Lumpy Adjustment: New Evidence and Aggregate Implications

Work in Progress

Christoph Görtz[1] Sisir Ramanan[2] John D. Tsoukalas[2] Thomas Walsh[2]

[1]University of Augsburg
[2]University of Glasgow

Table of contents

1. Context
2. Our Work
3. Data
4. Econometric Model
5. Results - Aggregate Dynamics
6. Results - Firm Dynamics
7. Ongoing Work

Context

A Micro Fact

- Investment at the (plant/firm) level is lumpy! (Doms and Dunne (1998), Cooper and Haltiwanger (2005), Becker et al (2006)).
- Lumpiness: Spikes (infrequent and large changes) and inaction.

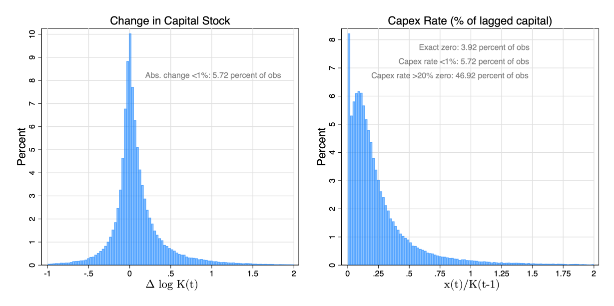


Figure 1: Lumpiness in U.S. Compustat Data of Public Firms

Agg Investment Rate = Lumpy + Nonlumpy Aggs

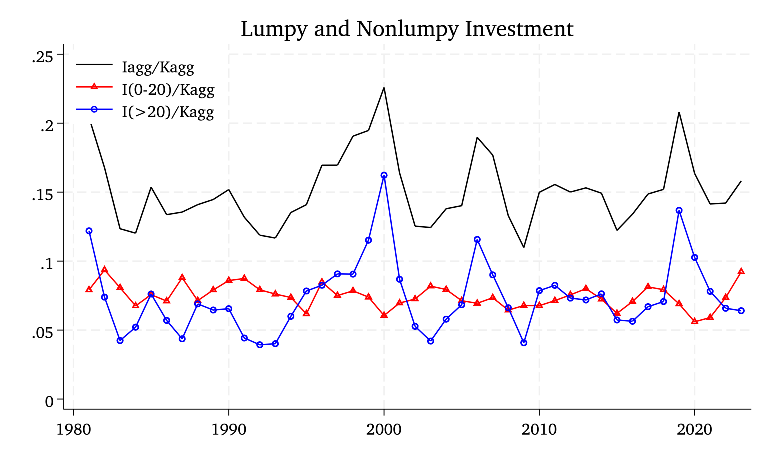


Figure 2: Investment Rate (Iagg/Kagg), Non Lumpy Investment Rate (I(0 − 20)/Kagg) and Lumpy Investment Rate (I(> 20)/Kagg

- Agg investment rate and its "Lumpy" part seem to co-move.

Lumpy Adjustments = Intensive + Extensive Margin

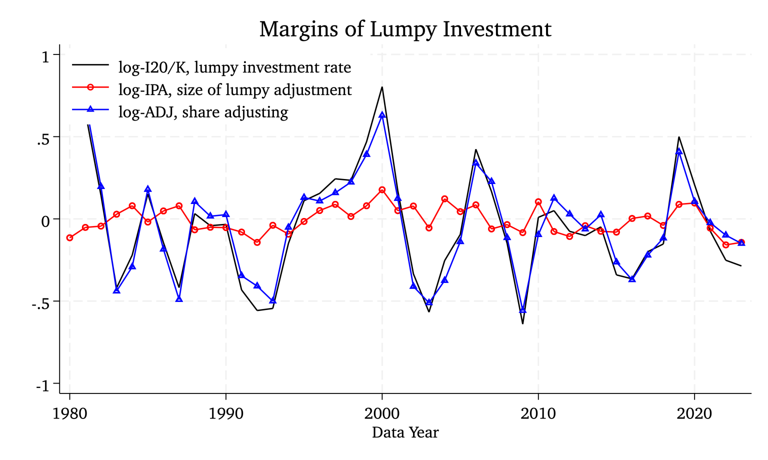


Figure 3: Lumpy Adjustments (I20/K) = Intensive Adjustments (IPA) + Extensive Adjustments (ADJ)

- Extensive Margin - the share of firms adjusting lumpily seem to be more important than the Intensive Margin - the size of lumpy adjustment.

Aggregate Implications

- Aggregate investment is not lumpy.
- The cross-sectional distribution of capital holdings is potentially important.
- **Does it matter for the aggregate?**
  - Thomas (JPE, 2002) and Khan and Thomas (Econometrica, 2008) show that distribution of capital is irrelevant for aggregate investment and output. GE effects: consumption smoothing affects interest rates and desired capital!
  - Bachmann, Caballero and Engel (AEJ: Macro, 2013) find agg. investment is conditionally heteroskedastic, state dependent response, can be rationalized with lumpy investment. Similar results by Winberry (AER, 2021).
- **Which margin is more important - Extensive vs Intensive?**
  - Guorio and Kashyap (2007) show that it is the number of firms making large investments (extensive margin) that determines bulk of aggregate variation rather than the average size of the spike (intensive margin).

Our Work

What We Do

- Existing literature use General Equilibrium theoretical models.
- In contrast, we use a "novel" empirical approach that combines:
  - A Dynamic Factor Model (DFM) at the firm level, and
  - A Vector Auto-Regression (VAR) at the aggregate level
- Identify business cycle shocks and map their reponses to aggregated/dis-aggregated firm outcomes.
- This framework is readily adaptable to other micro-macro stories.
- Our empirical evidence shows that:
  - **Lumpy adjustments significantly impact aggregate outcomes**
  - **Aggregate movements are driven by the extensive margin rather than the intensive margin**

Data

Data

- U.S. firm (public) level data:
    - Compustat. Around 14,400 firms covering years 1981-2022.
    - Annual frequency
- Additionally, we use macro variables like GDP in the VAR.

Variables

Main Firm-Level Variables:

- Standard measurement following the literature (Ottonello and Winberry (2020)).
- **Capital** ($\boldsymbol{K_{it}}$): Measured as PPE under the perpetual inventory method.
- **Investment** ($\boldsymbol{x_{it}}$): Capital expenditure (capex) spending.
- **Firm Investment Rate** ($\frac{x_{it}}{K_{it-1}}$): The ratio of current capex to lagged capital.
- **Aggregated Measures:**

$$I_{\text{agg}} = \sum_i x_{it}, \tag{1}$$

$$K_{\text{agg}} = \sum_i K_{it-1}. \tag{2}$$

Lumpy Variables

Aggregated Lumpy Variables:

- **Lumpy Investment**: The aggregate capex of firms that make lumpy adjustments,

$$I_{20} = \sum_{i \in \mathcal{L}} x_{it}, \tag{3}$$

  where $\mathcal{L}$ denotes the set of firms that make lumpy capital adjustments.

- **Lumpy Adjusters' Capital Stock**: The total lagged capital for these firms,

$$K_{20} = \sum_{i \in \mathcal{L}} K_{it-1}. \tag{4}$$

Extensive, Intensive margins of Lumpy Adjustment

- Following Guorio and Kashyap (2007), lumpy events can be decomposed into extensive and intensive margins

$$\begin{aligned} log\frac{I20}{Kagg} &= log\frac{I20}{K20} + log\frac{K20}{Kagg} && (5)\\ &= log\text{-}IPA + log\text{-}ADJ && (6)\\ &= size\ of\ adjustment + share\ adjusting && (7) \end{aligned}$$

- IPA - investment per adjuster (Intensive Margin)
- ADJ - number of firms adjusting (Extensive Margin).

Econometric Model

DFM-FAVAR Overview

- We implement a DFM-FAVAR approach to link firm-level dynamics with aggregate outcomes.
- Each firm-level variable is decomposed into:
    - A common component capturing cross-sectional co-movements, and
    - An idiosyncratic component.
- The baseline decomposition is given by:

$$x_{i,t} = \Lambda_{ij,t}\, C_t + \epsilon_{i,t}, \quad \epsilon_{i,t} \sim N(0, V_t) \tag{8}$$

- Here, $i = 1, \ldots, N$ indexes firms, $j = 1, \ldots, r$ indexes the common factors, and $t = 1, \ldots, T$ indexes time; V_t is diagonal.

Dynamic Factor Model Details

- **Time-Varying Loadings:**
  - The factor loadings evolve over time, following a random walk:

$$\Lambda_{ij,t} = \Lambda_{ij,t-1} + \eta_t, \quad \eta_t \sim N(0, W_t) \tag{9}$$

- **Common Components Evolution:**
  - The vector of common factors evolves according to a VAR process:

$$C_t = \beta\, C_{t-1} + u_t, \quad u_t \sim N(0, Q) \tag{10}$$

- Equations (1) and (2) jointly define the DFM-FAVAR system with time-varying loadings.

Identification and Lumpy Adjustments

- **Defining Lumpy Adjustments:**
  - Spikes in capital or labor adjustments are classified as lumpy.
  - A capital adjustment is considered lumpy if the investment-to-capital ratio exceeds a threshold:
    $$\frac{I_t}{K_{t-1}} > 0.2.$$
  - A similar threshold is applied for labor adjustments.
  - Threshold value consistent with Cooper and Haltiwanger (2006), Guorio and Kashyap (2007) and Görtz et al. (2023).
- **DFM Restrictions:**
  - In practice, we impose either one-to-one restrictions ($\Lambda_{ij,t} = 1$) or exclusion restrictions ($\Lambda_{ij,t} = 0$) on the sequence of firm-level loadings.
  - Additional restrictions address factor rotational and scale indeterminacies.
- **Identifying Business Cycle Shocks**:
  - Purely statistical (agnostic) identification.
  - Business Cycle shock/Credit shock identified as the one that maximizes the Forecast Error Variance of a target variable in the VAR over a finite horizon, see Uhlig (2003), Kurmann and Otrok (2013), Angeletos et al (2020) etc.
  - Target Variable: 1) GDP, 2) Aggregated Firm Sales, 3) Excess Bond Premium.

Estimation: Constructing Common Components

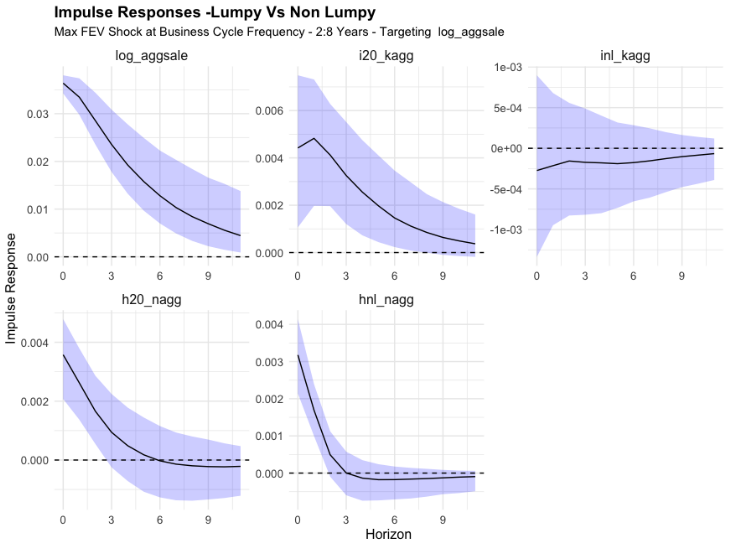
- **Common Components Construction:**
  - **Aggregate Approach:** Use macro-level variables such as GDP along with aggregated firm level variables such as:
    - Firm Sales
    - Lumpy and Non lumpy Adjustments
    - Extensive and Intensive Adjustments
  - **PCA Approach:** Extract principal components from relevant firm-level variables to form factors (e.g., Sales Factor, TFP Factor, lumpy and non-lumpy factors).
- These components serve as the building blocks for our DFM-FAVAR system.

Estimation: State-Space and VAR Implementation

- Equations (1) and (2) define a linear Gaussian state-space model. We obtain Kalman smoothed estimates of the time-varying loadings, $\Lambda_{ij,t}$.
- Variance terms are estimated using an EWMA approach, following Koop and Korobilis (2014).
- The VAR in Equation (3) is estimated using standard VAR procedures.
- Conditional on known (or initialized) values of $\tilde{C}_t$ and estimated parameters $\lambda_{ij,t}$, β, V_t, W_t, and Q, we update the Kalman smoothed estimates for C_t.

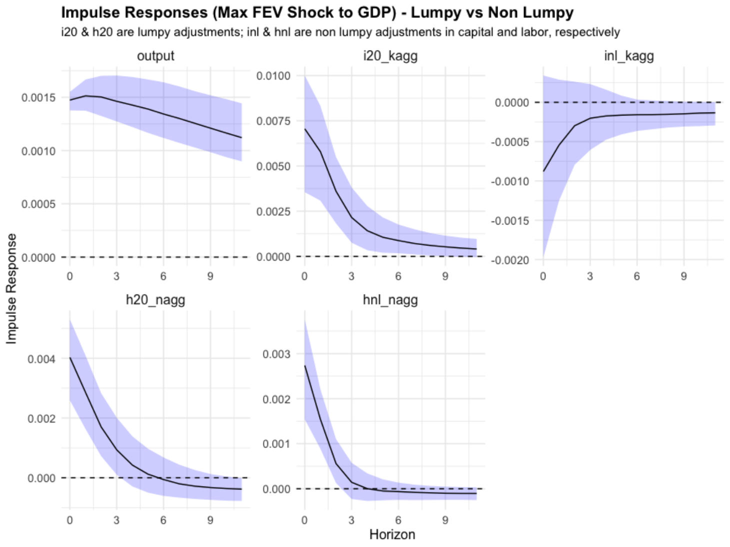
Results - Aggregate Dynamics

Impulse Responses - Lumpy vs Non Lumpy - Shock to Sales



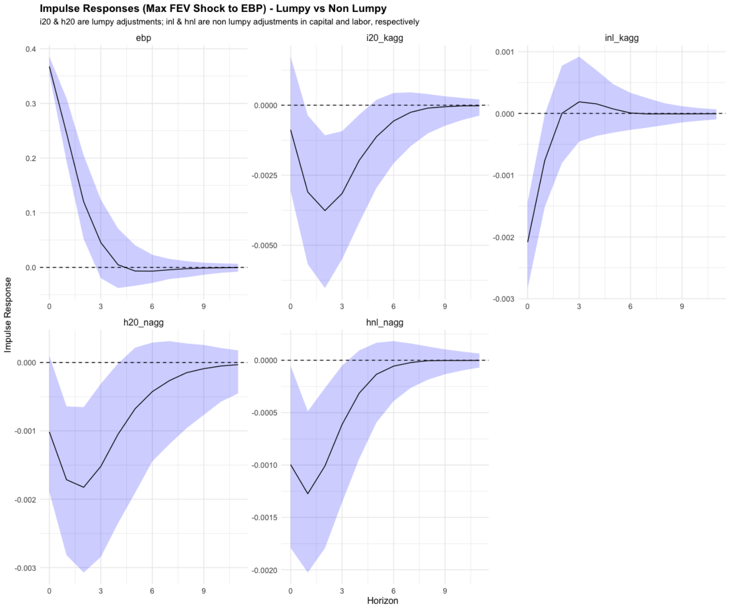
- Response in Lumpy (20) vs Non Lumpy Investment Rate (First Row), and
- Response in Lumpy (20) vs Non Lumpy Employment/Hiring Rate (Second Row).

Impulse Responses - Lumpy vs Non Lumpy - Shock to GDP



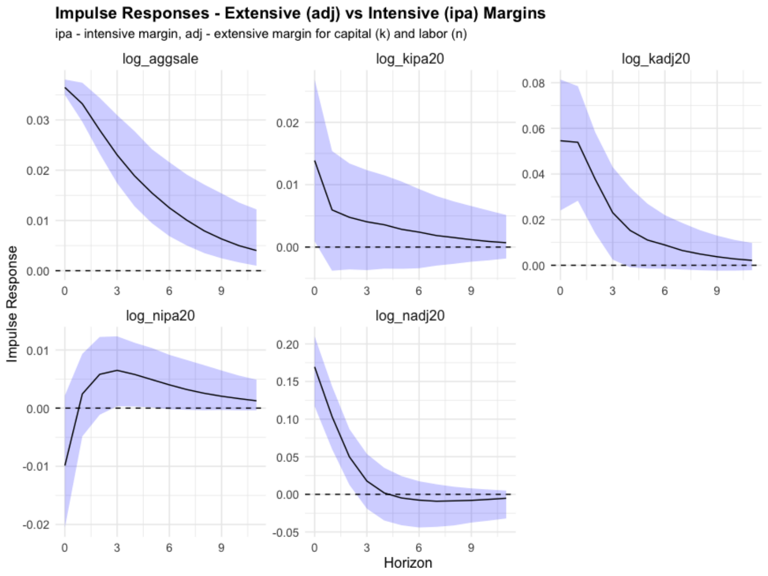
- Significant responses in both lumpy margins.
- Similar Responses when targeting GDP or (Aggregated) Firm Sales.

Impulse Responses - Lumpy vs Non Lumpy - Shock to Excess Bond Premium



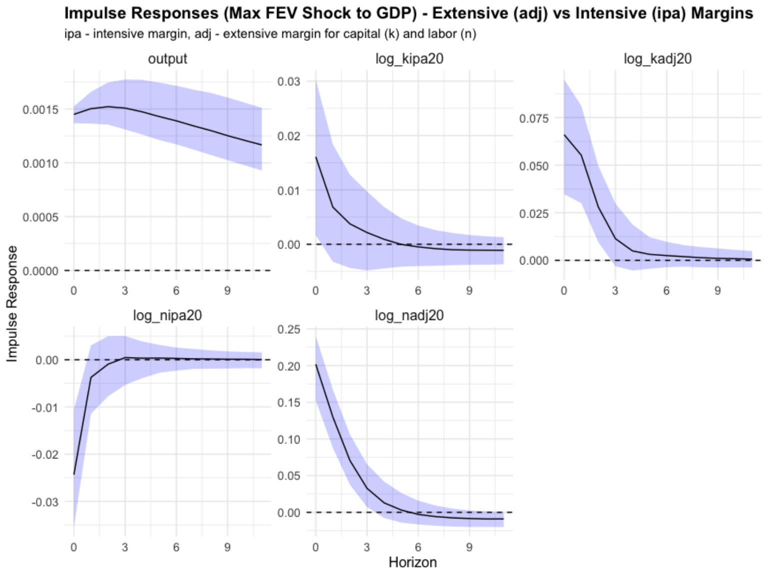
- Significant

Impulse Responses - Intensive vs Extensive - Shock to Sales



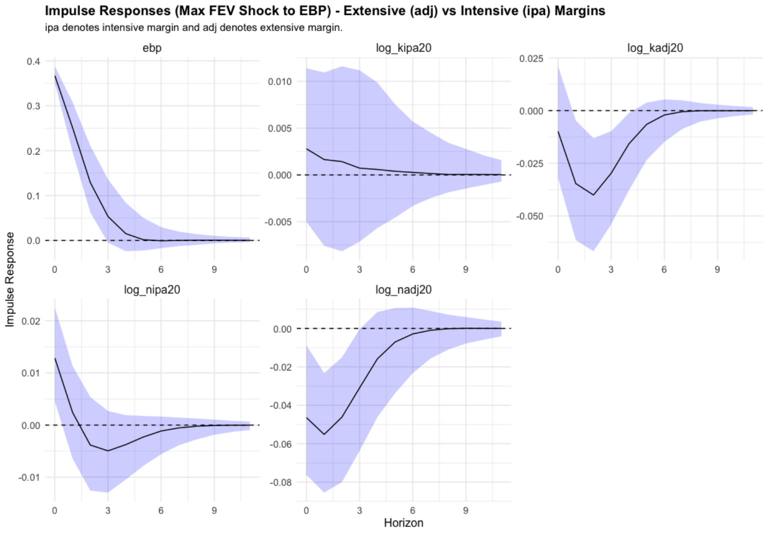
- Intensive (ipa) vs Extensive (adj) adjustments in capital (First Row) and Employment (Second Row).

Impulse Responses - Intensive vs Extensive - Shock to GDP



- Extensive margin is more important.

Impulse Responses - Intensive vs Extensive - Shock to Excess Bond Premium



- Similar pattern emerges: extensive margin drives the adjustment

Results - Firm Dynamics

Firm Level Impulse Responses

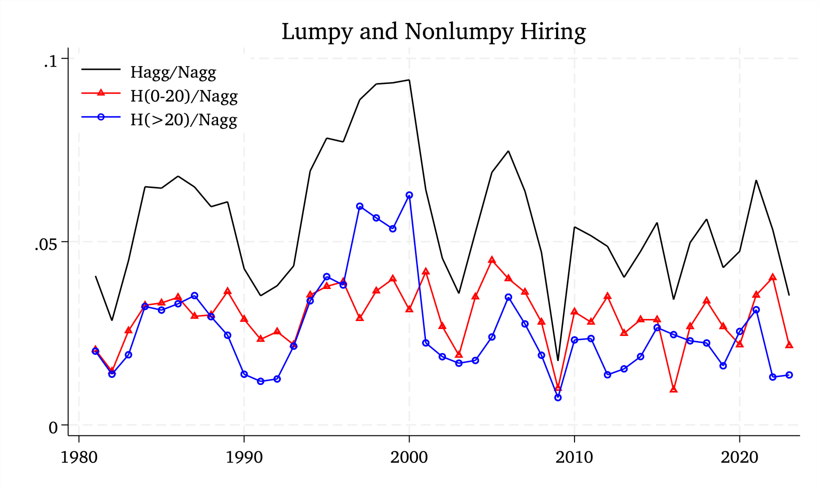
- Two-way mapping: aggregate response <==> firm level responses.
- Time varying loadings imply time varying impulse responses at the firm level.
- Can group responses impulse responses by firm characteristics:
  - Size:Small vs Big Size Firms.
  - Debt Growth: Low vs High Debt Growth Firms
  - Sales Growth: Low vs High Sales Growth Firms
  - Intangible Intensity: Low vs High Intangible Investment Firms
  - Capital Age: Newer vs Older Capital Vintage Firms - Age
- Effects bigger for extreme (quantile based) groupings:
  - Size: Very Small vs Very Big Size Firms
  - Sales Growth: Very Low vs Very High Sales Growth Firms
- Type of Aggregate Shock - Shock to EBP

Ongoing Work

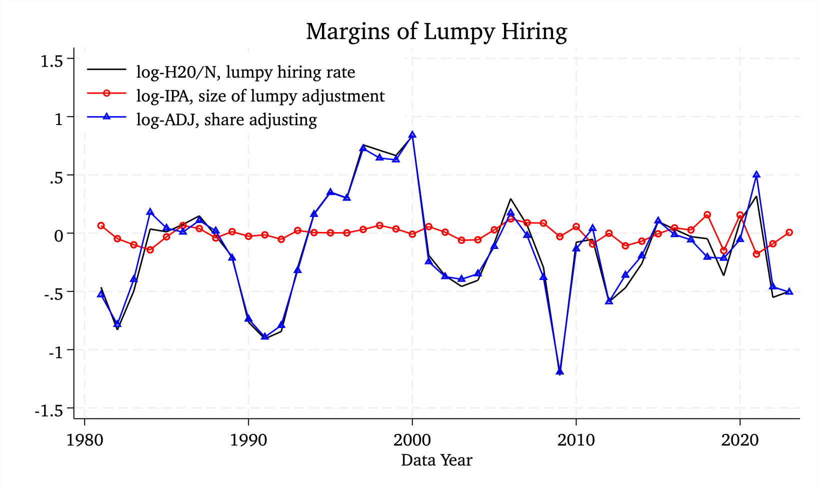
Data Expansion + Model Estimation & Simulation

- Data being expanded to cover private firms in the U.S. (ORBIS) and a separate analysis on UK firms (public + private in FAME).
- Estimating impulse responses on data simulated from a standard heterogeneous firm model (Khan and Thomas (2008)) + Habits in consumption preferences (Winberry (2021)).
- Idiosyncratic productivity shocks + Aggregate TFP shocks.
- Key Shock - Stochastic fixed costs of adjustments (iid over firms and time) drawn from a uniform distribution.
- Model estimated to our dataset - Macro + Micro.
- Part of a broader research agenda on uncovering investment gaps, productivity stagnation and decline in business dynamism.

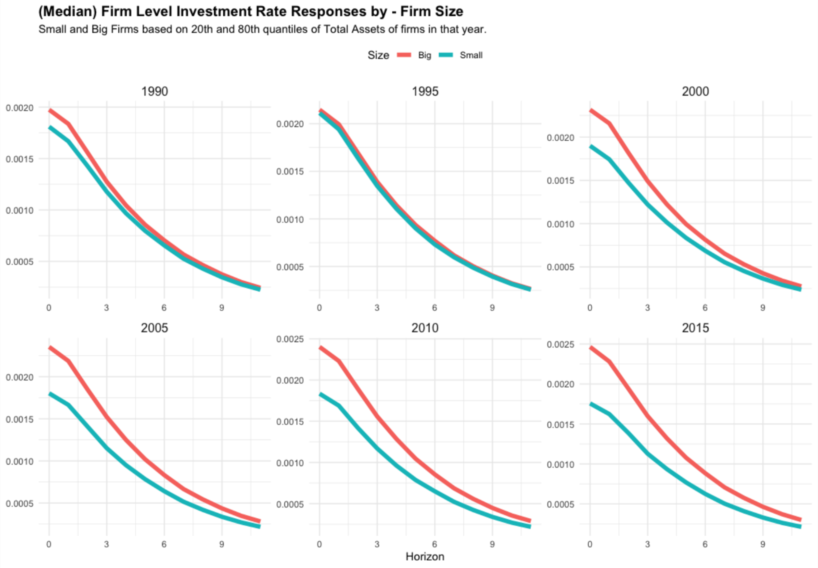
Employment - Lumpy and Nonlumpy Adjustments



Employment - Extensive and Intensive Margins



(Median) Investment Rate Response at the Firm Level - By Size (I)



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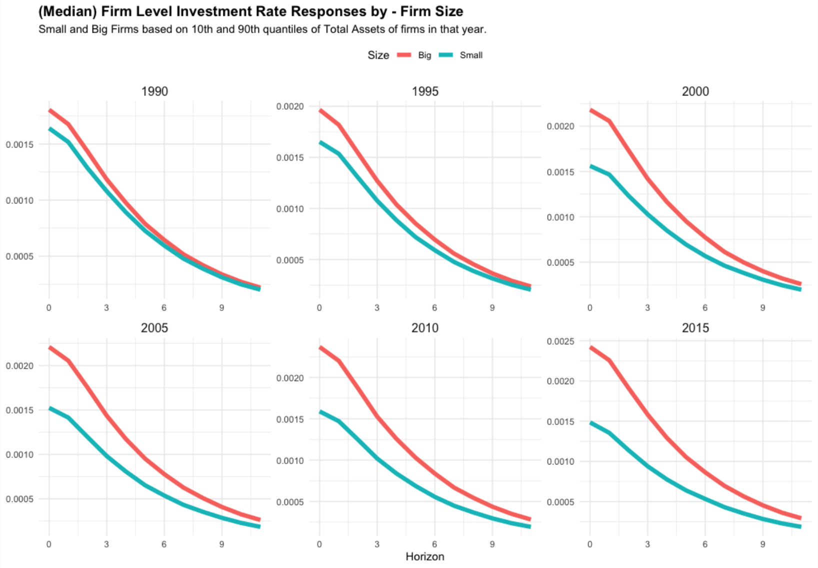
(Median) Investment Rate Response at the Firm Level - By Size (II)



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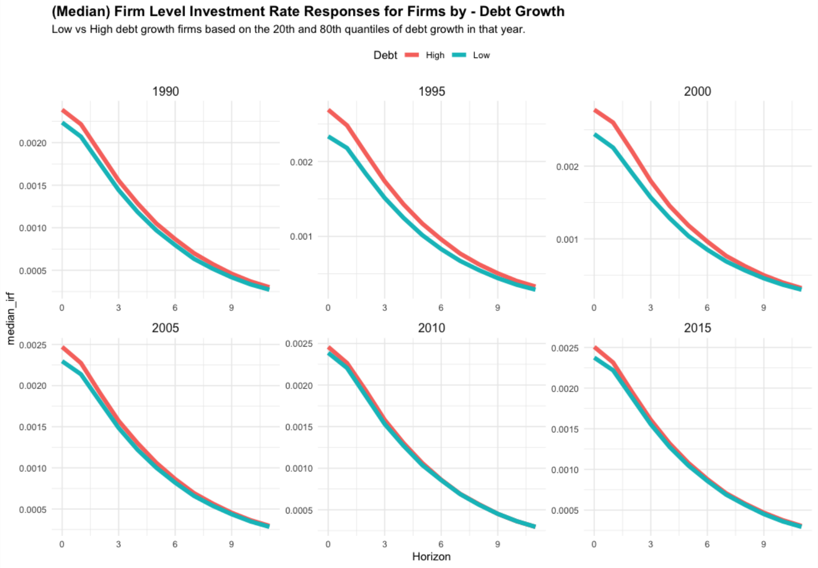
Investment Rate Response at the Firm Level - By Debt Growth



More pronounced effects as you go to more extreme quantiles. High debt growth firms have bigger investment rate responses. Back

Investment Rate Response at the Firm Level - By Sales Growth (I)

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Investment Rate Response at the Firm Level - By Sales Growth (II)

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Investment Rate Response at the Firm Level - By Intangible Intensity

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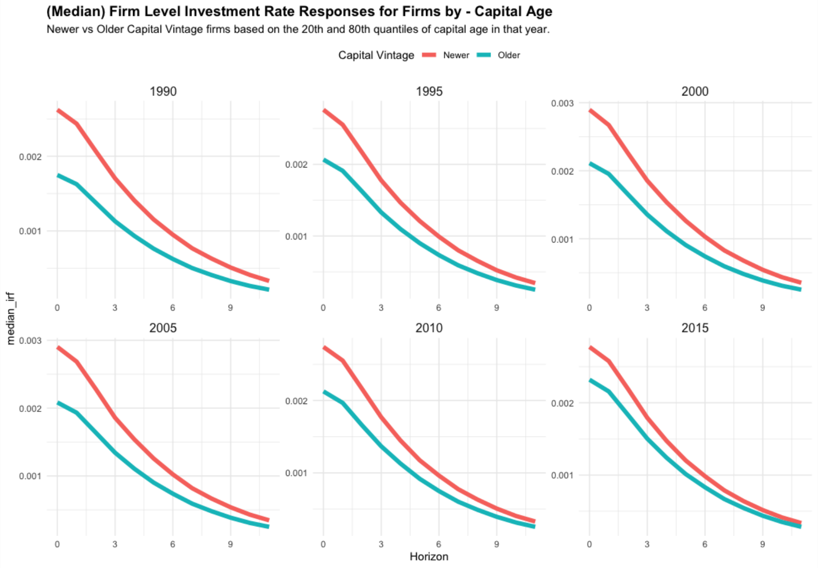
Investment Rate Response at the Firm Level - By Installed Capital Age



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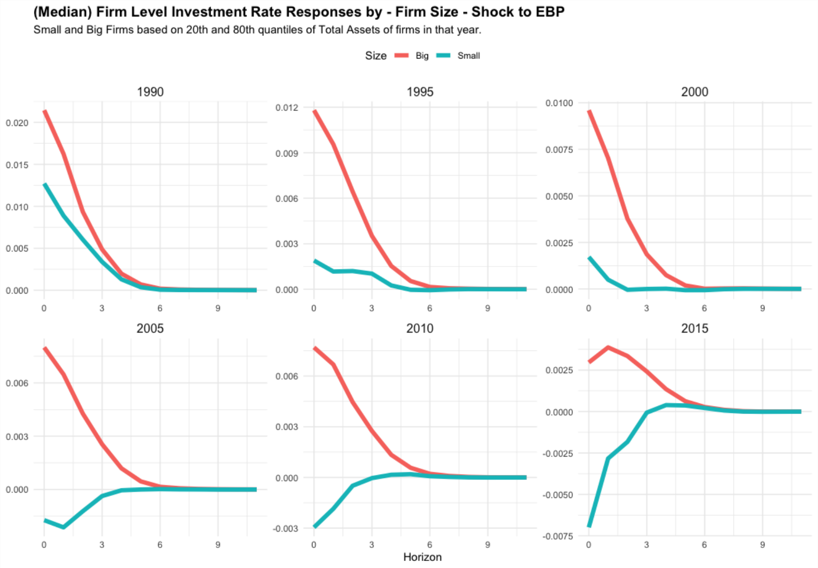
Investment Rate Response at the Firm Level - By Firm Size - Aggregate EBP Shock



Back