Fiscal Multipliers and Financial Crises

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The views expressed on this presentation do not necessarily reflect the positions of the Federal Reserve Bank of St. Louis or the Federal Reserve System.
Outline of the Talk

1. Problem and Motivation
2. Solution Method and Computation
3. Results and Conclusion
Problem and Motivation
Fiscal policy response to the 2008 financial crisis

“Conventional” fiscal stimulus

1. Govt purchases (Drautzburg & Uhlig ’11; Conley & Dupor ’13)
2. Transfers to households (Oh & Reis ’12; Parker et al. ’13; Kaplan & Violante ’14)

Financial sector interventions

3. Equity injections (Blinder & Zandi ’10; Philippon & Schnabl ’13)
4. Credit guarantees (Philippon & Skreta ’12; Lucas ’16)

Large debate on the effectiveness and composition of the response

This paper:

1. How important was the fiscal policy response?
2. Which tools were the most important?
3. How did their effects depend on the state of the economy?
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1. Structural model of fiscal policy
   - Potential stabilization roles for each of the tools
   - State dependent effects of shocks and policies

2. Quantitative Exercise
   - Calibrated model + data on fiscal policy response
   - Estimate structural shocks given policy response
   - Study counterfactuals
     - Crisis and Great Recession without fiscal response

3. Results:
   - Aggregate consumption falls by 50% more without policy response
   - Transfers and equity injections most important
   - Fiscal multipliers extremely state dependent
   - New transmission channels for fiscal policy
Approach and Results

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Nominal Rigidities $\implies$ Government purchases

Incomplete Markets $\implies$ Transfers

(Frictional) Financial Sector $\implies$ Bank Recaps.

Credit Risk & Default $\implies$ Credit Guarantees
Impulse and Propagation

- **Endogenous states**
  1. Bank debt, $D_t$
  2. Household debt, $B^b_t$
  3. Govt debt, $B^g_t$

- **Exogenous shocks**
  1. Technology, $A_t$
  2. Financial, $\sigma_t$
  3. Fiscal policies, $\{G_t, T^b_t, s^k_t, s^d_t\}$

- **Occasionally binding constraints**

  borrowers $\Rightarrow$ loan-to-value constraint
  \[ B^b_{t,\text{new}} \leq m p^h_t h_t \]

  banks $\Rightarrow$ capital requirement/leverage constraint
  \[ Q^b_t B^b_t \leq \Phi_t \theta E_t \]

Shock transmission depends on **bank leverage** and **household leverage**
$\Rightarrow$ and so do the effects of fiscal policy
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Solution Method
Solving DSGE models

• Consider an economy whose equilibrium is described by

  endogenous variables: \( x_t \)

  exogenous shocks: \( u_t \)

  state variables: \( z_t \), a subset of \( x_{t-1} \) and \( u_t \)

• In general, we can write the rational expectations equilibrium as

  \[
  F(\mathbb{E}_t[\phi(x_{t+1}, x_t, u_{t+1})], x_t, x_{t-1}, u_t) = 0
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• Ultimately, we are looking for a solution to the model of the type

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  x_t = G(x_{t-1}, u_t) = G(z_t)
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• Conventional method: 1st-order approximation around the steady state
  1. Find SS, \( \bar{x}, \bar{u} \)
  2. Take a first-order Taylor expansion of the equilibrium around the SS

  \[
  F(\cdot) \approx F_1 \hat{x}_t + F_2 \hat{x}_{t-1} + F_3 \hat{u}_t = 0
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First-order approximation around a steady state:

- Easy to implement, sometimes by hand
- No (or few) computational constraints
- Model solution is linear in states $\Rightarrow$ no state dependence
- Endogenous variables always respond in the same way to shocks
  1. State of the economy does not matter
  2. Size of the shock does not matter

Capturing state-dependence requires a global solution of the model.

- Compute a more general approximation
Conventional Methods and State Dependence

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Global Projection Methods

How do we implement this?

1. Create a discrete grid for the state space

\[
\mathbb{Z} = \{z_i\}_{i=1}^N = \{x_i, u_i\}_{i=1}^N
\]

2. Approximate \( G \) over \( \mathbb{Z} \) as

\[
G(z_i) = \sum_{j=1}^M b_j \Lambda_j(z_i)
\]

where \( \Lambda_j(\cdot) \) is a (known) element of some family of functions.

3. Use model equilibrium conditions to solve for \( \{b_j\}_{j=1}^M \)

- Grid-based method: \textbf{computationally expensive}!
- Different ways to do this: time iteration, etc.

This paper: Parametrized Expectations Algorithm

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This paper: Parametrized Expectations Algorithm

• **Basic idea**: approximate conditional expectations terms instead of policies directly

• Recall that equilibrium conditions are

\[ F\left(\mathbb{E}_t[\phi(x_{t+1}, x_t, u_{t+1})], x_t, x_{t-1}, u_t\right) = 0 \]

• Note that

\[ \mathbb{E}_t[\phi(x_{t+1}, x_t, u_{t+1})] = \mathbb{E}_t[\phi(G(z_{t+1}), z_{t+1})] = \Phi(z_t) \]

• PEA solves for \( \Phi(z_t) \) as a means to solve for \( G(z_t) \)
Implementation

Let \( \mathcal{Z} \equiv \{ z_i \}_{i=1}^N \) be a discretized grid of the states \( z_t \).

0. Create initial guesses \( \Phi^0(\mathcal{Z}) \) by interpolating over the grid \( \mathcal{Z} \)

1. For each \( z_i \in \mathcal{Z} \), the eq. is given by

\[
F(\Phi^{t-1}(z_i), x_i, z_i) = 0
\]

Solve for \( x_i \) using a standard non-linear solver.

2. Given solutions \( \hat{\mathbf{x}} = \{ x_i \}_{i=1}^N \), interpolate over the grid to generate \( G^t(\mathcal{Z}) \)

3. Use \( G^t(\mathcal{Z}) \) and integration/quadrature to compute \( \Phi^t(\mathcal{Z}) \)

4. Update approximants using dampening if needed

\[
\Phi^t(\mathcal{Z}) = \lambda \Phi^t(\mathcal{Z}) + (1 - \lambda) \Phi^{t-1}(\mathcal{Z})
\]

5. Check for convergence

\[
\| G^t(\mathcal{Z}) - G^{t-1}(\mathcal{Z}) \| \leq \varepsilon
\]

If algorithm has not converged, set \( t = t + 1 \) and return to 1.
Why do I need a HPC?

- First step: for each \( z_i \in \mathbb{Z} \), solve

\[
F(\Phi^{t-1}(z_i), x_i, z_i) = 0
\]

for \( x_i \) using a root-finder.

- Main bottleneck
  - Full version of the model has 10 states, 224,000 grid points
  - Each iteration of the PEA \( t \) uses a root-finder at each grid point \( i \)
  - 9 or 10-dimensional system to be solved

- Parallelization is easy to implement
  - Grid points can be visited independently, given \( \Phi^{t-1}(z_i) \)
  - Large speed gains
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Implementation: Other Aspects

- Matlab ⇒ Julia
- Inequalities transformed into equalities (Garcia and Zangwill, 1981)

\[ u'(C_t) = \beta E_t u'(C_{t+1}) + \lambda_t \]
\[ B_t \leq \Gamma \quad \lambda_t \geq 0 \]

becomes

\[ u'(C_t) = \beta E_t u'(C_{t+1}) + \max(0, \lambda_t)^2 \]
\[ B_t + \max(0, -\lambda_t)^2 = \Gamma \]

- PEA vs. Time Iteration (i.e. Judd, Maliar, Maliar, Valero 2014)
  - Easier to compute Jacobian!
  - Speeds up root-finding step.
State Dependence: Financial Shock with Low Leverage

GDP

Cons. Borrower

Value of the Bank

Bank Cost of Funds

% change from t-4

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Quarters after crisis

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Quarters after crisis
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Quarters after crisis
Quantitative Exercise and Results
1. Calibrate model to U.S. pre-crisis
   - Match moments on household and bank balance sheets

2. Use data to estimate sequences of structural shocks
   \[
   \{A_t, \sigma_t\}_{t=2000Q1}^{T=2015Q4}
   \]
   - \(Y^T\) \(\equiv\) Observed Macro Variables \(T = \{C_t, \text{spread}_t\}_t^T\)
   - \(\Omega^T\) \(\equiv\) Observed Fiscal Policy Response \(T = \{G_t, T^b_t, s^k_t, s^d_t\}_t^T\)

3. What are sequences \(\{\hat{A}_t, \hat{\sigma}_t\}_t^T\) that make model match \(Y^T\) given \(\Omega^T\)?

4. Use estimated \(\{\hat{A}_t, \hat{\sigma}_t\}_t^T\) to study counterfactual paths for \(\Omega^T\)
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Main Counterfactual: No Fiscal Policy

 Consumption

 Lending Spread

% dev. from trend

2007Q1 2008Q3 2013Q4

-3 -2 -1 0 1 2

Counterfactual
Data

2007Q1 2008Q3 2013Q4

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Counterfactual
Data
Time Series for Fiscal Multipliers

GDP Multiplier, Purchases

GDP Multiplier, Transfers

GDP Multiplier, Recaps
Conclusion

This Paper

- Analysis of fiscal policy response to the Great Recession
- Structural Model + Data

Contribution

- Conventional stimulus and financial sector interventions
  - Important for normative analysis
  - Quantitative evaluation
- New transmission channels for fiscal policy
  - Household-bank balance sheet interactions
  - State dependent effects
- Computation and analysis not feasible without HPC
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Appendix
Borrowers: Debt and Default

- Face value \( B^b_{t-1} \),
- Fraction \( \gamma \) matures every period
- Family construct (Landvoigt, 2015)

1. Borrower enters period with states
   \[
   h_{t-1}, B^b_{t-1}
   \]

2. Continuum of members \( i \in [0, 1] \), each with
   \[
   h_{t-1}, B^b_{t-1}, \nu_t(i)
   \]
   where \( \nu_t(i) \sim F_t^b \in [0, \infty) \)

3. Each member \( i \) can:
   3.1 Repay maturing debt \( \gamma B^b_{t-1} \), and keep houses worth \( \nu_t(i)p_t h_{t-1} \)
   or
   3.2 Default on maturing debt, lose collateral
Borrower Family Problem

\[
V_t^b(B_{t-1}^b, h_{t-1}) = \max_{c_t^b, n_t^b, h_t, B_t^b, \nu(\nu)} \left\{ u(c_t^b, n_t^b) + \xi^b \log(h_t) + \beta \mathbb{E}_t V_{t+1}^b \right\}
\]

subject to budget constraint

\[
c_t^b + \gamma \frac{B_{t-1}^b}{\Pi_t} \int [1 - \nu(\nu)]dF_t^b(\nu) + \underbrace{p_t h_t}_{\text{debt repayment}} \geq \underbrace{\text{house purchase}}_{\text{new debt}} \]

\[
(1 - \tau)w_t n_t^b + Q_t^b B_t^{b,\text{new}} + p_t h_{t-1} \int \nu[1 - \gamma \nu(\nu)]dF_t^b(\nu) - T_t + \underbrace{T_t^b}_{\text{Transfers}} \geq \underbrace{\text{sale of non-forecl. houses}}_{\text{new debt}}
\]

and borrowing constraint

\[
B_t^{b,\text{new}} \leq m p_t h_t
\]
Borrower Default

Default iff $\nu \leq \nu^*_t$,

\[ \nu^*_t = \frac{B^b_{t-1}}{\Pi_t p_t h_{t-1}} \simeq \text{Loan-to-Value} \]

- $F^b_t = \text{Beta}(1, \sigma^b_t)$
- $\sigma^b_t \sim \text{two-state Markov}$
- Mean preserving spread

Lenders earn (per unit of debt)

\[ Z_{t}^{\text{loans}} = (1 - \gamma) Q^b_t + \gamma \left\{ 1 - F^b_t(\nu^*_t) + (1 - \lambda^b) \int_{0}^{\nu^*_t} \nu \frac{p_t h_{t-1}}{B^b_{t-1}/\Pi_t} dF^b_t \right\} \]
Financial Intermediaries

- Fixed income portfolios, maturity transformation, risky deposits
- Fraction $1 - \theta$ of earnings paid out as dividends every period
- Invest in loan securities $b_t$, raise deposits $d_t$

Problem for intermediary $j \in [0, 1]$ with current earnings $e_{j,t}$

$$V^k_t(e_{j,t}) = \max_{b_{j,t}, d_{j,t}} \left\{ (1 - \theta)e_{j,t} + \mathbb{E}_t \left[ \Lambda^s_{t,t+1} \max \left\{ 0, V^k_{t+1}(e_{j,t+1}) \right\} \right] \right\}$$

subject to

flow of funds: $Q^b_t b_{j,t} = \theta e_{j,t} (1 + s^k_t) + Q^d_t d_{j,t}$

capital req.: $\kappa Q^b_t b_{j,t} \leq \mathbb{E}_t \left[ \Lambda^s_{t,t+1} \max \left\{ 0, V^k_{t+1}(e_{j,t+1}) \right\} \right]$

LoM earnings: $e_{j,t+1} = u_{j,t+1} Z^{\text{loans}}_{t+1} \frac{b_{j,t}}{\Pi_{t+1}} - \frac{d_{j,t}}{\Pi_{t+1}}$
Financial Intermediaries

- \( u_{j,t} \sim F^d \subseteq [u, \bar{u}] \)
- Default iff
  \[
  u_{j,t} < u^*_t \equiv \frac{d_{j,t-1}}{Z_{t_{loans}} b_{j,t-1}} \sim \text{Leverage}
  \]
- Aggregation \( \Rightarrow \) representative bank
  \[
  \int_{[0,1]} \mathbb{E}_t \left[ \prod_{t+1} \max \{0, V^k_{t+1}(e_{j,t+1})\} \right] \, dj \equiv \Phi_t \theta E_t
  \]
- Spreads reflect \text{Credit Risk} + \text{Current} + \text{Future} binding constraints
- Long-term debt \( \Rightarrow \) Pecuniary Externalities \( \Rightarrow \) Financial Accelerator
- Payoff per unit of deposits,

\[
Z_{t_{\text{deposits}}} = \left\{ \begin{array}{ll}
\underline{s^d_t} & \text{guaranteed} \\
(1-s^d_t) \left\{ 1 - F^d(u^*_t) + (1 - \lambda^d) \int_0^{u^*_t} u Z_{t_{loans}} \frac{B^b_{t-1}}{D_{t-1}} \, dF^d \right\} & \text{repaid} \\
\text{liquidated}
\end{array} \right.
\]
Closing the Model

Standard DSGE model w/ nominal rigidities

- Producers $\rightarrow$ Phillips Curve
- Savers $\rightarrow$ Euler Equation (IS)
- Housing in fixed supply,
  \[ h_t = 1 \]
- Central Bank $\rightarrow$ Taylor Rule
  \[ \frac{1}{Q_t} = \frac{1}{Q} \left[ \frac{\Pi_t}{\Pi} \right]^{\phi_\pi} \left[ \frac{Y_t}{Y} \right]^{\phi_y} \]
- Aggregate resource constraint,
  \[ C_t + G_t + \text{DWL Default}_t = A_t N_t \left[ 1 - d(\Pi_t) \right] = Y_t \]
  \(=\) Menu Costs
Budget constraint,

\[ \tau Y_t + T_t + Q_t B_t^g - \bar{G} - \frac{B_{t-1}^g}{\Pi_t} = \text{Net Cost from Discretionary Measures}_t \]

Standard Surplus

Fiscal rule for taxes,

\[ T_t = \phi_{\tau} \log \left( \frac{B_{t-1}^g}{\bar{B}^g} \right) \]

Net Cost from Discretionary Measures,

\[ (G_t - \bar{G}) + \chi T_t^b + s_t^k \theta E_t + s_t^d \frac{D_{t-1}}{\Pi_t} \times (1 - \text{Recovery Rate}_t) \]
1. **Crises**

\[ \sigma_t^b = [\sigma_t^{b,\text{normal}}, \sigma_t^{b,\text{crisis}}]^T \]

and

\[ \mathbf{P}^\sigma = \begin{bmatrix} .995 & .005 \\ .2 & .8 \end{bmatrix} \]

2. **Households**

<table>
<thead>
<tr>
<th>Target</th>
<th>Target Parameter</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction Borrowers</td>
<td>Parker et al. (2013)</td>
<td>( \chi = 0.475 )</td>
</tr>
<tr>
<td>Avg. Maturity</td>
<td>5 years</td>
<td>( \gamma = 1/20 )</td>
</tr>
<tr>
<td>Max LTV Ratio</td>
<td>80%</td>
<td>( m = 0.0383 )</td>
</tr>
<tr>
<td>Debt/GDP</td>
<td>80%</td>
<td>( \xi = 0.1565 )</td>
</tr>
<tr>
<td>Avg. Delinquency Rate</td>
<td>2%</td>
<td>( \sigma_{b,\text{normal}} = 8.205 )</td>
</tr>
</tbody>
</table>

3. **Banks**

\[ F_d(u) = \frac{u^\sigma - \underline{u}^\sigma}{\bar{u}^\sigma - u^\sigma} \]

<table>
<thead>
<tr>
<th>Target</th>
<th>Target</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book Leverage</td>
<td>10</td>
<td>( \kappa = 0.1 )</td>
</tr>
<tr>
<td>Payout Rate</td>
<td>15%</td>
<td>( \theta = 0.85 )</td>
</tr>
<tr>
<td>Avg. Lending Spread</td>
<td>2%</td>
<td>( \varpi = 0.0105 )</td>
</tr>
<tr>
<td>CDS-Implied Def. Prob.</td>
<td>2% in recessions</td>
<td>( u = 0.88, \sigma^d = 1.5 )</td>
</tr>
</tbody>
</table>
Smoothed Shocks

TFP

Credit Risk Shock

% Deviation from SS

2000Q1  2008Q3  2015Q4

% Deviation from SS

2000Q1  2008Q3  2015Q4