The Intertemporal Keynesian Cross

Adrien Auclert, Matt Rognlie and Ludwig Straub
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Q: How does the macroeconomy propagate shocks?
   • what micro moments are important?

   • Recent literature: **MPCs** are crucial for **PE** effects
     • Fiscal policy [Kaplan-Violante], monetary policy [Auclert], house prices [Berger et al], inequality [Auclert-Rognlie], ...

   • Here: “**intertemporal MPCs**” (iMPCs) are crucial for **GE**
Application: When is the fiscal multiplier large?

- Lots of theory + empirical work. Two workhorse models:

1. **Representative agent (RA)** models
   - **response of monetary policy** is key
   - large when at ZLB

   [Eggertsson 2004; Christiano-Eichenbaum-Rebelo 2011]

2. **Two agent (TA)** models
   - aggregate **MPC** is key
   - large when deficit financed, effects not persistent

   [Galí-López-Salido-Vallés 2007; Coenen et al 2012; Farhi-Werning 2017]
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**New:** **Heterogeneous-agents (HA) models**

→ iMPCs are key, can be used for calibration

→ large and persistent Y effect when deficit financed
1. **Benchmark model**, allows for RA, TA, HA
   
   - without capital & neutral monetary policy
   - multiplier = function of **iMPCs and deficits only**
     
     = 1 if zero deficits or flat iMPCs (RA)
     
     > 1 if **deficit-financed** and **realistic iMPCs** (HA, TA?)
Our contribution: Interaction of iMPCs and deficit-financing

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   - without capital & neutral monetary policy
   - multiplier = function of iMPCs and deficits only
     - \( = 1 \) if zero deficits or flat iMPCs (RA)
     - \( > 1 \) if deficit-financed and realistic iMPCs (HA, TA?)

2. **Quantitative model** with capital & Taylor rule
   - large & persistent \( Y \) effects, despite these extra elements
   - iMPCs still crucial for \( Y \) response
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3. Role of **iMPCs** for the GE effects of other shocks
Related literature

• **Fiscal multipliers**
  
  • **Theory**: IS-LM [Gelting 1941, Haavelmo 1945, Blinder-Solow 1973, ...]
  
  
  


• **Cross-sectional multipliers** [Shoag 2010, Chodorow-Reich et al. 2012, Nakamura-Steinsson 2014, Chodorow-Reich 2018, ...]

• **Partial to general equilibrium** [Farhi Werning 2017, Auclert-Rognlie 2018, Guren-McKay-Nakamura-Steinsson 2018, ...]
1. The intertemporal Keynesian Cross
2. iMPCs in models vs. data
3. Fiscal policy in the benchmark model
4. Fiscal policy in the quantitative model
5. Takeaways
The intertemporal Keynesian Cross
Common assumptions

• GE, discrete time $t = 0 \ldots \infty$, no aggregate risk

• Mass 1 of households:
  • idiosyncratic shocks to skills $e_{it}$, various market structures
  • real pre-tax income $y_{it} \equiv \frac{W_t}{P_t} e_{it} n_{it}$
  • after tax income $z_{it} \equiv y_{it} - T_t(y_{it}) \equiv \tau_t y_{it}^{1-\lambda}$ [Bénabou, HSV]
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- Government sets:
  - tax revenues $T_{t} = \int (y_{it} - z_{it}) \, di$
  - government spending $G_{t}$
  - “neutral” monetary policy: fixed real rate $= r$
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- Supply side:
  - linear production function $Y_t = N_t$
  - flexible prices $\Rightarrow P_t = W_t$
  - sticky $w \Rightarrow \pi^w_t = \kappa^w \int N_t (v' (n_{it}) - \frac{e-1}{e} \frac{\partial z_{it}}{\partial n_{it}} u' (c_{it}) \, di) + \beta \pi^w_{t+1}$
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Household $i$ solves

$$\max \mathbb{E} \left[ \sum \beta^t \{ u(c_{it}) - v(n_{it}) \} \right]$$

- **RA**: no risk in e (or complete markets)
- **TA**: share $\mu$ of agents with $c_{it} = z_{it}$
- **HA-std**: one asset model

$$c_{it} + a_{it} = (1 + r) a_{it-1} + z_{it}$$

$$a_{it} \geq 0$$

- **HA-iMPC**: simplified two asset model
  - **illiquid** account $a^{illiq} = \text{fixed}$ no. of bonds ( + capital)
  - **liquid** account $a_{it} = \text{all remaining}$ bonds + $ra^{illiq}$
The aggregate consumption function

• Equilibrium defined as usual

• Given \( \{a_{i_0}\} \) and \( r \), **aggregate consumption function** is

\[
C_t = \int c_{it} di = C_t (\{Z_s\})
\]

[Farhi Werning 2017, Auclert Rognlie 2016]

with \( Z_t \equiv \) aggregate after-tax labor income

\[
Z_t \equiv \int z_{it} di = Y_t - T_t
\]

• \( C \) summarizes the heterogeneity and market structure
Intertemporal MPCs

- Goods market clearing \( \leftrightarrow \)

\[
Y_t = G_t + C_t \left( \{ Y_s - T_s \} \right)
\]

- Impulse response to shock \( \{ dG_t, dT_t \} \)

\[
dY_t = dG_t + \sum_{s=0}^{\infty} \frac{\partial C_t}{\partial Z_s} \cdot (dY_s - dT_s) \quad (1)
\]

\( \rightarrow \) Response \( \{ dY_t \} \) entirely characterized by \( \{ M_{t,s} \} \)!

- *partial equilibrium* derivatives, \textbf{“intertemporal MPCs”}
- how much of income change at date \( s \) is spent at date \( t \)
- \[ \sum_{t=0}^{\infty} (1 + r)^{s-t} M_{t,s} = 1 \]
The intertemporal Keynesian cross

- Stack objects: $M = \{M_{t,s}\} = \left\{ \frac{\partial C_t}{\partial Z_s} \right\}$, $dY = \{dY_t\}$, etc

- Rewrite equation (1) as

$$dY = dG - MdT + MdY$$

- This is an **intertemporal Keynesian cross**
  - entire complexity of model is in $M$
  - with $M$ from data, could get $dY$ without model!
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- This is an **intertemporal Keynesian cross**
  - entire complexity of model is in \( M \)
  - with \( M \) from data, could get \( dY \) without model!
- When unique, solution is
  \[
dY = M \cdot (dG - MdT)
  \]
  where \( M \) is (essentially) \((I - M)^{-1}\)
Benchmark model takeaway

- Government chooses $dG$ and $dT$ such that
  \[ \sum_{t=0}^{\infty} \frac{G_t - T_t}{(1+r)^t} = 0 \]

- $dY$ is solution to **intertemporal Keynesian cross**
  \[ dY = dG - MdT + MdY \]

- **iMPCs** $M = \{M_{t,s}\}$ capture model response of aggregate consumption to changes in after-tax income
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- Government chooses $dG$ and $dT$ such that $\sum_{t=0}^{\infty} \frac{G_t-T_t}{(1+r)^t} = 0$

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- RA, TA, HA differ in their $M$ matrices
Benchmark model takeaway

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\[ dY = dG - MdT + MdY \]

• **iMPCs** $M = \{ M_{t,s} \}$ capture model response of aggregate consumption to changes in after-tax income

• RA, TA, HA differ in their $M$ matrices

• **Next:**
  • look at $M$’s in data and compare with RA, TA, HA
  • implications for $dY$
iMPCs in models vs. data
Measuring aggregate iMPCs using individual iMPCs

• Object of interest: \textbf{(aggregate) iMPCs}

\[ M_{t,s} = \frac{\partial C_t}{\partial Z_s} \]

where \( C_t = \int c_{it} di \) and \( Z_s = \int z_{is} di \)

• Direct evidence on \( M_{t,s} \) is hard to come by for general \( s \)

• More work on column \( s = o \) (unanticipated income shock)

• Can write

\[ M_{t,o} = \int \left( \frac{Z_{io}}{Z_o} \right) \cdot \frac{\partial c_{it}}{\partial z_{io}} \, di \]

\( \rightarrow \) aggregate iMPCs are \textbf{weighted individual iMPCs}
Obtain date-o iMPCs from cross-sectional microdata

- Two sources of evidence on $\frac{\partial c_{it}}{\partial z_{io}}$:

1. Fagereng Holm Natvik (2018) measure in Norwegian data

   \[ c_{it} = \alpha_i + \tau_t + \sum_{k=0}^{5} \gamma_k \text{lottery}_{i,t-k} + \theta x_{it} + \epsilon_{it} \]

   - Weighting by income in year of lottery receipt $\Rightarrow M_{t,o}$

2. Italian survey data (SHIW 2016) on $\frac{\partial c_{io}}{\partial z_{io}}$

   - Construct lower bound for impulse using distribution of MPCs + stationarity assumption
iMPCs in the data

- Annual $M_{0,0}$ consistent with evidence from other sources
Compare iMPCs across models

- **RA**
- **TA**: share of hand-to-mouth calibrated to match $M_{o,o}$
- **HA-std**: one-asset HA, standard calibration
- **HA-iMPC**: two-asset HA calibrated to match iMPCs
- ... and for fun:
  - **BU**: bonds-in-utility model, calibrated to match $M_{o,o}$
    [Michaillat Saez 2018; Hagedorn 2018; Kaplan Violante 2018]
iMPCs across models

(a) Data and model fit

(b) Alternative models
iMPCs across models including TABU

(a) Data and model fit

- Data
- HA-illiq
- TABU

(b) Alternative models

- Data
- RA
- TA
- HA-std
- BU
What about non-date-o iMPCs?

- Existing evidence useful for response to date-o income shocks, \( \{M_{t,o}\} \)

- What about responses to future shocks?

  \[ \text{use calibrated HA-iMPC model to fill in the blanks!} \]
Response of HA-iMPC to other income shocks

![Graph showing the response of HA-iMPC to income shocks](image)

The graph illustrates the response of HA-iMPC to income shocks across different years. The x-axis represents the year (t), and the y-axis represents the iMPC (Mt,s). Different lines represent different values of s (s = 0, s = 5, s = 10, s = 15, s = 20). Each line shows the peak response at a specific year, indicating the impact of income shocks at various levels of s.
Not entirely arbitrary → TABU is very similar!
Fiscal policy in the benchmark model
Fiscal policy in the benchmark model

• Recall intertemporal Keynesian cross:

\[ dY = dG - M \cdot dT + M \cdot dY \]

• \( dY \) entirely determined by iMPCs \( M \) and fiscal policy \((dG, dT)\)

• Next: Characterize role of iMPCs for
  1. balanced budget policies, \( dG = dT \)
  2. deficit-financed policies
The balanced-budget unit multiplier

• With **balanced budget**, \( dG = dT \Rightarrow \text{multiplier of 1:} \)

\[
dY = dG
\]

• Similar reasoning already in Haavelmo (1945)

• Generalizes Woodford’s RA results
  • heterogeneity irrelevant for balanced budget fiscal policy
  • similar to Werning (2015)’s result for monetary policy

• Proof: \( dY = dG \) is unique solution to

\[
dY = (I - M) \cdot dG + M \cdot dY
\]
• With deficit financing $dG \neq dT$ we have

$$dY = dG + \mathcal{M} \cdot M \cdot (dG - dT)$$

Consumption $dC$ depends on primary deficits $dG - dT$
Deficit-financed fiscal policy

- With deficit financing $dG \neq dT$ we have

$$dY = dG + M \cdot M \cdot (dG - dT)$$

Consumption $dC$ depends on primary deficits $dG - dT$

- Example: TA model with deficit financing

$$dY = dG + \frac{\mu}{1 - \mu} (dG - dT)$$

- consumption $dC$ depends only on current deficits
- **initial multiplier** can be large $\in \left[1, \frac{1}{1 - \mu}\right] \ldots$
- but **cumulative multiplier** is $= 1$!

$$\frac{\sum (1 + r)^{-t}dY_t}{\sum (1 + r)^{-t}dG_t} = 1$$
Simulate model responses for more general shocks

- Parametrize: $dG_t = \rho_G dG_{t-1}$ and $dB_t = \rho_B (dB_{t-1} + dG_t)$
  - vary **degree of deficit-financing** $\rho_B$
Simulate model responses for more general shocks

- Parametrize: $dG_t = \rho_G dG_{t-1}$ and $dB_t = \rho_B (dB_{t-1} + dG_t)$
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Impact multiplier

![Impact multiplier graph]

Cumulative multiplier

![Cumulative multiplier graph]

Calibration: $\rho_G = 0.7$
Fiscal policy in the quantitative model
Adding new elements to the HA-iMPC model …

- **Government:**
  - gov spending shock, \( dG_t = \rho_G dG_{t-1} \)
  - fiscal rule, \( dB_t = \rho_B (dB_{t-1} + dG_t) \)
  - Taylor rule, \( i_t = r_{ss} + \phi \pi_t, \phi > 1 \)

- **Supply side:**
  - Cobb-Douglas production, \( Y_t = K_t^\alpha N_t^{1-\alpha} \)
  - \( K_t \) subject to quadratic capital adjustment costs
  - sticky prices à la Calvo, \( \pi_t = \kappa_p mc_t + \frac{1}{1+r_t} \pi_{t+1} \)

- **Two reasons for lower multipliers:**
  - monetary policy & crowding-out of investment
Sizeable output response to deficit-financed $G$

Calibration: $\rho_G = 0.7$, $\kappa^W = \kappa^P = 0.1$, $\phi = 1.5$; vary $\rho_B$ in $dB_t = \rho_B (dB_{t-1} + dG_t)$
Equilibrium effect from $Y$ important for both $C$ and $I$

Calibration: $\rho_G = 0.7, \rho_B = 0.7, \kappa^w = \kappa^p = 0.1, \phi = 1.5$
iMPCs still a crucial determinant of response!

Calibration: $\rho_G = 0.7$, $\kappa^w = \kappa^p = 0.1$, $\rho_B = 0.5$, $\phi = 1.5$
Summary: HA-iMPC & TA have large **on-impact** multipliers

On-impact multipliers $\frac{dY_o}{dG_o}$

<table>
<thead>
<tr>
<th>Fiscal rule</th>
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<th>RA</th>
<th>HA-std</th>
<th>TA</th>
<th>HA-illiq</th>
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<tbody>
<tr>
<td><strong>bal. budget</strong></td>
<td>benchmark</td>
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<td>1.0</td>
<td>1.0</td>
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<tr>
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<td>0.6</td>
<td>0.6</td>
<td>1.3</td>
<td>1.6</td>
</tr>
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</table>

Calibration: $\rho_G = 0.7, \kappa^w = \kappa^p = 0.1, \rho_B = 0.5, \phi = 1.5$
... but only HA-iMPC has large **cumulative** multipliers

Cumulative multipliers \[
\sum_t \frac{(1+r)^{-t} dY_t}{\sum_t (1+r)^{-t} dG_t}
\]

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<td>0.4</td>
<td>0.8</td>
<td>1.4</td>
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</table>
Takeaways
What can we learn for other shocks? – back to benchmark

- Aggregate consumption may depend on other shocks $\theta$,

\[ C_t = C_t (\{Z_s\}, \theta) \]

[e.g. deleveraging, inequality, preferences, mon. policy]

- Can define partial equilibrium effect as

\[ \partial Y \equiv dG - MdT + C_\theta d\theta \]

- Same intertemporal Keynesian cross applies:

\[ dY = \partial Y + MdY \]

→ iMPCs also determine propagation of other shocks
**Conclusion**

**M** matters for **Macro**!

→ crucial for GE propagation
→ new insights for fiscal policy

**New avenues:**

\[
\begin{align*}
\text{more evidence on } & \text{M} \\
\text{implications for other shocks}
\end{align*}
\]
Extra slides
Unions

- Mass 1 of unions. Each union \( k \)
  - employs every individual, \( n_i = \int n_{ik} dk \)
  - produces task \( N_k = \int e_i n_{ik} di \) from member hours
  - pays common wage \( w_k \) per efficient unit of work \( e \)
  - requires that all individuals work \( n_{ik} = N_k \)
- Final good firms aggregate \( N = \left( \int O N_k^{1/\epsilon} dk \right)^{\epsilon/\epsilon-1} \)
- Union \( k \) sets \( w_{kt} \) each period to maximize
  \[
  \max_{w_{kt}} \sum_{\tau \geq 0} \beta^\tau \left\{ \int \left\{ u(c_{it+\tau}) - v(n_{it+\tau}) \right\} di - \frac{\psi}{2} \left( \frac{W_{kt+\tau}}{W_{kt+\tau-1}} \right)^2 \right\}
  \]
  - \( \Rightarrow \) nonlinear wage Phillips curve
  \[
  (1 + \pi_t^w) \pi_t^w = \frac{\epsilon}{\psi} \int N_t \left( v'(n_{it}) - \frac{\epsilon - 1}{\epsilon} \frac{\partial Z_{it}}{\partial n_{it}} u'(c_{it}) \right) di
  \]
  \[
  + \beta \pi_{t+1} (1 + \pi_{t+1})
  \]
• Given \( \{G_t, T_t\} \), a **general equilibrium** is a set of prices, household decision rules and quantities s.t. at all \( t \):

1. firms optimize
2. households optimize
3. fiscal and monetary policy rules are satisfied
4. the goods market clears
Calibration: homothetic durables model with $d_{it} = 0.1 \cdot c_{it}$ and $\delta_D = 20\%$
Calibration for benchmark model

- Preferences: \( u(c) = \frac{c^{1-\frac{1}{\nu}}}{1-\frac{1}{\nu}}, \quad v(n) = b \frac{n^{1+\frac{1}{\phi}}}{1+\frac{1}{\phi}} \)
- Income process: \( \log e_t = \rho_e \log e_{t-1} + \sigma \epsilon_t \)

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>HA-illiq</th>
<th>HA-std</th>
</tr>
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<tbody>
<tr>
<td>( \nu )</td>
<td>EIS</td>
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<td></td>
</tr>
<tr>
<td>( \phi )</td>
<td>Frisch</td>
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<td></td>
</tr>
<tr>
<td>( \rho_e )</td>
<td>Log e persistence</td>
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</tr>
<tr>
<td>( \sigma )</td>
<td>Log e st dev</td>
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</tr>
<tr>
<td>( \lambda )</td>
<td>Tax progressivity</td>
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<td>Spending-to-GDP</td>
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<tr>
<td>( A/Z )</td>
<td>Wealth-to-aftertax income</td>
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<tr>
<td>( B/Z )</td>
<td>Liquid assets to aftertax income</td>
<td>0.15</td>
<td>8.2</td>
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<tr>
<td>( \beta )</td>
<td>Discount factor</td>
<td>0.80</td>
<td>0.92</td>
</tr>
<tr>
<td>( r )</td>
<td>Real interest rate</td>
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</tr>
<tr>
<td>( \kappa^w )</td>
<td>Wage flexibility</td>
<td>0.1</td>
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</tbody>
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Calibration for quantitative model

- As in benchmark model, plus:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Capital share</td>
<td>0.33</td>
</tr>
<tr>
<td>$B/Y$</td>
<td>Debt-to-GDP</td>
<td>0.7</td>
</tr>
<tr>
<td>$K/Y$</td>
<td>Capital-to-GDP</td>
<td>2.5</td>
</tr>
<tr>
<td>$\mu$</td>
<td>SS markup</td>
<td>1.015</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate</td>
<td>0.08</td>
</tr>
<tr>
<td>$\epsilon_1$</td>
<td>Invest elasticity to $q$</td>
<td>4</td>
</tr>
<tr>
<td>$\kappa^p$</td>
<td>Price flexibility</td>
<td>0.1</td>
</tr>
<tr>
<td>$\kappa^w$</td>
<td>Wage flexibility</td>
<td>0.1</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Taylor rule coefficient</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Impulse responses in benchmark model

Calibration: $\rho_G = \rho_B = 0.7$
Impulse responses in quantitative model

Calibration: $\rho_G = \rho_B = 0.7$, $\kappa^W = \kappa^P = 0.1$, $\phi = 1.5$
True unless very responsive Taylor rule

Calibration: \( \rho_G = 0.7, \kappa^w = \kappa^p = 0.1, \rho_B = 0.5, \) and vary \( \phi \) in Taylor rule
True even with more flexible prices (unless very flexible)

Years | Per cent of s.s. output
--- | ---
0 | 2.5
2 | 2.0
4 | 1.5
6 | 1.0
8 | 0.5
10 | 0.0

Years | Investment
--- | ---
0 | 0.5
2 | 0.0
4 | -0.5
6 | -1.0
8 | -1.5
10 | -2.0

Calibration: $\rho_G = 0.7, \kappa^w = 0.1, \rho_B = 0.5, \phi = 1.5$, and vary $\kappa^p$ in price Phillips curve
True even with more flexible wages (unless very flexible)

Calibration: $\rho_G = 0.7$, $\kappa_p = 0.1$, $\rho_B = 0.5$, $\phi = 1.5$, and vary $\kappa_w$ in wage Phillips curve