Do Low Interest Rates Sow the Seeds of Financial Crises?

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The views expressed are those of the authors, not necessarily those of the Bank of Canada.
Interest Rate Policy and Risk Taking

- Empirical evidence suggest a link between low interest rates and risk taking of financial intermediaries
  - e.g. Ioannidou, Ongena and Peydró (2009); Jiménez, Ongena, Peydró and Saurina (2009); Altunbas, Gambacorta, and Marques-Ibane (2010); Delis and Kouretas (2010); López, Tenjo and Zárate (2011)

- This paper: policy influences risk taking via repo market
  - Intermediaries increasingly use repos to adjust portfolios
  - Repo rates are strongly influenced by policy
What We Do

In model where interest rate policy affects risk taking:

- find optimal interest rate policy
- evaluate consequences of deviating from the optimal policy
What We Do

In model where interest rate policy affects risk taking:
- find optimal interest rate policy
- evaluate consequences of deviating from the optimal policy

Risk taking is *excessive* if investments in high risk projects
- exceed the amount a social planner would choose
Two Risk Taking Channels of Policy

Dynamic model with aggregate and idiosyncratic risk:

- Financial intermediaries with limited liability
  - are initially identical
  - choose safe bonds and risky projects
  - find out type specific productivity risk: high or low
  - adjust portfolios via collateralized borrowing in repo market

- Interest rate policy affects risk taking through
  - returns to safe bonds
  - amount of collateral
Two Risk Taking Channels of Policy

Dynamic model with aggregate and idiosyncratic risk:
- Financial intermediaries with limited liability
  - are initially identical
  - choose safe bonds and risky projects
  - find out type specific productivity risk: high or low
  - adjust portfolios via collateralized borrowing in repo market
- Interest rate policy affects risk taking through
  - returns to safe bonds → portfolio channel
  - amount of collateral → collateral channel
Empirical Importance of Collateral Channel

- Repo market: large and growing market in U.S.

- Evidence of link between policy and repo market
  - Fed funds rate is highly correlated with repo rate
  - Government bonds big part of collateral used in repo market

- Evidence of link between repo market and risk taking
  Adrian and Shin (2010) show that changes in repo positions
  - key margin of balance sheet adjustment for intermediaries
  - indicate changes in financial market risk
What We Find

In model where interest rate policy affects risk taking through portfolio and collateral channel, we find:

- Optimal policy implies *excessive* risk taking
- Lower than optimal interest rates reduce risk taking
Why Lower Rates Reduce Risk Taking?

Lower than optimal interest rates have two effects:

1. **Portfolio channel**: buy less bonds in primary bond market
   - all intermediaries put more resources in risky assets

2. **Collateral channel**: have less bonds for repo transactions
   - in good times, high risk FI have high expected returns; want more risky assets; are constrained by amount of collateral
   - moral hazard problem is lessened

Collateral channel is quantitatively stronger lower than optimal interest rates
Why Lower Rates Reduce Risk Taking?

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Collateral channel is quantitatively stronger

lower than optimal interest rates $\Rightarrow$ less risk taking
Why Collateral Channel Dominates?

Main imperfection: limited liability

Optimal interest rates policy:
- aims to restrict risk taking by high risk FI
- makes collateral constraint for high risk FI binds

Collateral channel is quantitatively stronger because it allows to selectively control risk taking
Our Model with Mispriced Collateral

Add to the model the possibility of mispriced collateral:

- Financial intermediaries issue private bonds
- Rating agencies misreport riskiness of these private bonds
- There is foreign demand for safe domestic bonds

In this environment

- intermediaries have more collateral for repo market
- lower than optimal interest rates $\Rightarrow$ MORE risk taking
Model Outline
Model Economy

- **Households**: invest deposits and equity, consume and work
- **Nonfinancial sector firms**:  
  - financed through equity  
  - invest all equity as capital in their production technology
- **Financial sector firms**: have limited liability  
  - financed through equity and deposits  
  - invest in safe government bonds and risky projects; risky projects are investments into production technologies of small firms; two types: high-risk or low-risk projects
- **Government**: issues bonds, taxes, offers deposit insurance
Timeline of Main Events

End of period $t - 1$

- Government sets bond price in primary market, $p(s^{t-1})$
- Financial intermediaries (FI)
  - invest $k(s^{t-1})$ in risky projects and $b(s^{t-1})$ in safe bonds
  - learn riskiness of projects: high-risk or low-risk $j \in \{h, l\}$
  - adjust portfolios in repo market, using bonds as collateral
    - safe bonds: $b(s^{t-1}) - \tilde{b}_j(s^{t-1})$
    - risky capital: $k_j(s^{t-1}) \equiv k(s^{t-1}) + \tilde{p}(s^{t-1})\tilde{b}_j(s^{t-1})$

Beginning of period $t$

- Aggregate shock, $s_t$, is realized (persistent)
- Productivity of FI: $q_j(s_t), j \in \{h, l\}$; nonfin. firms: $q_m(s_t)$
- Production takes place, bankruptcy may occur
**Portfolio Choices of Financial Intermediaries**

Intermediaries maximize expected value of equity $E [V_j(s^t)]$

Two stage problem:

- primary market choices: $j$ and $s_t$ unknown
- adjustment via repo market: $j$ known, $s_t$ unknown

\[
V_j(s^t) = \max \left\{ \left( \begin{array}{c}
q_j(s_t) [k_j(s^{t-1})]^\theta [l(s^{t-1})]^{1-\theta-\alpha} \\
+ q_j(s_t) (1 - \delta) k_j(s^{t-1}) \\
+ [b(s^{t-1}) - \tilde{b}_j(s^{t-1})] \\
- \text{payments}
\end{array} \right), 0 \right\}
\]

- recall: $k_j(s^{t-1}) \equiv k(s^{t-1}) + \tilde{p}(s^{t-1})\tilde{b}_j(s^{t-1})$
Portfolio Adjustments via Repo Market

Are beneficial

- expansions: resources flow from low-risk to high-risk FI
  - high-risk FI have high expected returns
  - trade bonds on repo market to invest more in risky projects
  - equilibrium has constrained repo market if $\tilde{b}_h(s^{t-1}) = b(s^{t-1})$
- recessions: high-risk FI seek safer assets

Are influenced by interest rate policy

- In equilibrium, $\tilde{p}(s^{t-1}) = p(s^{t-1})$
Role for Policy

In good times, high risk financial intermediaries (FI)
- overinvest in risky projects
- disregard potential losses in the event of a bad aggregate state due to limited liability
- if bad state occurs, high-risk intermediaries are bankrupt

Depositors disregard these losses due to deposit insurance

Optimal interest rate policy aims to mitigate moral hazard problem by making collateral constraint bind
Model Results
Experiments

Exp. 1 Optimal interest rate policy, $1/p^*$
Exp. 2 Level shifts in optimal policy’s returns on bonds:

$$1/p^* \pm \Delta \text{ percentage points}$$

Exp. 3 Private mispriced bonds and foreign demand

Examine welfare and risk taking relative to the social planner
Welfare Measurement

Lifetime consumption equivalent (LTCE): percentage decrease in the optimal consumption from SP needed to generate the same welfare as the CE with a given interest rate policy.
BENCHMARK: WELFARE IMPLICATIONS OF POLICY

Deviations from optimal policy: not too costly

Optimal policy CE: close, but below, the social planner
Optimal policy CE: close, but below, the social planner

Deviations from optimal policy: not too costly
Risk Taking is the percentage deviation in resources invested in the high-risk projects in a CE relative to the SP.

\[ r(s^{t-1}) = \frac{k^{CE}_{h}(s^{t-1}) - k^{SP}_{h}(s^{t-1})}{k^{SP}_{h}(s^{t-1})} \]

- We measure aggregate risk taking as \( r \equiv E[r(s^{t-1})] \)
Benchmark: Risk Implications of Policy

Optimal Policy CE:
- more risk relative to social planner
- Close to optimum
- Lowering rates: reduces risk taking

Risk taking (in %)

Deviations from Optimal Policy, $1/p^*$

Optimal policy CE

Constrained Repo Market

Unconstrained Repo Market
Our Model with Mispriced Collateral

Fin. intermediaries may issue private bonds after repo trades

- With prob. $\pi_F$, there is foreign demand for safe bonds
- Pay cost $\xi a_j(s^{t-1})$ to have private bonds rated as safe
  - In this case, resources invested into risky projects become

$$k(s^{t-1}) + \tilde{p}(s^{t-1})\tilde{b}_j(s^{t-1}) + \tilde{p}(s^{t-1})a_j(s^{t-1})$$
Risk Taking with Mispriced Collateral

Model extension
- Much more risk
- Lowering rates: increases risk taking

Benchmark Model
- Lowering rates: reduces risk taking

Risk taking (in %)

Deviations from Optimal Policy, $1/p^*$
Conclusion

We examine the link between interest rate policy and risk taking.

At the optimal interest rate policy, our decentralized economy
- has welfare below, but very close to the social optimum
- features excessive risk taking

Lower than optimal interest rates
- generally reduce risk taking
- together with mispriced collateral increase risk taking
  - this amplifies the severity of recessions
Thank you!
Model Economy

- **Households**: invest deposits and equity, consume and work

- **Nonfinancial sector firms**:  
  - financed through equity
  - invest all equity as capital in their production technology

- **Financial sector firms**: have limited liability  
  - financed through equity and deposits  
  - invest in safe government bonds and risky projects; risky projects are investments into production technologies of small firms; two types: high-risk or low-risk projects

- **Government**: issues bonds, taxes, offers deposit insurance
Timing of Model Events

- **End of period** $t$
  - Household wealth, $w(s^t)$, is realized
  - Households consume and save in equity and deposits
  - Financial intermediaries buy safe government bonds, and invest in risky projects without knowing their type
  - Riskiness of projects is revealed
  - Financial intermediaries trade bonds in repo market

- **Beginning of period** $t + 1$
  - Aggregate state is revealed
  - Intermediaries (with limited liability) pay wages, deposits and dividends, in this order
  - Declare bankruptcy, if they can’t repay all obligations
  - Government transfers deposit insurance as needed
Household’s Problem

\[
\max \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \varphi (s^t) \log C (s^t)
\]

subject to:

\[
\begin{align*}
\omega (s^t) &= R^m (s^t) M (s^{t-1}) + R^d (s^{t-1}) D_h (s^{t-1}) + R^z (s^t) Z (s^{t-1}) \\
&\quad + \pi_m W_m (s^t) + (1 - \pi_m) \left[ \pi_l W_l (s^t) + \pi_h W_h (s^t) \right] + T (s^t) \\
\omega (s^t) &= C (s^t) + M (s^t) + D_h (s^t) + Z (s^t)
\end{align*}
\]
Nonfinancial Sector

\[
\max \left\{ q_m(s_t) \left( k_m(s_t^{t-1}) \right)^\theta \left( l_m(s_t^{t-1}) \right)^{1-\theta} + q_m(s_t) \left( 1 - \delta \right) k_m(s_t^{t-1}) - R^m(s_t)k_m(s_t^{t-1}) - W_m(s_t)l_m(s_t^{t-1}) \right\}
\]

Nonfinancial sector allows model to match U.S. data:

- on equity to deposit ratios in different sectors:
  - high for households, low for financial sector
- on share of production in financial and nonfinancial sectors
Financial Intermediaries

Portfolio Choices in the Primary Market

$$\max_{k(s^{t-1}), b(s^{t-1}), d(s^{t-1}), l(s^{t-1})} \sum_{j \in \{h,l\}} \pi_j \sum_{s^t | s^{t-1}} \lambda(s^t) V_j(s^t)$$

subject to:

$$z(s^{t-1}) + d(s^{t-1}) = k(s^{t-1}) + p(s^{t-1}) b(s^{t-1})$$

$$V_j(s^t) = \max \left\{ q_j(s_t) [k_j(s^{t-1})]^\theta [l(s^{t-1})]^{1-\theta-\alpha} + q_j(s_t) (1-\delta) k_j(s^{t-1}) + [b(s^{t-1}) - \tilde{b}_j(s^{t-1})] - R^d(s^{t-1}) d(s^{t-1}) - W_j(s^t) l(s^{t-1}), 0 \right\}$$

where $$k_j(s^{t-1}) \equiv k(s^{t-1}) + \tilde{p}(s^{t-1}) \tilde{b}_j(s^{t-1})$$

$$\eta \leq z(s^{t-1}) / k(s^{t-1})$$ capital regulation
Financial Intermediaries
Portfolio Adjustments Via the Repo Market

Riskiness of projects is revealed: \( q_h (\bar{s}) > q_l (\bar{s}) \geq q_l (s) > q_h (s) \)

\[
\max_{\tilde{b}_j(s^{t-1})} \sum_{s^t|s^{t-1}} \lambda(s^t)V_j(s^t)
\]

where \( V_j(s^t) \) are profits as before

\[
\tilde{b}_j(s^{t-1}) \in \left[ -\frac{k(s^{t-1})}{\tilde{p}(s^{t-1})}, b(s^{t-1}) \right]
\]

Two possible equilibria:

**Constraint:** \( \tilde{b}_j(s^{t-1}) = b_{t-1} \) for some \( j \in \{h, l\} \)

**Unconstraint:** \( \tilde{b}_j(s^{t-1}) < b_{t-1} \) for both \( j \in \{h, l\} \)
Government

1 Safe government bonds serve two functions:
   - Safe store of value
   - Medium of exchange in repo market

2 Monetary policy affects risk-taking in two ways:
   - Changes returns to safe assets
   - Controls liquidity in the repo market
Goods and Labor Market Clear

Goods market:

\[
C(s^t) + M(s^t) + D_h(s^t) + Z(s^t) \\
= \pi_m q_m(s_t) \left[ \left( k_m(s^{t-1}) \right)^\theta + (1 - \delta) k_m(s^{t-1}) \right] \\
+ (1 - \pi_m) \sum_{j \in \{l,h\}} \pi_j q_j(s_t) \left[ \left( k_j(s^{t-1}) \right)^\theta + (1 - \delta) k_j(s^{t-1}) \right]
\]

Labor market:

\[
(1 - \pi_m) l \left( s^{t-1} \right) = 1 - \pi_m \\
\pi_m l_m \left( s^{t-1} \right) = \pi_m
\]
Financial Markets Clear

Deposit market:

\[ D_h(s^{t-1}) + D_g(s^{t-1}) = D(s^{t-1}) = (1 - \pi_m) d(s^{t-1}) \]

Primary bond market:

\[ B(s^{t-1}) = (1 - \pi_m) b(s^{t-1}) \]

Repo market:

\[ \sum_{j \in \{l,h\}} \pi_j \tilde{b}_j(s^{t-1}) = 0 \]

Equity market:

\[ M(s^{t-1}) = \pi_m k_m(s^{t-1}) \]
\[ Z(s^{t-1}) = (1 - \pi_m) z(s^{t-1}) \]
High-risk intermediaries may go bankrupt
- Limited liability $\Rightarrow$ overinvest in risky projects

Redistribution via the repo market is beneficial
- as long as cost of issuing bonds is sufficiently low
- expansions: resources flow from low-risk to high-risk FI
- recessions: vice-versa; high-risk FI seek safer assets

Multiple equilibria exist for a given policy $p(s^t)$
- equilibria with positive or zero bond holdings
- focus on the former (see point 2)

We classify equilibria as constraint or unconstraint
- depending on the repo market trades
Bond Prices and Returns to Deposits

**Proposition:** In equilibrium, if government bond holdings are positive and capital regulation does not bind, then

\[ p(s^{t-1}) = \tilde{p}(s^{t-1}) \]

\[ R^d(s^{t-1}) \geq \frac{1}{p(s^{t-1})} \]

**Intuition:**
- No aggregate uncertainty resolved between primary and secondary market.
- If \( R^d(s^{t-1}) < 1/p(s^{t-1}) \), then intermediaries have an arbitrage opportunity.
Social Planner Problem

$$\max E \sum_{t=0}^{\infty} \beta^t \log(C_t)$$

subject to:

$$C(s^t) + \pi_m k_m(s^t) + (1 - \pi_m) k(s^t)$$

$$= \pi_m q_m(s_t) \left[ \left( k_m(s_t^{-1}) \right)^\theta + (1 - \delta) k_m(s_t^{-1}) \right]$$

$$+ (1 - \pi_m) \sum_{j \in \{l,h\}} \pi_j q_j(s_t) \left[ \left( k_j(s_t^{-1}) \right)^\theta + (1 - \delta) \left( k_j(s_t^{-1}) \right) \right]$$

$$k_l(s^t) = k(s^t) - \left( \frac{\pi_h}{\pi_l} + \iota_n(s^t)\tau \right) n(s^t)$$

$$k_h(s^t) = k(s^t) + (1 - \iota_n(s^t)\tau) n(s^t)$$

$$\iota_n(s^t) = 1 \text{ if } n(s^t) \geq 0 \text{ and } 0 \text{ otherwise}$$
Implementability

Result: The Social Planner’s allocation can not be implemented as a competitive equilibrium.

Intuition: In a bad aggregate state, high risk financial intermediaries need to purchase a large value of bonds to shift their portfolios away from their risky projects. This would require $R^d < 1/\bar{p}$. 
Find optimal bond price that solves:

\[
p^* = \arg \max_p E \left[ \sum_{t=0}^{\infty} \beta^t \log \tilde{C}(s^t) \right]
\]

subject to: \( \tilde{C}(s^t) \) is part of a C.E. given policy \( p^* \)

Perform experiments in the optimal bond price equilibrium.
## Potential equilibria

<table>
<thead>
<tr>
<th>Aggregate state ex ante</th>
<th>Secondary market Real resources move from</th>
<th>Type outcome</th>
<th>$h$ bankrupt in bad state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>$l \rightarrow h$</td>
<td>Constraint</td>
<td>Yes</td>
</tr>
<tr>
<td>Good</td>
<td>$l \rightarrow h$</td>
<td>Constraint</td>
<td>No</td>
</tr>
<tr>
<td>Good</td>
<td>$l \rightarrow h$</td>
<td>Unconstraint</td>
<td>No</td>
</tr>
<tr>
<td>Good or Bad</td>
<td><em>No distribution</em></td>
<td>Constraint</td>
<td>Yes</td>
</tr>
<tr>
<td>Bad</td>
<td>$h \rightarrow l$</td>
<td>Constraint</td>
<td>No</td>
</tr>
<tr>
<td>Bad</td>
<td>$h \rightarrow l$</td>
<td>Unconstraint</td>
<td>No</td>
</tr>
</tbody>
</table>
Calibration
## Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Moment matched</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta = 0.99$</td>
<td>Real interest rate of 4%</td>
</tr>
<tr>
<td>$\theta = 0.29$</td>
<td>Capital income share</td>
</tr>
<tr>
<td>$\tau = 0.008%$</td>
<td>Brokerage fees for issuance of U.S. T-bills</td>
</tr>
<tr>
<td>$\Phi = \begin{bmatrix} 0.9447 &amp; 0.0553 \ 0.2 &amp; 0.8 \end{bmatrix}$</td>
<td>Expansions and contractions of U.S. business sector</td>
</tr>
<tr>
<td>$\pi_h = 0.15$</td>
<td>Sensitivity analysis</td>
</tr>
</tbody>
</table>
Estimated Parameters

Normalization: \( q_h(\bar{s}) = 1 \).

We estimate \( Q = \{ \pi_m, \alpha, \delta, q_m(\bar{s}), q_m(\bar{s}), q_l(\bar{s}), q_l(\bar{s}), q_h(\bar{s}) \} \)

\[
Q^* = \arg\min_Q \sum_{i=1}^{8} \left( \frac{\Omega_i - \tilde{\Omega}_i}{\tilde{\Omega}_i} \right)^2
\]

subject to:

\[
q_h(\bar{s}) < q_m(\bar{s}) < q_l(\bar{s}) \leq q_l(\bar{s}) < q_m(\bar{s}) \leq q_h(\bar{s}) \text{ and } \Omega_i \text{ is implied in a competitive equilibrium given policy } p^*
\]

where \( \tilde{\Omega}_i \) is data moment \( i \) and \( \Omega_i \) is model moment \( i \).
## Estimated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed factor income share</td>
<td>$\alpha = 0.0007$</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$\delta = 0.0264$</td>
</tr>
<tr>
<td>Share of nonfinancial firms</td>
<td>$\pi_m = 0.695$</td>
</tr>
<tr>
<td>Productivity of high-risk intermediaries</td>
<td>$[q_h(\bar{s}), q_h(\bar{s})] = [1, 0.6785]$</td>
</tr>
<tr>
<td>Productivity of low-risk intermediaries</td>
<td>$[q_l(\bar{s}), q_l(\bar{s})] = [0.938, 0.934]$</td>
</tr>
<tr>
<td>Productivity of nonfinancial sector</td>
<td>$[q_m(\bar{s}), q_m(\bar{s})] = [0.962, 0.928]$</td>
</tr>
</tbody>
</table>
# Moments Targeted

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data in %</th>
<th>Model in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean output share of nonfinancial sector</td>
<td>66.9</td>
<td>71.3</td>
</tr>
<tr>
<td>Average capital depreciation rate</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Equity to asset ratio of financial sector</td>
<td>7.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Recovery rate in case of bankruptcy</td>
<td>42.0</td>
<td>28.4</td>
</tr>
<tr>
<td>Households: mean deposits to fin. assets</td>
<td>17.2</td>
<td>26.0</td>
</tr>
<tr>
<td>Maximum decline in output averaged over contractions since 1947</td>
<td>6.48</td>
<td>6.98</td>
</tr>
<tr>
<td>Coef. of variation of output</td>
<td>3.75</td>
<td>3.94</td>
</tr>
<tr>
<td>Coef. of variation of household net worth</td>
<td>8.17</td>
<td>9.11</td>
</tr>
</tbody>
</table>
Model Extension
Fin. intermediaries may issue private bonds after repo trades

- Pay cost $\xi a_j(s^{t-1})$ to have private bonds rated as safe
- With prob. $\pi_F$, there is foreign demand for these bonds.
  - In this case, resources invested into risky projects become

  $$k_j(s^{t-1}) = k(s^{t-1}) + \tilde{p}(s^{t-1})\tilde{b}_j(s^{t-1}) + \tilde{p}_{t-1}a_j(s^{t-1})$$
Results
The **Lifetime Consumption Equivalent** (LTCE) is the percentage decrease in the optimal consumption from the social planner problem needed to generate the same welfare as the competitive equilibrium with a given interest rate policy.

**Risk taking** is the percentage deviation in resources invested in the high-risk projects in a CE relative to the SP.

\[
r(s^{t-1}) = \frac{k_h^{CE}(s^{t-1}) - k_h^{SP}(s^{t-1})}{k_h^{SP}(s^{t-1})}
\]

- Often measure aggregate risk taking \( r \equiv E \left[ r(s^{t-1}) \right] \)
Returns to Bonds and Portfolio Investments

- **Primary market, all intermediaries**
- **After repo trades, low-risk intermediary**
- **After repo trades, high-risk intermediary**

The graph illustrates the relationship between gross bond return and the share of bond investment, distinguishing between primary market investments and those after repo trades with low- and high-risk intermediaries.
Simulation of Benchmark Model

- Aggregate state
- Returns are at annual rates
- Risk taking relative to SP
- Risk-taking relative to SP
- Expected Rz
Simulation of Model Extension
## Welfare and Risk Taking Results Relative to Social Planner

<table>
<thead>
<tr>
<th>Experiment*</th>
<th>LTCE in %</th>
<th>Risk taking in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No repo market</td>
<td>−0.8754</td>
<td>33.1</td>
</tr>
<tr>
<td>Optimal interest rate policy</td>
<td>−0.0431</td>
<td>23.6</td>
</tr>
<tr>
<td>Optimal policy −0.1 pp</td>
<td>−0.0433</td>
<td>21.1</td>
</tr>
<tr>
<td>Optimal policy +0.1 pp</td>
<td>−0.0436</td>
<td>26.2</td>
</tr>
<tr>
<td>Optimal policy &amp; capital regulation</td>
<td>−0.0444</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*Results are from 5000-period simulations.
## Sensitivity to Fraction of High Risk FIs

<table>
<thead>
<tr>
<th>( \pi_h ) value</th>
<th>LTCE in %</th>
<th>Risk taking in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>No Repo Market</td>
<td>−0.78</td>
<td>−0.88</td>
</tr>
<tr>
<td>Optimal int. rate policy</td>
<td>−0.04</td>
<td>−0.04</td>
</tr>
<tr>
<td>Optimal policy −0.1 pp</td>
<td>−0.05</td>
<td>−0.04</td>
</tr>
<tr>
<td>Optimal policy +0.1 pp</td>
<td>−0.44</td>
<td>−0.04</td>
</tr>
</tbody>
</table>
Output in Benchmark Model and Extension

![Graph showing the output comparison between Benchmark and Extension models over a simulation period. The graph displays two curves, one for the Benchmark (CE Benchmark) and another for the Extension (CE Extension), highlighting trends and changes throughout the simulation period.]
Benchmark: No Amplification of Cycles

Optimal policy
Optimal policy - 50bp
With Mispriced Collateral: Amplified Cycles

The diagram illustrates the simulation period with benchmark and extension, showing a decrease in the benchmark performance and an increase in the extension with extension: -50pb.
Benchmark: Leverage (Assets to Equity Ratio)
Benchmark: Equity Premium

Simulation period

0 20 40 60 80 100

0 0.005 0.01 0.015 0.02 0.025 0.03

simulation period
CitiGroup and RBC

Comparison of CitiGroup with RBC

- Balance sheet risks
- Income
- Off-balance sheet risks

Source: RBC and CitiGroup
Balance sheet risks

Total capital ratio = (Tier 1 capital + Tier 2 capital)/Risk weighted assets
Off-balance sheet risks

![Graph showing trends in off-balance sheet risks from 2001 to 2010 for different financial metrics: Citi VIE/Assets, Citi (VIE1+QSPV1)/Assets, Citi (VIE2+QSPV2)/Assets, and RBC SPE/Assets. The graph indicates fluctuations and comparisons over time.]