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

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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

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- Interest rate policy affects risk taking through
  - returns to safe bonds $\rightarrow$ portfolio channel
  - amount of collateral $\rightarrow$ 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

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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 $E\left[V_j(s^t)\right]$

Two stage problem:

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

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

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

Porfolio 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:

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

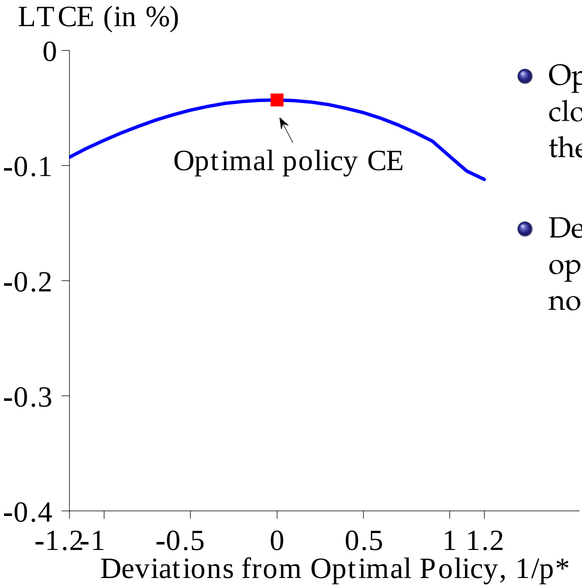
Exp. 3 Private mispriced bonds and foreign demand

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



- Optimal policy CE: close, but below, the social planner
- Deviations from optimal policy: not too costly

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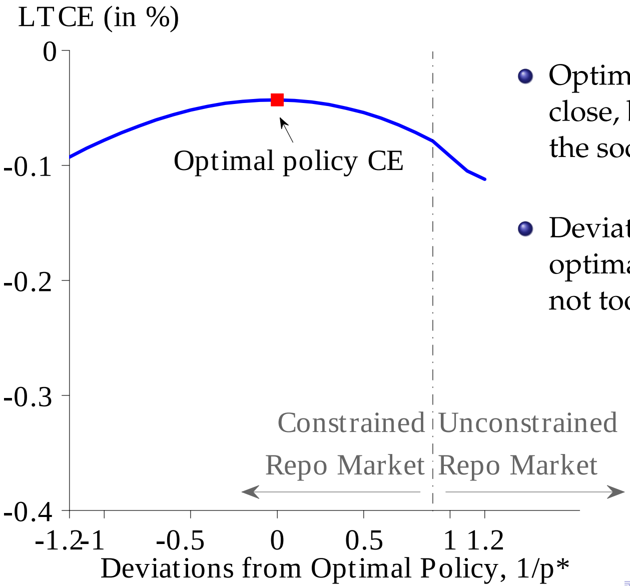

- Optimal policy CE: close, but below, the social planner
- Deviations from optimal policy: not too costly

Risk Taking Measurement

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

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

- We measure aggregate risk taking as $r \equiv E\left[r(s^{t-1})\right]$

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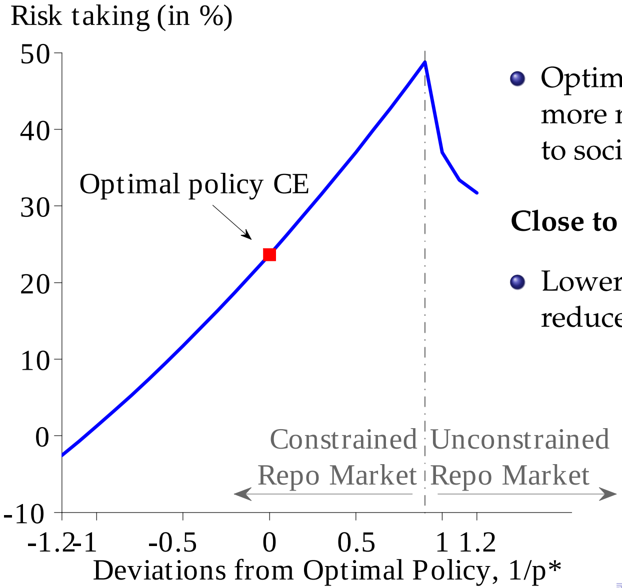


- Optimal Policy CE: more risk relative to social planner

Close to optimum

- Lowering rates: reduces risk taking

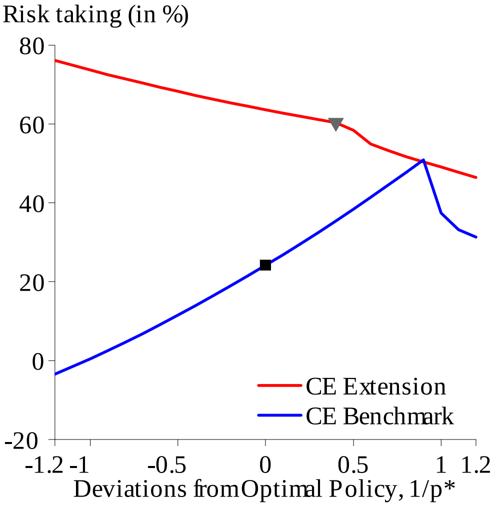
Our Model with Mispriced Collateral

Fin. intermediaries may issue private bonds after repo trades

- With prob. π_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

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!

Appendix

Model Economy

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- **Government**: issues bonds, taxes, offers deposit insurance

Timing of Model Events

- End of period t
  - Household wealth, $w\left(s^t\right)$, 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 reveiled
  - 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

$$\max \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \varphi\left(s^t\right) \log C\left(s^t\right)$$

subject to:

$$\begin{aligned} w(s^t) &= R^m(s^t)M(s^{t-1}) + R^d(s^{t-1})D_h(s^{t-1}) + R^z(s^t)Z(s^{t-1}) \\ &\quad + \pi_m W_m(s^t) + (1-\pi_m)\left[\pi_l W_l(s^t) + \pi_h W_h(s^t)\right] + T(s^t) \end{aligned}$$

$$w(s^t) = C(s^t) + M(s^t) + D_h(s^t) + Z(s^t)$$

Nonfinancial Sector

$$\max \left\{ \begin{array}{c} q_m(s_t)\left(k_m(s^{t-1})\right)^{\theta}\left(l_m(s^{t-1})\right)^{1-\theta} + q_m(s_t)\,(1-\delta)\,k_m(s^{t-1}) \\ -R^m(s^t)k_m(s^{t-1}) - W_m(s^t)l_m(s^{t-1}) \end{array} \right\}$$

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

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

subject to:

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

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

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 reavealed: $q_h(\bar{s}) > q_l(\bar{s}) \geq q_l(\underline{s}) > q_h(\underline{s})$

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

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:

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

Labor market:

$$\begin{aligned} (1-\pi_m) l \left(s^{t-1} \right) &= 1 - \pi_m \\ \pi_m l_m \left(s^{t-1} \right) &= \pi_m \end{aligned}$$

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:

$$\begin{aligned} M(s^{t-1}) &= \pi_m k_m(s^{t-1}) \\ Z(s^{t-1}) &= (1 - \pi_m)\, z(s^{t-1}) \end{aligned}$$

Equilibrium Properties

1. High-risk intermediaries may go bankrupt
   - Limited liability⇒overinvest in risky projects
2. 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
3. Multiple equilibria exist for a given policy $p(s^t)$
   - equilibria with positive or zero bond holdings
   - focus on the former (see point 2)
4. 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

$$\begin{aligned} p(s^{t-1}) &= \tilde{p}(s^{t-1}) \\ R^d(s^{t-1}) &\geq \frac{1}{p(s^{t-1})} \end{aligned}$$

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:

$$\begin{aligned}
& C(s^t) + \pi_m k_m(s^t) + (1-\pi_m)\,k(s^t) \\
= \quad & \pi_m q_m(s_t)\left[\left(k_m(s^{t-1})\right)^{\theta} + (1-\delta)\,k_m(s^{t-1})\right] \\
& + (1-\pi_m) \sum_{j\in\{l,h\}} \pi_j q_j(s_t)\left[\left(k_j(s^{t-1})\right)^{\theta} + (1-\delta)\left(k_j(s^{t-1})\right)\right]
\end{aligned}$$

$$\begin{aligned}
k_l(s^t) &= k(s^t) - \left(\frac{\pi_h}{\pi_l} + \iota_n(s^t)\tau\right) n(s^t) \\
k_h(s^t) &= k(s^t) + (1 - \iota_n(s^t)\tau)\, n(s^t) \\
\iota_n(s^t) &= 1 \text{ if } n(s^t) \geq 0 \text{ and } 0 \text{ otherwise}
\end{aligned}$$

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 $R^d < 1/\tilde{p}$.

Second Best

Find optimal bond price that solves:

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

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

Perform experiments in the optimal bond price equilibrium.

Potential equilibria

Aggregate state ex ante	Secondary market: Real resources move from	Secondary market: Type outcome	h bankrupt in bad state
Good	$l \longrightarrow h$	**Constraint**	**Yes**
Good	$l \longrightarrow h$	**Constraint**	**No**
Good	$l \longrightarrow h$	Unconstraint	No
Good or Bad	*No distribution*	**Constraint**	**Yes**
Bad	$h \longrightarrow l$	**Constraint**	**No**
Bad	$h \longrightarrow l$	Unconstraint	No

Calibration

Calibrated Parameters

Parameter	Moment matched
$\beta = 0.99$	Real interest rate of 4%
$\theta = 0.29$	Capital income share
$\tau = 0.008\%$	Brokerage fees for issuance of U.S. T-bills
$\Phi = \begin{bmatrix} 0.9447 & 0.0553 \\ 0.2 & 0.8 \end{bmatrix}$	Expansions and contractions of U.S. business sector
$\pi_h = 0.15$	Sensitivity analysis

Estimated Parameters

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

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

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

subject to:

$$q_h(\underline{s}) < q_m(\underline{s}) < q_l(\underline{s}) \leq q_l(\bar{s}) < q_m(\bar{s}) \leq q_h(\bar{s}) \text{ and}$$

Ω_i is implied in a competitive equilibrium given policy p^*

where $\tilde{\Omega}_i$ is data moment i and Ω_i is model moment i.

Estimated Parameters

Parameter	Value
Fixed factor income share	$\alpha = 0.0007$
Depreciation	$\delta = 0.0264$
Share of nonfinancial firms	$\pi_m = 0.695$
Productivity of	
high-risk intermediaries	$[q_h(\bar{s}), \quad q_h(\underline{s})] = [1, \quad 0.6785]$
low-risk intermediaries	$[q_l(\bar{s}), \quad q_l(\underline{s})] = [0.938, 0.934]$
nonfinancial sector	$[q_m(\bar{s}), q_m(\underline{s})] = [0.962, 0.928]$

Moments Targeted

Moment	Data in %	Model in %
Mean output share of nonfinancial sector	66.9	71.3
Average capital depreciation rate	2.5	2.5
Equity to asset ratio of financial sector	7.6	5.2
Recovery rate in case of bankruptcy	42.0	28.4
Households: mean deposits to fin. assets	17.2	26.0
Maximum decline in output averaged over contractions since 1947	6.48	6.98
Coef. of variation of output	3.75	3.94
Coef. of variation of household net worth	8.17	9.11

Model Extension

Model with Rating Agencies, Private Bonds and Foreign Demand

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. π_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

Measurement: Welfare and Risk Taking

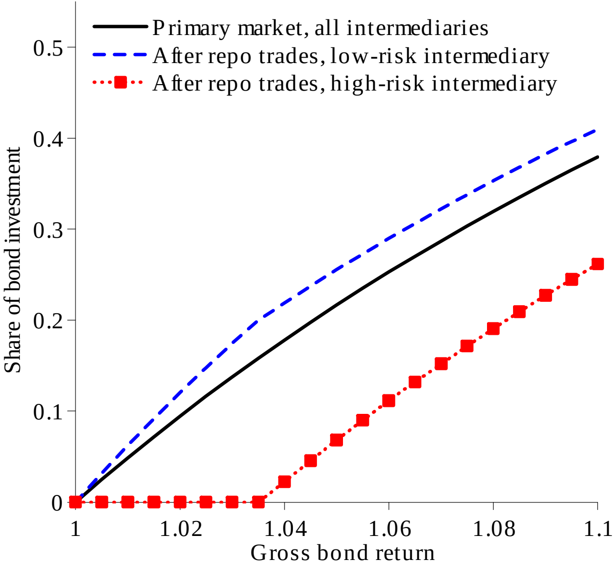
The **Lifetime Consumption Equivalent** (LTCE) is the percentage decrease in the optimal consumption from the social planner problem needed to generate the same welfare as the competitive equilibrium with a given interest rate policy.

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

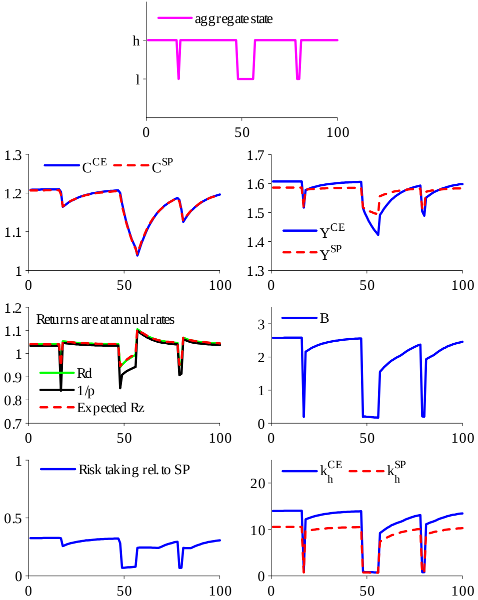
$$r(s^{t-1}) = \frac{k_h^{CE}(s^{t-1}) - k_h^{SP}(s^{t-1})}{k_h^{SP}(s^{t-1})}$$

- Often measure aggregate risk taking $r \equiv E\left[r(s^{t-1})\right]$

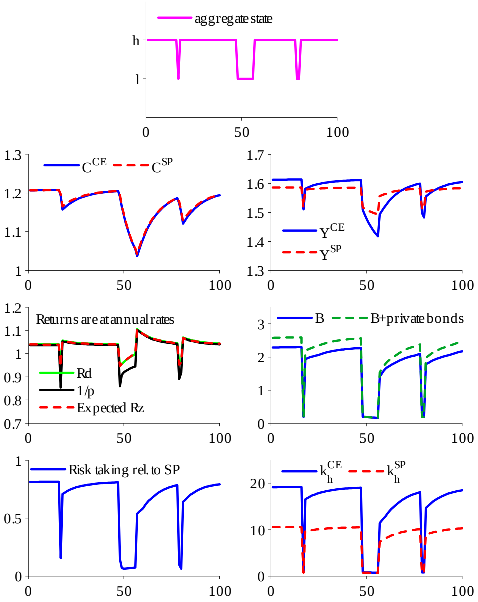
Returns to Bonds and Portfolio Investments



Simulation of Benchmark Model



Simulation of Model Extension



Welfare and Risk Taking Results Relative to Social Planner

Experiment*	LTCE in %	Risk taking in %
No repo market	-0.8754	33.1
Optimal interest rate policy	-0.0431	23.6
Optimal policy -0.1 pp	-0.0433	21.1
Optimal policy $+0.1$ pp	-0.0436	26.2
Optimal policy & capital regulation	-0.0444	0.3

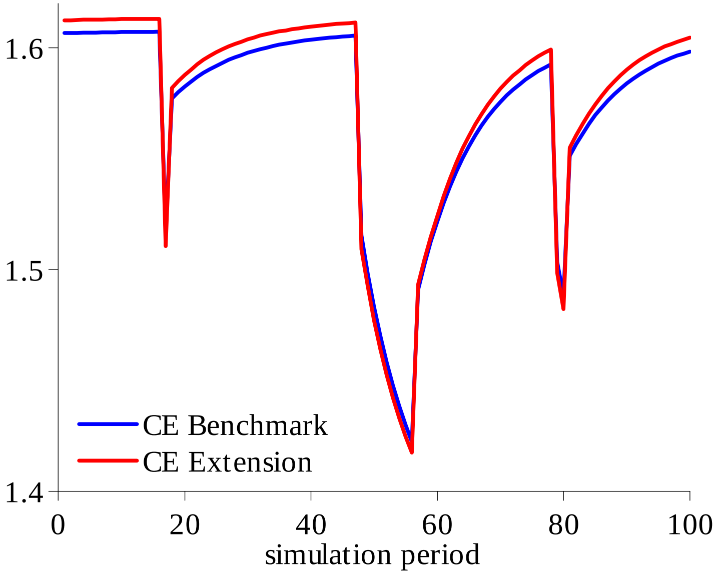
*Results are from 5000-period simulations.

Sensitivity to Fraction of High Risk FIs

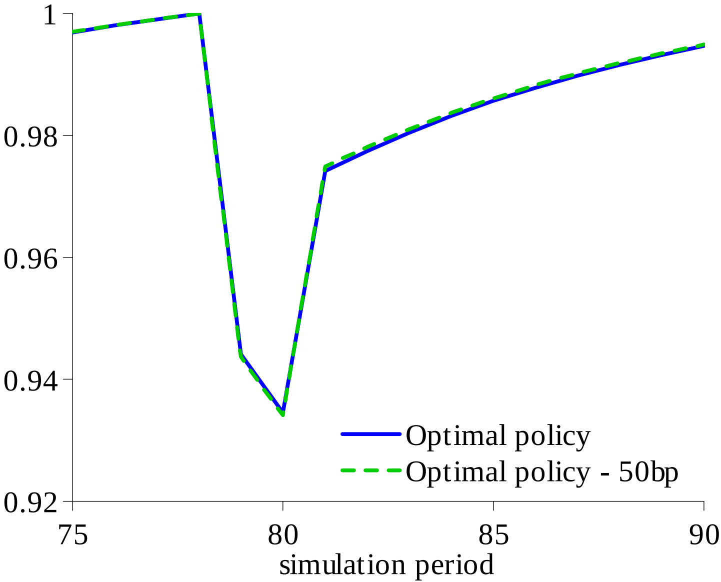
	LTCE in %		
π_h value	0.13	**0.15**	0.17
No Repo Market	-0.78	$-$**0.88**	-0.96
Optimal int. rate policy	-0.04	$-$**0.04**	-0.04
Optimal policy -0.1 pp	-0.05	$-$**0.04**	-0.05
Optimal policy $+0.1$ pp	-0.44	$-$**0.04**	-0.04

	Risk taking in %		
π_h value	0.13	**0.15**	0.17
No Repo Market	-0.78	$-$**0.88**	-0.96
Optimal int. rate policy	-0.04	$-$**0.04**	-0.04
Optimal policy -0.1 pp	-0.05	$-$**0.04**	-0.05
Optimal policy $+0.1$ pp	-0.44	$-$**0.04**	-0.04

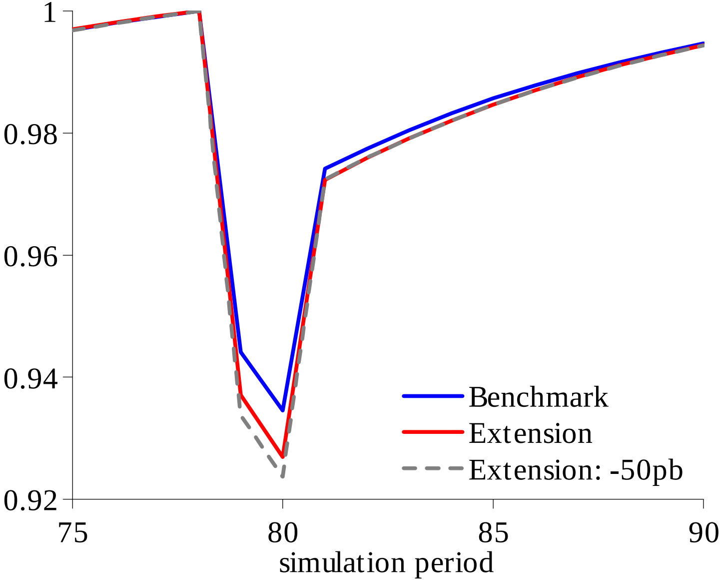
Output in Benchmark Model and Extension



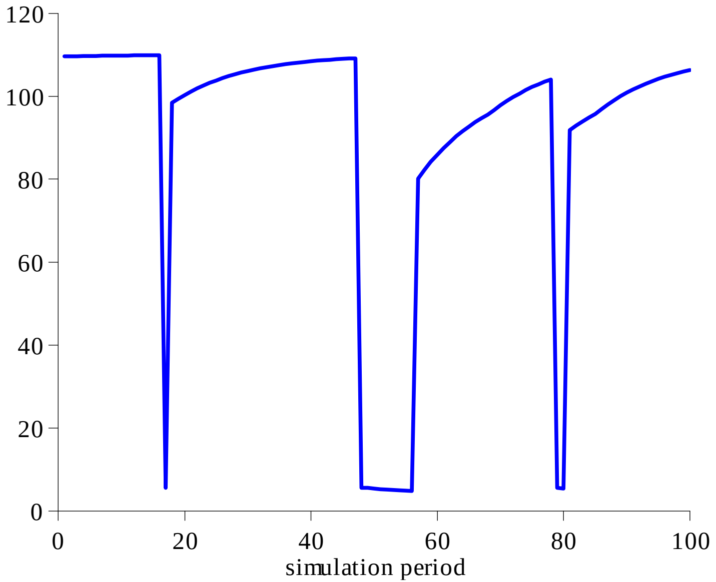
Benchmark: No Amplification of Cycles



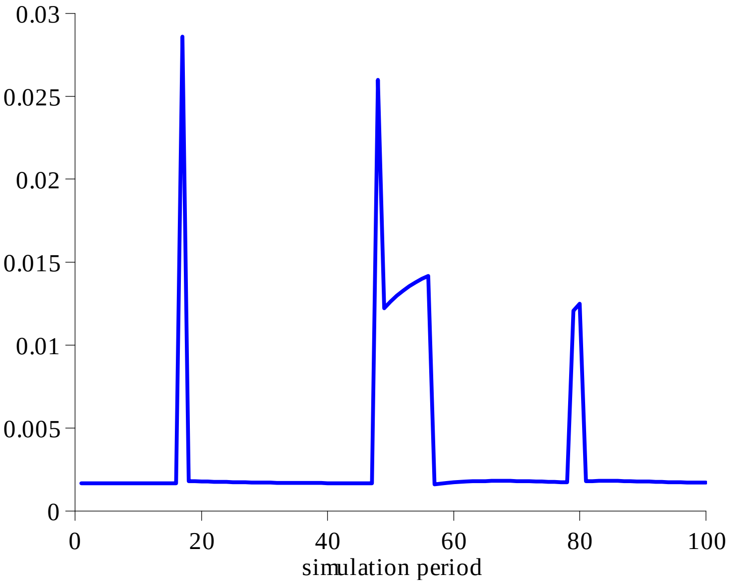
With Mispriced Collateral: Amplified Cycles



Benchmark: Leverage (Assets to Equity Ratio)



Benchmark: Equity Premium



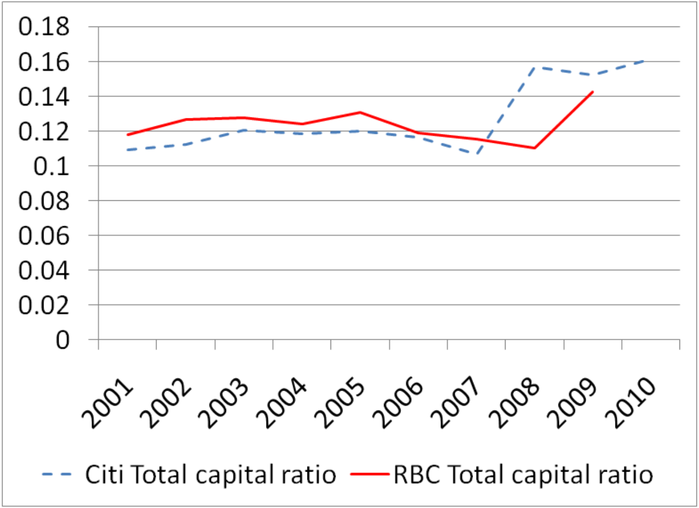
CitiGroup and RBC

Comparison of CitiGroup with RBC

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

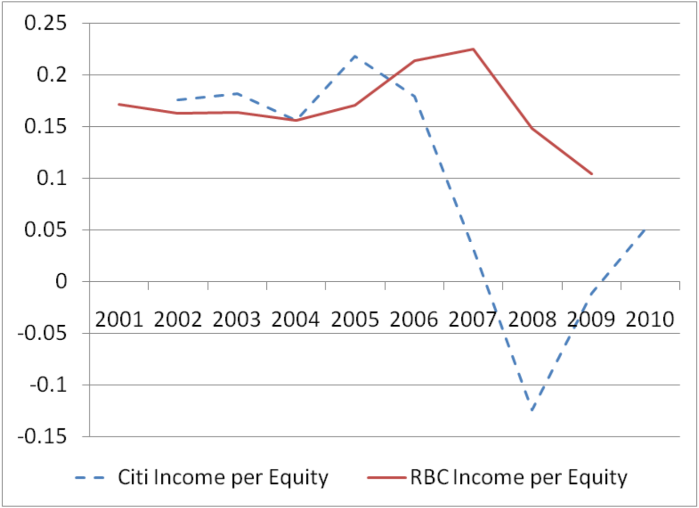
Source: RBC and CitiGroup

Balance sheet risks



Total capital ratio = (Tier 1 capital + Tier 2 capital)/Risk weighted assets

Income


0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Citi Income per Equity
RBC Income per Equity

Off-balance sheet risks