncertain, PLUS
  - economy or economic PLUS
  - congress, legislation, white house, regulation, federal reserve, the Fed, or deficit.
- Normalize by total number of articles in the same paper$\times$month
- Sum over all newspapers. Index is stated relative to average between 1985-2009.

Newspaper-based uncertainty measure



Newspaper-based uncertainty measure: Audits

True Positive 3

Executive Dip In Confidence

Manufacturing businesses' confidence slipped in April for the second consecutive month, partly because of uncertainty about the Clinton Administration's plans, Cahners Economics Inc. said today.

period for the industrial sector, rather than a reversal," Cahners said after surveying about 400 business executives. Its findings cover businesses in four areas sensitive to economic cycles, computers, construction, consumer goods and general manufacturing.

The Cahners business confidence index, which had risen for four straight months until March, fell to 66.3 in April from 67.8 in March and 68.9 in February.

Only 59 percent of the executives surveyed said business conditions were good or excellent, down from 62 percent in March. The portion of executives who expected improvement slipped to 71 percent in April from 79 percent in March.

The survey found that business executives want deficit reduction to be the top priority for the Administration, with 55 percent saying that should be the case. Twenty-nine percent of the executives said job creation through an economic revitalization program should be Government's top priority.

Code as EPU = 1, because the article attributes the decline in business confidence partly to uncertainty about economic plans and policies of the Clinton Administration.

- Source: Baker et al. (2014): Measuring Economic Policy Uncertainty: Guide for Human Audit of Newspaper-Based Index of Economic Policy Uncertainty

Newspaper-based uncertainty measure: Audits

False Positive 3

CREDIT MARKETS; Little Change in Treasury Prices

By KENNETH N. GILPIN
Published: February 14, 1991

Lethargy continued to rule in the credit markets yesterday, as prices of Treasury securities were little changed in light trading. But some market participants said certain investors were getting edgy.

Despite yesterday's weak retail sales report for January and a big downward revision in December's retailing figures, "some institutional accounts are concerned about the rise in the stock market and are starting to reassess their view on the economy," said John P. Costas, director of taxable fixed income at the First Boston Corporation.

Bond yields have fallen sharply over the last few months as evidence of the current recession has mounted. The recent rise in stock prices, however, has caused some to wonder how long the current economic downturn will last. A short, shallow recession followed by a return to economic growth -- a development the stock market currently seems to anticipate -- could possibly rekindle inflation fears and cause interest rates to rise. Uncertain Message

Mr. Costas said the uncertainty about the stock market's message had prompted some positions in long-term bonds to be liquidated.

Special note: This article was coded EPU=1 under our original filter for policy-related terms but not under our current filter.

Code as EPU = 0, because the article does not mention any aspects of uncertainty over policy or its effects, only uncertainty as to the implications of recent market moves. It mentions 'tax' in regards to tax-exempt bonds, so is coded as EPU = 1 by the automated search.

41

- Source: Baker et al. (2014): Measuring Economic Policy Uncertainty: Guide for Human Audit of Newspaper-Based Index of Economic Policy Uncertainty

Newspaper-based uncertainty measure: Audits

False Positive 1, continued

"The magnitude and direction are correct," Mr. Ehrlich insisted.

Two factors were responsible for the private analysts' skepticism about the housing report.

They contended that the seasonal adjustment process had been thrown out of kilter by the January 1996 blizzard and the exceptionally cold weather of January 1995.

Abnormally low sales in those two months may have resulted in an exaggerated increase this year, said Stuart G. Hoffman, chief economist at PNC Bank in Pittsburgh.

In addition, they pointed to a footnote in the Government's release disclosing that its data

Mr. Ehrlich said he was uncertain whether the upward bias would prove a one-time phenomenon or would show a permanently higher level of sales.

The long-term result would depend on whether the new process was merely capturing data faster or was picking up data that had previously been missed.

Compounding the uncertainty is the fact that the home sales figures always have a huge margin of error, plus or minus 11 percentage points. This means that the actual result for January, now reported at an annual rate of 870,000, may have ranged anywhere from 20 percent higher than in December to 2 percent lower than in December.

39

- Source: Baker et al. (2014): Measuring Economic Policy Uncertainty: Guide for Human Audit of Newspaper-Based Index of Economic Policy Uncertainty

Newspaper-based uncertainty measure: Audits

False Negative 1

The negotiators will also be discussing where to establish the headquarters of the Free Trade Area of the Americas, a prize that Miami is pursuing with at least a half-dozen other cities from the Western Hemisphere, including Atlanta and Panama City. Economists have estimated that establishing the headquarters would create 15,000 jobs for white-collar professionals including diplomats, lawyers and accountants, in the host city.

"That kind of throughput of new professionals would generate phenomenal demand for financial services in Miami," said Thomas P. Noonan, president of the Florida International Bankers Association and chief executive of BAC Florida Bank, an institution with strong ties to several Central American banks.

Still, the formation of an Americas-wide trade agreement remains uncertain, mired in protracted disagreements, mainly between the United States and Brazil, over tariffs on agricultural products, like oranges and sugar, and differences on barriers to investment in areas including financial services and software licensing.

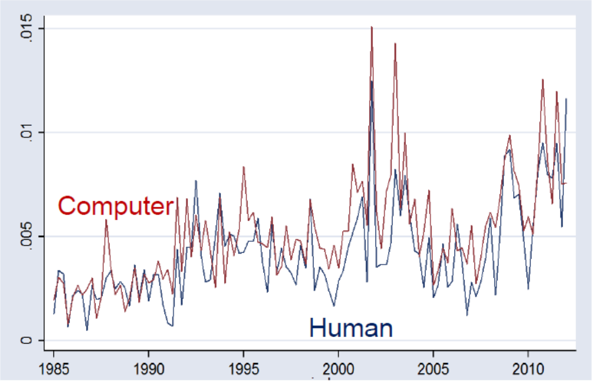
Miami, meanwhile, is struggling to rebuild its international banking industry, now in the fifth year of a slump. Since 1998, the number of foreign banks with agencies in Miami has dwindled to 36 from 42, while the number of representative offices has fallen to 15 from 20. Total assets held in foreign banks in Miami have declined to $14.5 billion from $20 billion five years ago, said David N. Devick, a financial control analyst at Florida's Office of Financial Regulation in Tallahassee. Loans at the Miami branches of foreign banks declined about 20 percent, to $3.8 billion from $4.7 billion, in the 12 months ended June 30.

Code as EPU = 1, because the article mentions uncertainty over the formation of a free trade area. The automated search incorrectly codes the article as EPU = 0, because it contains none of the terms in the "policy" part of our search filter.

- Source: Baker et al. (2014): Measuring Economic Policy Uncertainty: Guide for Human Audit of Newspaper-Based Index of Economic Policy Uncertainty

Newspaper-based uncertainty measure: Audit Results

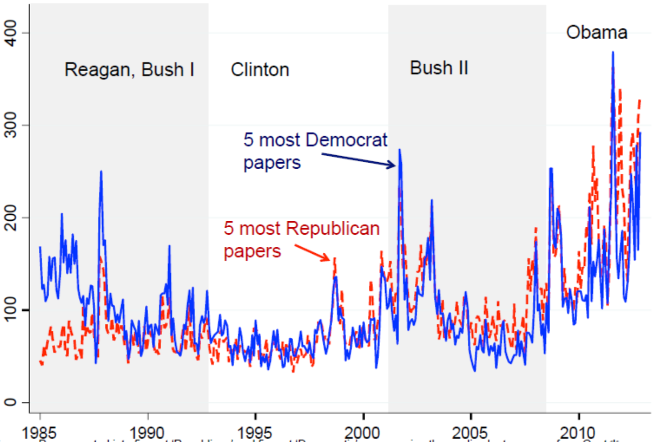
Figure 8: Human Readings and Automated Computer Methods Yield Similar News-Based EPU Indexes, 1985Q1 to 2012Q2



Note: Based on random samples of 45 articles per quarter (fewer prior to 1993) coded EU=1 by automated methods. For these articles, we calculate quarterly EPU rates based on human readings and based on automated computer methods. We multiply by The two lines show the share defined as being about economic policy uncertainty (EPU=1) by our human auditors and by the ratio (EU=1/Count of all articles) for each quarter to obtain the audit sample estimate of (EPU=1)/(Count of all articles).

Partisan slant in the newspaper-based uncertainty measure?

Figure 9: Political slant plays little role in our news-based EPU index



Source: Papers sorted into 5 most 'Republican' and 5 most 'Democratic' groups using the media slant measure from Gentzkow and Shapiro (2010).

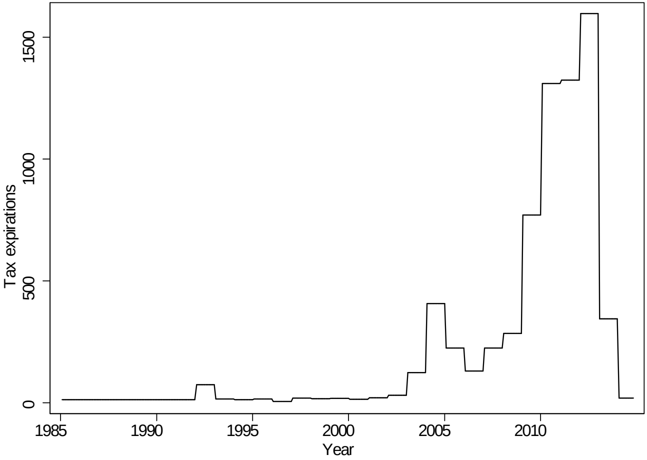
Tax Expirations

- Congressional Budget Office (CBO) compiles data on tax provisions that are set to expire in the upcoming year.
- With non-negligible probability, these tax provisions (almost always cuts) are extended, but there is some uncertainty.
- Example: 2010 Tax Act Estate and Gift Provisions, set to expire on 12/31/12. Costs by year:

'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22
0.7	4.8	30.8	36.9	41.3	45.1	48.2	51.3	54.5	57.9	61.5

$I_{\text{Jan, 2012}} = \sum_{y=0}^{10} \left(\frac{1}{2}\right)^{y+\frac{m}{12}} c_{y+2012} = \$10.5$ billion

Tax Expirations



Philadelphia Fed Survey of Professional Forecasters

Section 2. Real GDP and Its Components

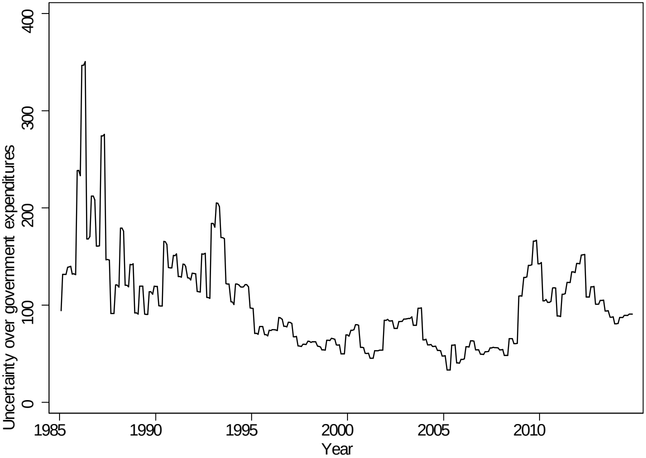
Chain-weighted (2005$)	L / G	Quarterly Data 2009:Q4	2010:Q1	2010:Q2	2010:Q3	2010:Q4	2011:Q1	Annual Data [a] 2009	2010	2011	2012	2013
12. Real GDP		13155.0						12988.7				
13. Real Personal Cons Expenditures		9298.5						9237.3				
14. Real Nonres Fixed Investment		1278.1						1289.2				
15. Real Res Fixed Investment		364.6						359.1				
16. Real Fed Government C & GI		1043.5						1026.7				
17. Real State & Local Govt C & GI		1544.3						1542.8				
18. Real Change in Private Inventories	L	-33.5						-111.7				
19. Real Net Exports of Goods & Services	L	-341.1						-353.9				

Section 3. CPI and PCE Inflation

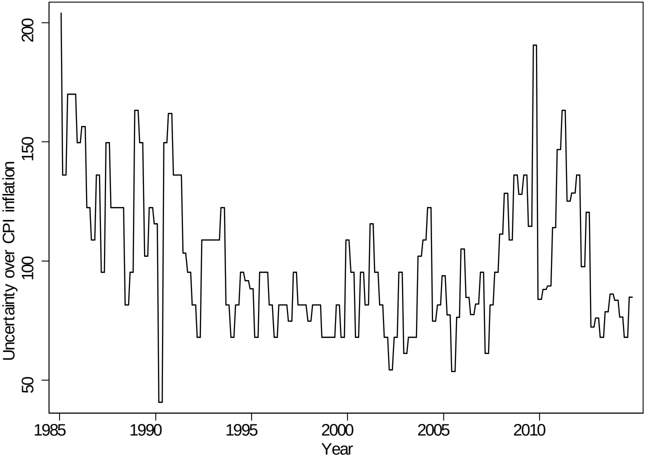
	Quarterly Data (Q/Q) 2009:Q4	2010:Q1	2010:Q2	2010:Q3	2010:Q4	2011:Q1	Annual Data (Q4/Q4) [c] 2009	2010	2011	2012
20. CPI Inflation Rate	3.4						1.5			
21. Core CPI Inflation Rate	1.5						1.7			
22. PCE Inflation Rate	2.7						1.3			
23. Core PCE Inflation Rate	1.4						1.4			

[c] Annual growth rate forecasts in Section 3 should be computed as a fourth-quarter over fourth-quarter percent change.

Disagreement over Government Expenditures

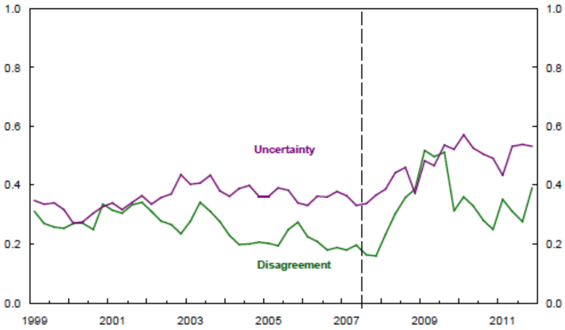


Disagreement over CPI Inflation



Does disagreement = uncertainty?

- ECB has a similar survey of forecasters, asks both for forecasts and uncertainty about each individual's forecast.
- For the ECB data, we can compare forecaster disagreement vs average forecaster uncertainty.
  - Disagreement can account for at most 20% of the variation in uncertainty.

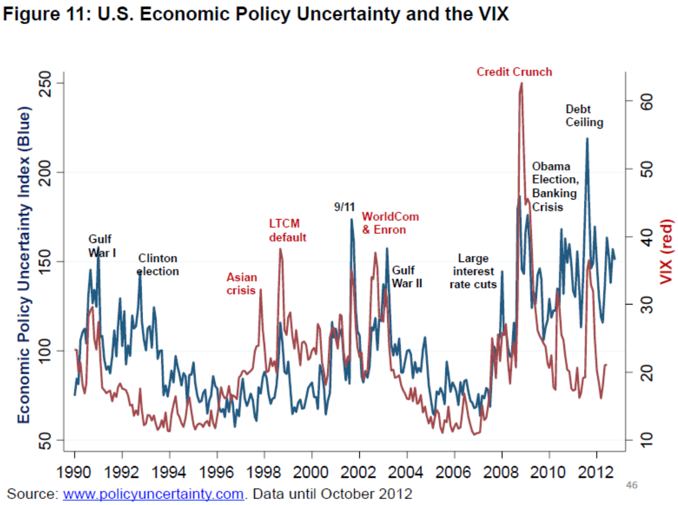


- Source: Rich, Song, Tracy (2012)

Correlations among components of the policy uncertainty index

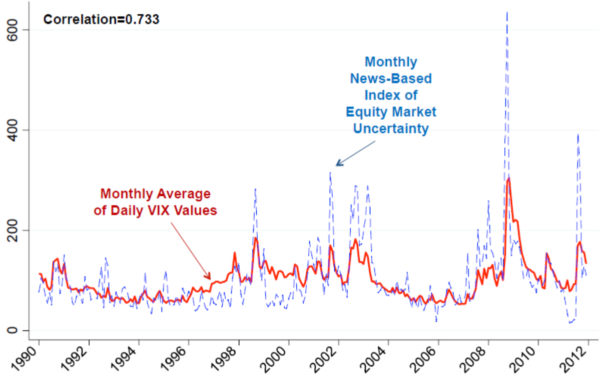
Newspaper	1			
Disagreement: Fiscal	0.15	1		
Disagreement: CPI	0.14	0.48	1	
Tax Expirations	0.41	0.07	0.17	1

Comparison between the policy uncertainty index and VIX



Comparison between a newspaper equity uncertainty index and VIX

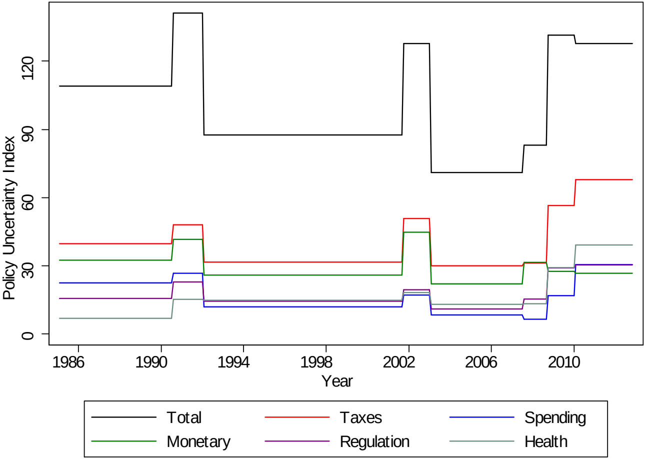
Figure 7: News-based index of equity market uncertainty compared to market-based VIX, January 1990 to December 2012



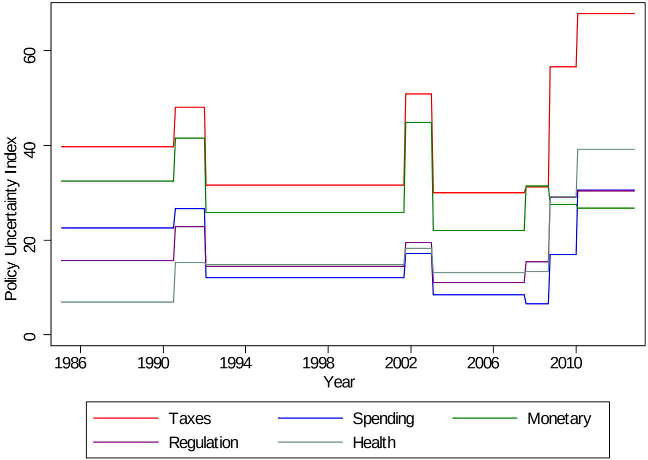
Notes: The news-based index of equity market uncertainty is based on the count of articles that reference 'economy' or 'economic', and 'uncertain' or 'uncertainty" and one of 'stock price', 'equity price', or 'stock market' in 10 major U.S. newspapers, scaled by the number of articles in each month and paper. The news-based index and the VIX are normalized to a mean of 100 over sthe period.

- Correlation higher here (0.73) than before (0.58)$\Rightarrow$ Differences in uncertainty indices have to do with focus of attention.

Souces of economic policy uncertainty



Souces of economic policy uncertainty



Does policy uncertainty reduce investment?

- Idea: Compare investment patterns of firms that sell to the government (firms in guided missiles, misc. transportation equipment, guidance for aeronautical or nautical systems) in times of low vs. high policy uncertainty.
- Data on exposure to government:
  - http://www.usaspending.gov/data . Data on all federal government contracts from 1999 to the present, roughly 100 thousand per year.
    - Includes information on name of the firm receiving the away, DUNS number of the recipient, government agency makding the award, dollar amount, much more.
  - Combine contracts of all firms within each 4-digit SIC industry

Does policy uncertainty reduce investment?

$$\frac{I_{it}}{K_{it-1}} = \beta_{\beta_{\text{Uncertainty}}} \Delta \log(\text{Uncertainty}) \times \text{Exposure to Gov't}$$

$$\beta_i + \beta_t + \text{Other Controls} \times \text{Exposure to Gov't} + \epsilon$$

	(1)	(2)	(3)	(4)
$\beta_{\text{Uncertainty}}$	-0.058*	-0.064*	-0.065*	-0.056*
$\beta_{\Delta \frac{\text{Forecast Fed Exp}}{GDP}}$		2.10*	2.00*	2.99*
$\beta_{\Delta \frac{\text{Fed Exp}}{GDP}}$			2.27	1.51
$\beta_{\Delta \text{VIX}}$				-0.01

- Average-exposure (1.2%) firm: investment goes down by 0.1 percentage points when policy uncertainty doubles.
- 90$^{\text{th}}$ percentile exposure firm: Investment goes down by 0.8 to 5.0 percentage points when uncertainty doubles.

Investment and firm dynamics: Concluding remarks

Summary

- Do firms respond differently to changes in aggregate conditions?
  - Caballero and Hammour; Kehrig: Less productive plants have a harder (or easier) time surviving in recessions.
  - Caballero and Engel and others: Plants near the edge of their inaction region will respond to industry (or aggregate) shocks. Most firms may not.
- Does this heterogeneity, in responses, matter?
  - Aggregate productivity endogeneously could be lower in recessions, due to these heterogeneous responses (Bloom, Kehrig).
  - Caballero and Engel: In good times, more plants are at the edge of their inaction region. (Looks like conditional heteroskedasticity in aggregate investment data)
  - For fitting aggregate investment/hiring/output patterns...

Do we need to model firm heterogeneity to fit aggregate investment patterns?

- Cooper and Haltiwanger (2006) : To fit time series of aggregate investment the micro model with quadratic adjustment costs only seemed to fit the data pretty well. (In other words, non-convex adjustment costs seemed to "average out.").
  - Implication: Firm heterogeneity doesn't matter so much if we're interested in aggregate patterns.
  - Other papers (e.g., Khan and Thomas 2008) reinforce this conclusion, say that general equilibrium price responses make non-convex adjustment costs even *less* important.
- Bachman, Caballero, and Engel (2013) reach the opposite conclusion: Lumpy investment and firm heterogeneity matter for fitting aggregate investment patterns.
  - Difference in conclusions arises from differences in what moments the authors are trying to match.

Are uncertainty shocks important?

Bayer and Bachman (2014): Are Bloom's uncertainty effects quantitatively important for explaining cyclicality of investment?

- Dispersion of productivity growth varies a lot less in the data than in Bloom's calibration. Difference in dispersion of growth rates in high vs. low uncertainty states is not so big, either. $\Rightarrow$ Wait-and-see effect may not be so important.
- There are other ways in which uncertainty shocks could result in lower aggregate activity, for example through financial frictions (Christiano, Motto, Rostagno 2014).
- Bloom, Floetto, Jaimovich, Saporta-Eksten, Terry (2014) have a DSGE model in which uncertainty shocks are quantitatively important.

The volatility of GDP growth has been lower since the early 80s