Inflation, Demand for Liquidity, and Welfare

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Mpls Fed, CAERP

Sixty Years Since Baumol-Tobin: A Celebration Conference
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The views expressed are those of the authors and not of the Bank of Canada, the Federal Reserve Bank of Minneapolis or the Federal Reserve System.
Motivation

- Inflation affects relative prices of holding different types of assets and hence welfare.

- Most previous studies use representative-agent models and aggregate evidence to measure the cost.

- Heterogeneous behavior and micro evidence can be important.
Motivation

- Recent work on welfare cost of inflation take into account heterogeneity.
  - Aggregate welfare effects can differ when heterogeneity is considered

- Not much done in the literature:
  - Money holding for transaction purpose varies with age.

- This is important because
  - Welfare cost of inflation will differ across age groups
  - Potential nonlinear effects of inflation when aggregated
Other literature

- Lucas (2000) points out an importance of using micro data to estimate the gains/costs of inflation.
- Mulligan and Sala-i-Martin (2000) and Attanasio et al. (2002) use micro data to estimate the welfare cost of inflation.
- Dotsey and Ireland (1996) analyze a general equilibrium model of money demand with an intermediation cost of credit transaction technology.
- Erosa and Venture (2002) incorporates heterogeneity over household income.
- Chui and Molico (2010) uses a search model of demand for money.
- Heer and Maussner (2012) analyze the effects of inflation on distributions of both income and wealth.
- Heer et al. (2007) document that the money-age profile is hump-shaped and money is weakly correlated with income and wealth.
What we do

1. Ask welfare implications of inflation by
   - building an OLG model where money and credit are used for transaction; and
   - calibrating model to capture age, cohort and time effects on money-consumption ratios.

2. Document money-consumption ratios, i.e., liquidity demand for money
   - People are very different between ages and between social classes over money holdings and wealth

3. Use data to disentangle age, cohort and time effects
Findings

- Money-consumption ratio is higher for older and poor households.
  - 5 times higher for old households (aged 76-85) relative to that for young (aged 26-35)
  - 2 times higher for poor households relative to that for rich households
- These effects do not disappear once we control for cohort and time effects.
- Age-specific transaction cost captures age profile of money holding.
- Aggregate welfare effects when inflation ↑ from 1.92% to 10%,
  - Aggregate consumption decreases by 0.83%.
- Distributional effects are summarize as follows,
  - To be added
Data: Two Household Surveys

- Our main data sources are two household surveys (repeated cross-section)
  - Canadian Financial Monitor (CFM), 1999-2010, by Ipsos Reid
    - “money” holdings information available for all years
    - consumption information available only for 2008-2010
    - no information on money holdings
    - consumption information available for all years
- Money: checking account and some savings accounts (for transactions)
- Consumption: durables (excluding housing), non-durables, and service
To separate out age, cohort and time effects, we need data on money-con ratios over a longer period than 2008-2010 from CFM.

Obtain a 11-year series by combining CFM and SHS, following Bethencourt and Ríos-Rull (2009):

1. From 2008-2010 CFM, calculate a joint distribution (in quintile) of households over money and consumption.

2. For each year over 1999-2009, calculate average money holdings of households in each quintile from CFM and average consumption in each quintile from SHS.

3. Holding fixed the joint distribution from Step (1), assign the average money holdings and consumption in the respective quintile in each year over 1999-2009.

4. For each year and each consumption quintile, calculate average money-consumption ratios over money quintile using the marginal distribution from Step (1) as weights.
CFM 2008-2010 contain household-level information regarding money and consumption. Hence, we can construct a joint distribution of households over money and consumption:

<table>
<thead>
<tr>
<th>Marginal Dist.</th>
<th>5th</th>
<th>4th</th>
<th>3rd</th>
<th>2nd</th>
<th>1st</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
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<tr>
<td>Money Quintile</td>
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<tr>
<td>5th</td>
<td>$w_{51}$</td>
<td>$w_{52}$</td>
<td>$w_{53}$</td>
<td>$w_{54}$</td>
<td>$w_{55}$</td>
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<td>$w_{41}$</td>
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<td>$w_{43}$</td>
<td>$w_{44}$</td>
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</tr>
<tr>
<td>3rd</td>
<td>$w_{31}$</td>
<td>$w_{32}$</td>
<td>$w_{33}$</td>
<td>$w_{34}$</td>
<td>$w_{35}$</td>
<td>$w_3.$</td>
<td></td>
<td></td>
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<tr>
<td>2nd</td>
<td>$w_{21}$</td>
<td>$w_{22}$</td>
<td>$w_{23}$</td>
<td>$w_{24}$</td>
<td>$w_{25}$</td>
<td>$w_2.$</td>
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<tr>
<td>1st</td>
<td>$w_{11}$</td>
<td>$w_{12}$</td>
<td>$w_{13}$</td>
<td>$w_{14}$</td>
<td>$w_{15}$</td>
<td>$w_1.$</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Data: Joint distribution of Money and Consumption
Data: Joint distribution of Money and Consumption

For each year over the 1999-2007 period,

- CFM has information on money, \( \{w_1, \ldots, w_5\} \), and we can calculate average money holdings in each quintile.
- SHS has information on consumption, \( \{w_{.1}, \ldots, w_{.5}\} \), and we can calculate average consumption in each quintile.

Use these information to approximate money-consumption ratios in each consumption quintile.
Data: Combining CFM and SHS

- Do this for six age groups:
Money-consumption ratio declines as consumption increases.
Money-consumption ratio rises with household age.
Money-Consumption Ratio by Cohort

- Money-consumption ratio declines for newer cohorts.
  - Older cohorts have higher money-consumption ratios given consumption.
Money-Consumption Ratio by Cohort

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Inflation, Demand for Liquidity, and Welfare

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Aggregate money-consumption ratios change over time with the macroeconomic environment.
Empirical Analysis on Money-Consumption Ratios by Age, Cohort and Time

- It is difficult to separate out these three effects.

- Our identification strategy and assumptions are:
  
  ▶ Three effects are independent
  
  ▶ Cohort effects are assumed to be exponential with respect to the differences in birth year \( \mu \Delta \text{birth year}/10 \)
  
  ▶ Time effects are time-specific \( \lambda_{time} \)
  
  ▶ Age effects are age-specific \( \alpha_{age} \)

- Estimate \( \mu, \lambda_t \) and \( \alpha_i \) using annual data on money-consumption ratios from 1999 to 2009, with six 10-year age groups.
Estimation of cohort, time and age effects

- Use the following moment conditions:

\[
\begin{align*}
(m/c)_{1,1999} &= \alpha_1 \\
(m/c)_{1,2000} &= \alpha_1 \mu^{\frac{1}{10}} \lambda_{2000} \\
\vdots & \quad \vdots \\
(m/c)_{i,1999} &= \alpha_i \mu^{\frac{1}{1-i}} \\
(m/c)_{i,2000} &= \alpha_i \mu^{\frac{1}{1-i}} \lambda_{2000} \\
\vdots & \quad \vdots \\
(m/c)_{l,1999} &= \alpha_l \mu^{\frac{1}{1-l}} \\
(m/c)_{l,2000} &= \alpha_l \mu^{\frac{1}{1-l}} \lambda_{2000} \\
\vdots & \quad \vdots \\
(m/c)_{1,2009} &= \alpha_1 \mu \lambda_{2009} \\
(m/c)_{2,2009} &= \alpha_2 \lambda_{2009} \\
\vdots & \quad \vdots \\
(m/c)_{i,2009} &= \alpha_i \mu^{\frac{1}{1-i}} \lambda_{2009} \\
(m/c)_{j,2009} &= \alpha_j \mu^{\frac{1}{1-j}} \lambda_{2009}
\end{align*}
\]

- This gives us \( l \times 11 \) equations and \( l + 11 \) parameters.
Additional assumptions we make are:

- Cohort effects reduce the demand for money over time: $\mu \in (0, 1)$
### Estimation results

<table>
<thead>
<tr>
<th>( \alpha_1 )</th>
<th>( \alpha_2 )</th>
<th>( \alpha_3 )</th>
<th>( \alpha_4 )</th>
<th>( \alpha_5 )</th>
<th>( \alpha_6 )</th>
<th>( \mu )</th>
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<tbody>
<tr>
<td>0.091</td>
<td>0.109</td>
<td>0.123</td>
<td>0.175</td>
<td>0.297</td>
<td>0.498</td>
<td>0.994</td>
</tr>
<tr>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.007)</td>
<td>(0.864)</td>
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</table>

<table>
<thead>
<tr>
<th>( \lambda_{00} )</th>
<th>( \lambda_{01} )</th>
<th>( \lambda_{02} )</th>
<th>( \lambda_{03} )</th>
<th>( \lambda_{04} )</th>
<th>( \lambda_{05} )</th>
<th>( \lambda_{06} )</th>
<th>( \lambda_{07} )</th>
<th>( \lambda_{08} )</th>
<th>( \lambda_{09} )</th>
</tr>
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<tbody>
<tr>
<td>0.96</td>
<td>0.86</td>
<td>0.72</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>1.02</td>
<td>0.93</td>
<td>0.77</td>
<td>0.67</td>
</tr>
<tr>
<td>(0.014)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.016)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td>(0.013)</td>
<td>(0.007)</td>
</tr>
</tbody>
</table>

- \( \lambda_{99} \equiv 1 \) by normalization
- Use the estimates to calibrate the following model.
- For calibration, the averages over \( \lambda_{99} - \lambda_{04} \) and \( \lambda_{05} - \lambda_{09} \) are used as the time effects since the model period is 10 years.
We build on Erosa and Ventura (2002)

Seminal work on distribution of welfare cost of inflation:

- An infinitely-lived agent model with costly credit transaction.
- Study distribution of welfare cost over income.
- But abstract from life-cycle effects of inflation which is our focus.
Model

- Build an OLG model
- Consumption can be purchased with money and costly credit
- Agents live for $I = 7$ periods
- Agents differ in income profile ($J = 5$ exogenous income groups)
- Focus on transaction demand for money, and abstract from other roles of money such as hedging for liquidity risks
- Exogenous labour endowments and supply
Household’s problem

\[
\max \left\{ c_{ij}, s_{ij}, m_{i+1,j}, a_{i+1,j} \right\} \sum_{i=1}^{l} \beta^{i-1} \frac{c_{ij}^{1-\sigma}}{1 - \sigma} \quad \text{s.t.}
\]

\[
c_{ij}(1 - s_{ij}) \leq m_{ij};
\]

\[
c_{ij} + w \cdot \int_{0}^{s_{ij}} \gamma_{j}(x) \, dx + a_{i+1,j} + (1 + \pi)m_{i+1,j} \leq \underbrace{\text{transaction cost}}_{\text{inflation, demand for liquidity, and welfare}}
\]

\[
[1 + r(1 - \tau_{a})]a_{ij} + m_{ij} + (1 - \tau_{z})w z_{ij};
\]

\[
a_{1,j} = 0, \quad m_{1,j} = m
\]
• Government budget constraint ($G$—exogenous government spending):

$$G = \pi M/P + \pi_l w L + \pi_a r A$$

• All money is held by households.

$$\sum_{i=1}^{I} \sum_{j=1}^{J} \mu_{ij} m_{i+1,j} = M/P$$

• There is a constant inflation rate.

$$M_{t+1} = (1 + \pi) M_t$$
Transaction technology

\[ \gamma_i(x) = \gamma_i \eta_{t_i} \cdot \left( \frac{x}{1-x} \right)^{\theta_i} \]

- Fixed cost with respect to consumption and variable with respect to money-credit ratios
- Age effects: \( \gamma_i \) and \( \theta_i \)
- Cohort effects (new): we assume cohort effects (\( \eta_{t_i} \)) on transaction costs to vary with cohort (indexed by \( t_i \))
- Use data to discipline \( \gamma_i, \theta_i, \eta_{t_i} \)
Calibration strategy

- Household money demand for consumption \( \frac{m_{ij}}{c_{ij}} \) are different in age \((i)\), income \((j)\) and time \((t)\).
- Assume that time effects are driven by macroeconomic parameters such as tax rates, inflation and interest rates.
- Our focus will be on matching money-consumption ratios and consumption from the model to those in the data.
  - **Data:** \( \frac{m_{ijt}}{c_{ijt}} = f_{ijt}(\alpha_i, \mu, \lambda_t) \) and \( c_{ijt} \)
  - **Model:** \( \frac{m_{ijt}}{c_{ijt}} = \frac{1}{1+\left[\hat{R}_t c_{ijt} / (\gamma_i \eta_t)\right]^{1/\theta_i}} \) and \( c_{ijt} \)
- Dynamically calibrate along a transition where macroeconomic parameters are changing.
- Use \( \tau_{zt} \) to balance the government budget.
Dimension of calibration

- Household groups:
  - Age, $I = 7$ (We will not target $i = 1$ HHs for calibration as their portfolio is fixed by assumption.)
  - Income (and consumption class), $J = 5$
  - Total 35 groups (30 groups without $i = 1$ HHs)

- Time periods: 2 periods, 1999 and 2009
Calibration: Data

- 2 periods x 35 household labour income, \( \{ Z_{ijt} \}_{i=1,j=1,t=1}^{I,J,T} \)
- 2 periods x 30 household consumption, \( \{ c_{ijt} \}_{i=2,j=1,t=1}^{I,J,T} \)
- 2 periods x 30 household money-consumption ratios, \( \{ \frac{m_{ijt}}{c_{ijt}} \}_{i=2,j=1,t=1}^{I,J,T} \)
  - Out of these, estimate 6 \( \alpha_i \)'s (age), \( \mu \) (cohort) and \( \lambda \) (time)
- 2 periods x 5 aggregate moments: \( \pi_t, r_t, \tilde{R}_t, \tau_{at} \) and \( G_t \)
Calibration: List of parameters

- 35 household labour endowments, \( \{z_{ij}\}_{i=1,j=1}^{I,J} \)
- 30 discount factors, \( \{\beta_{ij}\}_{i=2,j=1}^{I,J} \)
- 12 age-dependent credit-transaction cost parameters: 6 \( \gamma_i \)'s and 6 \( \theta_i \)'s
- 6 cohort-effects parameter, \( \{\eta_{ti}\}_{t_i=t_2}^{t_7} \), \( t_i \) is the birth year for \( i = 2, \ldots, 7 \)
- 10 aggregate parameters: \( \pi_t, r_t, \tilde{R}_t, \tau_{at} \) and \( G_t \)
Calibration WITHOUT solving the model: Parameters and moments

- 35 labour endowments: \[ \{ z_{ij} \}_{i=1,j=1}^{I,J} = \frac{1}{T} \{ z_{ijt}^{\text{data}} \}_{i=1,j=1,t=1}^{I,J,T} \]

- 10 agg. parameters: \[ \pi_t = \pi_t^{\text{data}}, \quad r_t = r_t^{\text{data}}, \quad \tilde{R}_t = \tilde{R}_t^{\text{data}}, \quad \tau_{at} = \tau_{at}^{\text{data}}, \]
  and \[ G_t = G_t^{\text{data}} \text{ for } t = 1, 2 \]
30 discount factors, \( \{\beta_{ij}\}_{i=2,j=1}^{I,J} \)

12 age-dependent credit-transaction cost parameters: 6 \( \gamma_i \)'s and 6 \( \theta_i \)'s

6 cohort-effects parameter, \( \{\eta_{ti}\}_{t_i=t_2}^{t_7} \), \( t_i \) is the birth year for \( i = 2, \ldots, 7 \), and set \( \eta_{t_1} = \eta_{t_2} = 1 \),

2 periods of \( \tau_{zt}, w_t \)
Calibration WITH solving the model: Moments

- 30 household consumption at $t = 1$, $\{c_{ij,t=1}^{data}\}_{i=2,j=1}^{I,J} = \{c_{ij,t=1}\}_{i=2,j=1}^{I,J}$

- 6 age-$i$ average household money-consumption ratios at $t = 1$,

$$\frac{1}{J} \sum_{j=1}^{J} \left\{ \frac{m_{ij,t=1}^{data}}{c_{ij,t=1}^{data}} \right\}_{j=1}^{J} = \frac{1}{J} \sum_{j=1}^{J} \frac{1}{1 + \left[ \frac{R_{t=1} c_{ij}/(w \gamma i \eta t_i)}{1/\theta_i} \right]}$$

- 6 age-$i$ averaged slope of household money-consumption ratios over consumption at $t = 1$ (and/or $t = 2$),

$$\frac{1}{J} \sum_{j=1}^{J} \left[ \left( \frac{m_{i,j+1,t=1}^{data}}{c_{i,j+1,t=1}^{data}} - \frac{m_{ij,t=1}^{data}}{c_{ij,t=1}^{data}} \right) / \left( c_{i,j+1,t=1}^{data} - c_{ij,t=1}^{data} \right) \right] =$$

$$\frac{1}{J} \sum_{j=1}^{J} \left( \frac{1}{1 + \left[ \frac{R_{t=1} c_{i,j+1,t=1}/(w \gamma i \eta t_i)}{1/\theta_i} \right]^{1/\theta_i}} - \frac{1}{1 + \left[ \frac{R_{t=1} c_{ij,t=1}/(w \gamma i \eta t_i)}{1/\theta_i} \right]^{1/\theta_i}} \right) / \left( c_{i,j+1,t=1}^{data} - c_{ij,t=1}^{data} \right)$$
Calibration WITH solving the model: Moments

- 6 ratios of averaged money-consumption ratios over income; for \( i = 2 \) to 7

\[
\frac{1}{\mu \cdot \lambda} = \frac{\sum_{j=1}^{J} \frac{1}{1 + \left[ \widetilde{R}_{t=1} c_{ij}, t=1 / (w_{t=1} \gamma_{i} \eta_{ti}) \right]^{1/\theta_{i}}}}{\sum_{j=1}^{J} \frac{1}{1 + \left[ \widetilde{R}_{t=2} c_{ij}, t=2 / (w_{t=2} \gamma_{i} \eta_{ti} + 1) \right]^{1/\theta_{i}}}}
\]

- 2 periods of government budget equations,

\[
G_{t}^{data} = \pi_{t}^{data} M_{t} + \tau_{a}^{data} r_{t}^{data} A_{t} + \tau_{zt} w_{t} Z_{t}^{data}
\]

- 2 periods of labour demand: \( w_{t} = f_{L}(K_{t}, L_{t}) \)
## Calibration results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_2$</td>
<td>0.0013</td>
<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{2,j}$</td>
<td>0.1457</td>
<td>0.1315</td>
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<tr>
<td>$\gamma_3$</td>
<td>0.0020</td>
<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{3,j}$</td>
<td>0.1754</td>
<td>0.1595</td>
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<tr>
<td>$\gamma_4$</td>
<td>0.0041</td>
<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{4,j}$</td>
<td>0.2324</td>
<td>0.2093</td>
</tr>
<tr>
<td>$\gamma_5$</td>
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<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{5,j}$</td>
<td>0.2888</td>
<td>0.2662</td>
</tr>
<tr>
<td>$\gamma_6$</td>
<td>0.0060</td>
<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{6,j}$</td>
<td>0.4127</td>
<td>0.3817</td>
</tr>
<tr>
<td>$\gamma_7$</td>
<td>0.0083</td>
<td>$\frac{1}{5} \sum_j \left( \frac{m_c}{c} \right)_{7,j}$</td>
<td>0.6087</td>
<td>0.6675</td>
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<tr>
<td>$\theta_2$</td>
<td>1.7790</td>
<td>$\frac{1}{4} \sum_j \Delta \left( \frac{m_c}{c} \right)_{2,j}$</td>
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<td>-0.0959</td>
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<td>$\theta_3$</td>
<td>1.6838</td>
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<td>$\theta_4$</td>
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<td>-0.9254</td>
<td>-0.9988</td>
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## Calibration results

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<thead>
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<tbody>
<tr>
<td>$\eta_2$</td>
<td>0.6783</td>
<td>$\frac{\lambda_{9904}}{\mu \cdot \lambda_{0509}}$</td>
<td>1.0580</td>
<td>0.9610</td>
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<tr>
<td>$\eta_3$</td>
<td>0.4629</td>
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<td>1.0580</td>
<td>0.9669</td>
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<td>0.9621</td>
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<td>0.2244</td>
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<td>0.9542</td>
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<td>0.9572</td>
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<tr>
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<td>$\frac{\lambda_{9904}}{\mu \cdot \lambda_{0509}}$</td>
<td>1.0580</td>
<td>0.9577</td>
</tr>
<tr>
<td>$\beta_{i,1}$</td>
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<td>$c_{i,1}$</td>
<td>0.3827,...,0.2573</td>
<td>0.3684,...,0.2319</td>
</tr>
<tr>
<td>$\beta_{i,2}$</td>
<td>0.9308,...,0.7617</td>
<td>$c_{i,2}$</td>
<td>0.6828,...,0.4632</td>
<td>0.6605,...,0.4171</td>
</tr>
<tr>
<td>$\beta_{i,3}$</td>
<td>0.9221,...,0.7628</td>
<td>$c_{i,3}$</td>
<td>0.9368,...,0.6779</td>
<td>0.9133,...,0.6130</td>
</tr>
<tr>
<td>$\beta_{i,4}$</td>
<td>0.9175,...,0.7660</td>
<td>$c_{i,4}$</td>
<td>1.2710,...,1.0054</td>
<td>1.2723,...,0.9070</td>
</tr>
<tr>
<td>$\beta_{i,5}$</td>
<td>0.9548,...,0.8082</td>
<td>$c_{i,5}$</td>
<td>2.0730,...,1.7970</td>
<td>2.0619,...,1.8499</td>
</tr>
</tbody>
</table>
Calibration results - Money-consumption ratios
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Inflation, Demand for Liquidity, and Welfare
Results – to be added