Credit spreads: do macro shocks matter (in theory)?

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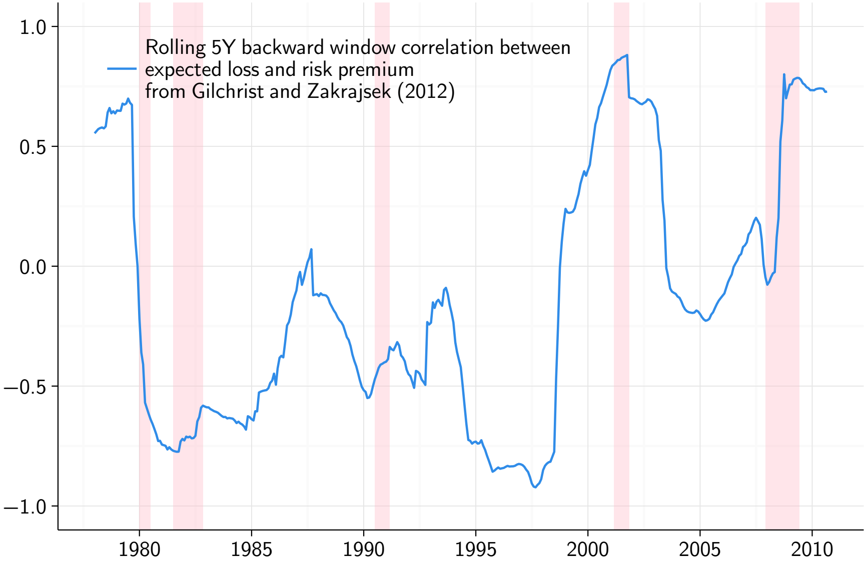
Credit spreads: expected loss and risk premium

Think one-period zero-coupon defaultable debt:

$$\text{Credit spread}_t = \underbrace{\mathbb{E}_t\left[\text{Log-loss}_{t+1}\right]}_{\text{Expected loss at time } t} + \underbrace{\mathbb{E}_t\left[\text{Excess log-return}_{t+1}\right]}_{\text{Risk premium at time } t}$$

- Expected loss can not fully explain fluctuations of credit spreads ('credit spread puzzle': Collin-Dufresne, Goldstein, and Martin, 2001 etc.);
- On the aggregate level risk premium is more volatile than expected loss, has more pronounced macro-forecasting power, and may be related to credit supply constraints (Gilchrist and Zakrajsek, 2012, model-based decomposition);
- Both components are sensitive to monetary policy shocks (Gertler and Karadi, 2015);
- **On the firm level half of credit spreads variation is due to expected loss, and firm investment decisions are more sensitive to expected loss shocks (Nozawa, 2014, model-free decomposition).**

Are two components of credit spread independent?



This paper

- Analyzes fluctuations of credit spreads due to expected loss driven by macro disturbances:

$$\text{Credit spread}_t = \mathbb{E}_t\left[\text{Log-loss}_{t+1}\right] + \mathbb{E}_t\left[\text{Excess log-return}_{t+1}\right]$$

- Demonstrates how spreads respond to macro shocks in a calibrated New Keynesian DSGE model with financial accelerator (Bernanke, Gertler, and Gilchrist, 1999 model).

  Spreads, probabilities of default and (market) leverage are all countercyclical and quite responsive to technological and monetary policy shocks.

- **Extends the Bernanke, Gertler, and Gilchrist, 1999 model** to show how responses change when borrower faces occasionally binding credit supply constraint.

  Borrowing constraint works as an amplifier of macro shocks, and its additional impact may be huge if constraint is 'severe'.

Macro aspects in credit spreads literature

- **General equilibrium:**
  explaining interaction between credit risk and macro shocks with full-fledged firm strategic decisions but relatively unconventional macro structure – no rule-based monetary policy (ex. Miao and Wang, 2010; Gomes and Schmid, 2012), no nominal rigidities (ex. Bhamra, Fisher, and Kuehn, 2011).
- **Partial equilibrium:**
  - **Matching moments:** by means of proper modelling of risk premium and/or proper calibration (ex. Chen, Collin-Dufresne, and Goldstein, 2009; Huang and Huang, 2012; Feldhutter and Schaefer, 2015);
  - **Explaining firm decisions:** dynamic capital structure choice amid macro disturbances (ex. Hackbarth, Miao, and Morellec, 2006).

These models lack feedback loops between firm-specific and macro quantities.

Outline

- Key model ingredients and solution approach
- Deterministic steady-state and model calibration
- Dynamic equilibrium and key results

Entrepreneur and lender: setup

The entrepreneur has available funds N_t and borrows B_t to buy at a price Q_t capital K_t to be used in period $t+1$: $B_t + N_t = Q_t K_t$. Capital earns rents at $t+1$ and is sold afterwards. Realized gross return on capital is $\omega_{t+1} R^k_{t+1}$ where ω_{t+1} is idiosyncratic log-normally distributed shock with unit mean.

The debt contract between entrepreneur and lender is a **state-contingent debt contract**. Entrepreneur proposes and lender accepts a state-contingent cut-off rate $\bar{\omega}_{t+1}$ such that:

$$\text{Lender's payoff} = \begin{cases} \bar{\omega}_{t+1} R^k_{t+1} Q_t K_t & \text{if } \omega_{t+1} > \bar{\omega}_{t+1} \\ (1-\mu)\omega_{t+1} R^k_{t+1} Q_t K_t & \text{otheriwse} \end{cases}$$

The entrepreneur gets $(\omega_{t+1} - \bar{\omega}_{t+1}) R^k_{t+1} Q_t K_t$ in 'no default' and zero otherwise.

The entrepreneur's objective is to maximize next period expected payoff by choosing cut-off $\bar{\omega}_{t+1}$ and leverage $\lambda_t = {}^{Q_t K_t}/_{N_t}$ such that:

- the risk-averse lender accepts the debt contract;
- exogenous debt limit $\bar{\lambda}_t N_t$ is not breached.

Model timeline here

Entrepreneur and lender: optimality

Call $g(\bar{\omega}_{t+1})$ and $h(\bar{\omega}_{t+1})$ shares of realized return going respectively to the entrepreneur and the lender. Formulas here Call $R_{t+1} \equiv \left(\lambda_t/\lambda_t - 1\right) R^k_{t+1} h(\bar{\omega}_{t+1})$ lender's return **over all loans given to a unit mass of identical entrepreneurs** (identity is due to the LLN = no 'idiosyncratic risk' in lender's total returns). What about aggregate (macro) risk?

We **follow the BGG model and assume** that the lender requires:

$$\mathbb{E}_t \left[M_{t+1}\right] R_{t+1} = 1$$

where M is the household SDF. R_{t+1} is pre-determined, $R^k_{t+1} h(\bar{\omega}_{t+1})$ is $\mathcal{F}_t$-measurable.[1]

Entrepreneur's Lagrangian:

$$\mathcal{L} = \mathbb{E}_t \Big\{ \lambda_t N_t R^k_{t+1} g\left(\bar{\omega}_{t+1}\right) + \phi_{1,t+1} \left(1 - \mathbb{E}_t\left[M_{t,t+1}\right] \frac{\lambda_t}{\lambda_t - 1} R^k_{t+1} h(\bar{\omega}_{t+1})\right) + $$
$$+ \phi_{2,t}\left(\bar{\lambda}_t N_t - \lambda_t N_t\right) \Big\}$$

Kuhn-Tucker conditions:

$$\underbrace{\left(\mathbb{E}_t\left[R^k_{t+1} g(\bar{\omega}_{t+1})\right] + \mathbb{E}_t\left[\frac{g_\omega(\bar{\omega}_{t+1})}{h_\omega(\bar{\omega}_{t+1})}\right] \frac{1}{\lambda_t \mathbb{E}_t\left[M_{t,t+1}\right]}\right)}_{\geqslant 0} \underbrace{\left(\bar{\lambda}_t - \lambda_t\right)}_{\geqslant 0} = 0$$

[1] Model was also solved for $\mathbb{E}_t\left[M_{t+1} R_{t+1}\right] = 1$, but due to log-linearization risk premium is zero anyway

Entrepreneur's credit risk profile

We define the following credit-related quantities which are key for the subsequent analysis:

- Credit spread:

$$S_t = \frac{\lambda_{t-1}}{\lambda_{t-1} - 1} R_t^k \bar{\omega}_t - R_t$$

- Probability of default:

$$PD_t = F(\bar{\omega}_t)$$

  where $F(\cdot)$ is log-normal cdf with parameters $-\frac{\sigma_\omega^2}{2}$ and σ_ω;

- Recovery rate in default:

$$RR_t = (1 - \mu) \, R_t^k \frac{\lambda_{t-1}}{\lambda_{t-1} - 1} \frac{\int_0^{\bar{\omega}_t} \omega_t dF(\omega_t)}{F(\bar{\omega}_t)}$$

Entrepreneurs stay in business with exogenous probability γ. If they do, they supply labor, hence their net worth is given by $N_t = \gamma N_{t-1} \lambda_{t-1} R_t^k g(\bar{\omega}_t) + W_t^e$. If they do not, they consume $C_t^e = N_{t-1} \lambda_{t-1} R_t^k g(\bar{\omega}_t)$.

Model timeline here

The model in general equilibrium

The rest of the model endogenizes R^k_{t+1}, Q_t, M_{t+1}. The agents are:

- **Households:** maximize CRRA utility of consumption and hours worked given the budget constraint. Revenues are wages earned, and payoffs from nominal one-period bonds and real one-period deposits. Outlays are conspumption, new bonds purchased and deposits placed;
- **Wholesalers:** perfect competitors who rent capital and labor to produce wholesale output with Cobb-Douglas production technology (s.t. tech shock);
- **Retail firms:** monopolistic competitors who differentiate wholesale goods into final goods according to a standard Calvo pricing scheme;
- **Capital producers:** competitively 'produce' capital goods (subject to capital adjustment costs), sell them at price Q_t to entrepreneurs and buy back at Q_{t+1};
- **Fiscal authoritites:** collect taxes and spend the proceeds on final goods (s.t. fiscal shock);
- **Monetary authoritites:** set the nominal interest rate R^n_t (s.t. monetary shock);

Zero inflation unit price of capital deterministic steady-state

Key equation for the optimal steady-state cut-off $\bar{\omega}$ (admits only numerical solution):

$$\frac{g_\omega}{\beta\left(hg_\omega - gh_\omega\right)}\left(1 + \frac{\alpha}{(1-\alpha)(1-\Omega)}g\left(\beta\frac{h_\omega}{g_\omega} + \gamma\right)\right) = 1 - \delta.$$

Optimal steady-state cut-off $\bar{\omega}$ depends on seven model parameters: μ, σ_ω, γ, Ω, α, δ, β.

The first four are calibrated such that in the steady state:

- annualized steady-state **probability of default is 0.3%** (Moody's Baa-rated average for 1920-2014);
- steady-state **recovery rate is 55%** (all Moody's-rated bonds average for 1987-2014).

For the last three we use standard values from the macro literature : $\alpha = 0.33$, $\delta = 0.025$, $\beta = 0.99$ (quarterly model).

Steady-state calibration

	Calibrated parameters				Implied steady-state quantities			
	μ	σ_ω	γ	Ω	S (b.p.)	PD (%)	RR (%)	λ
This model	0.4020	0.3617	0.9860	0.9881	13.8	0.3	55.0	1.40
Original BGG	0.1200	0.5292	0.9728	0.9900	337.2	11.6	77.4	1.48

Table: Calibrated parameters and implied steady-state values of credit spread (S), probability of default (PD), recovery rate (RR), and leverage (λ) in our model and in the original paper. The model is calibrated at the quarterly frequency, reported steady-state levels of S and PD are annualized numbers. Leverage λ is the ratio of total entrepreneur's assets to net worth (equals to 1 if no debt is taken), i.e. should be viewed as a model proxy for market leverage.

Comparison with the Merton model

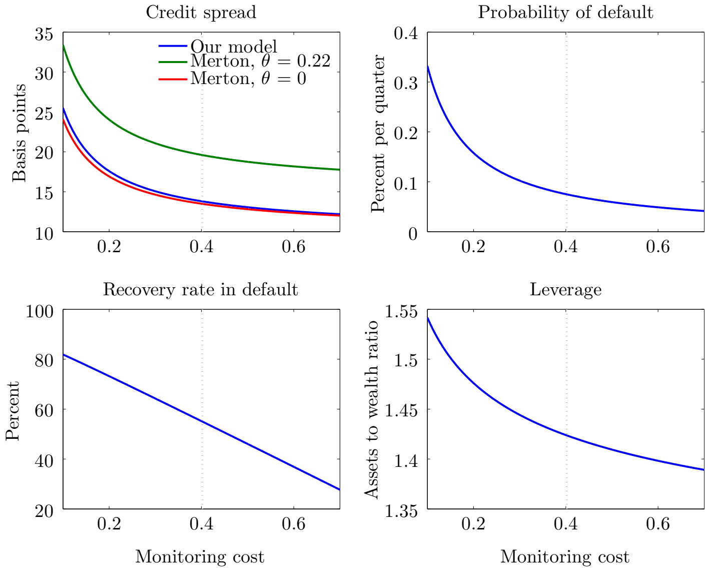
Credit spread in the Merton, 1974 model is:

$$S^{\text{Merton}} = -\frac{1}{T} \log \left(1 - L \cdot \Phi \left(\Phi^{-1} \left(\pi^{\mathbb{P}}\right) + \theta^{\text{Merton}} \sqrt{T}\right)\right).$$

Comparison of our model's spreads with Merton-implied spreads is done as follows:

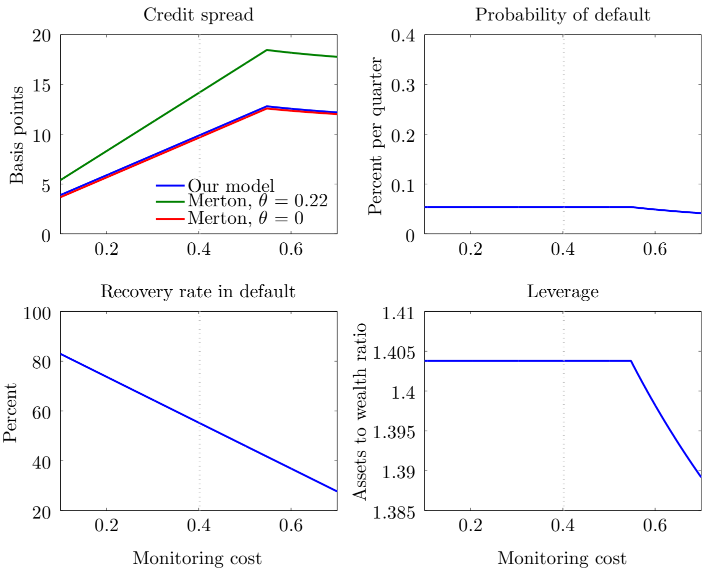
- for a given set of our model's parameters equilibrium probability of default (counterpart of $\pi^{\mathbb{P}}$) and recovery rate (counterpart of $1 - L$) are computed;
- T is set at 0.25;
- two values of the market price of risk $\theta^{\text{Merton}} \in \{0; 0.22\}$ are considered. The former case $\theta = 0$ corresponds to the 'no risk premium contribution to credit spread' situation, $\theta = 0.22$ is a value observed in the data.

Comparative statics: changes in μ (unconstrained case)



Changes in σ_ω here

Comparative statics: changes in μ (constrained case, $\lambda = 1.404$)



Dynamic rational expectations equilibrium

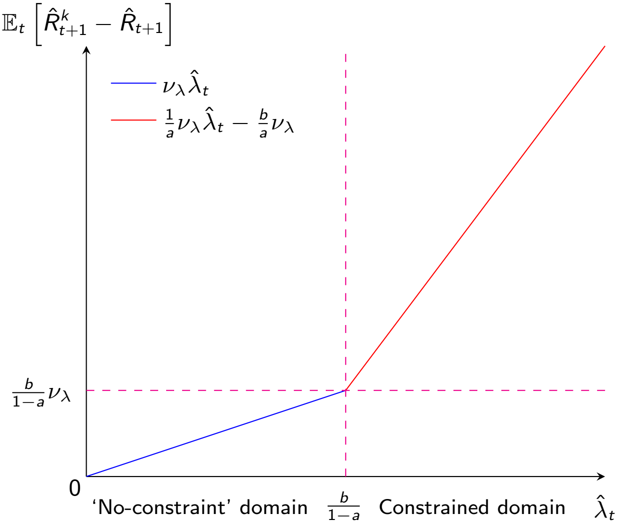
- The model is linearized around the non-stochastic steady state and put into `Dynare` to seek for dynamic rational expectations equilibrium. We assume that the reference regime of the model is the one where leverage constraint doesn't bind.
- Yet, we allow for occasionally binding leverage constraint in deviation from the steady-state (`OccBin` toolbox for `Dynare` by Guerrieri and Iacoviello, 2015).
- Key equation of the linearized model when leverage constraint doesn't bind:

$$\mathbb{E}_t\left[\hat{R}^k_{t+1}\right] - \hat{R}_{t+1} = \nu_\lambda \hat{\lambda}_t.$$

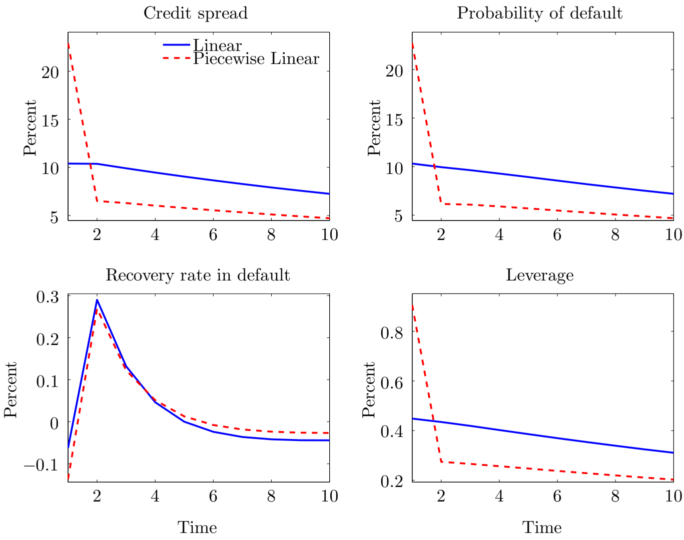
- Our **assumption** about the dynamics of the leverage constraint $\hat{\hat{\lambda}}_t$:

$$\hat{\hat{\lambda}}_t = b + a\frac{1}{\nu_\lambda}\mathbb{E}_t\left[\hat{R}^k_{t+1} - \hat{R}_{t+1}\right].$$

Two leverage regimes: an illustratitive example



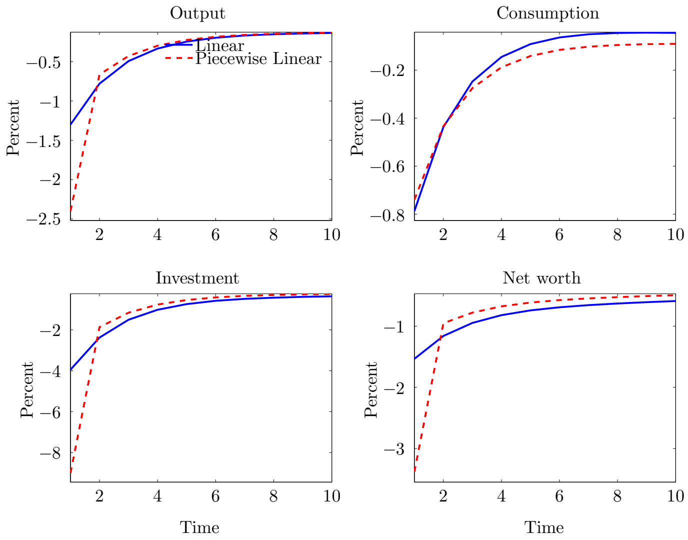
Impulse response to 50 b.p. policy rate jump (credit aspect)



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters *a* and *b* are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 70 times steeper in this domain.

Negative tech shock here Rate shock in MCC contract here

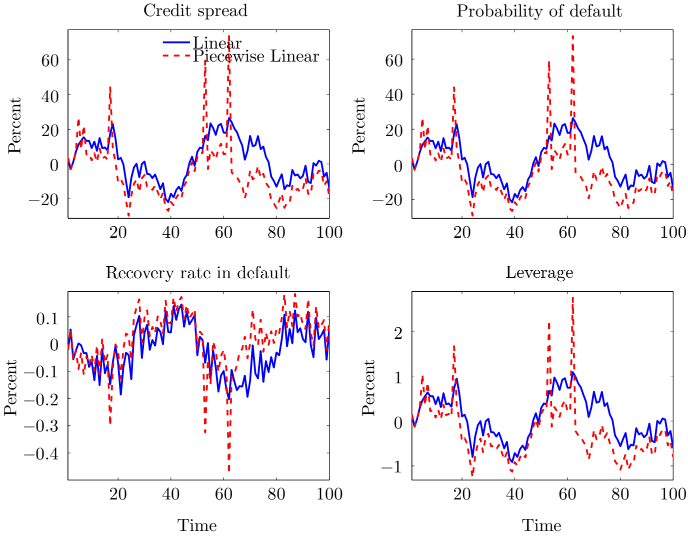
Impulse response to 50 b.p. policy rate jump (macro aspect)



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters *a* and *b* are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 70 times steeper in this domain.

Rate shock in MCC contract here

Simulated paths for policy rate shock with 50 b.p. volatility



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters *a* and *b* are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 70 times steeper in this domain.

Empirical example

Simulated moments

	No leverage constraints				Leverage constraint			
x:	S	PD	RR	λ	S	PD	RR	λ
Panel A: technological shock								
$\sigma_{\hat{x}_t}$, % of steady-state value	26.13	25.89	0.18	1.09	36.34	36.01	0.23	1.42
$\rho_{\hat{x}_t,\hat{x}_{t-1}}$	0.89	0.89	0.63	0.90	0.39	0.39	0.42	0.43
$\rho_{\hat{x}_t,\hat{Y}_t}$	-0.44	-0.44	0.40	-0.42	-0.41	-0.41	0.43	-0.39
Panel B: monetary policy shock								
$\sigma_{\hat{x}_t}$, % of steady-state value	27.25	26.82	0.36	1.16	37.91	37.45	0.36	1.50
$\rho_{\hat{x}_t,\hat{x}_{t-1}}$	0.91	0.90	0.37	0.91	0.39	0.39	0.17	0.43
$\rho_{\hat{x}_t,\hat{Y}_t}$	-0.74	-0.74	-0.30	-0.74	-0.91	-0.91	0.14	-0.91

Panel A corresponds to the economy that is hit every period with a normally distributed technological shock with a standard deviation of 2%. Panel B corresponds to the economy that is hit every period with a normally distributed monetary policy shock with a standard deviation of 50 b.p. (annualized). Each economy was simulated 100 times, numbers presented are averages over these 100 repetitions. Each simulation contains 100 periods (25 years). Parameters a and b are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 70 times steeper in this domain.

Summary of results and testable implications

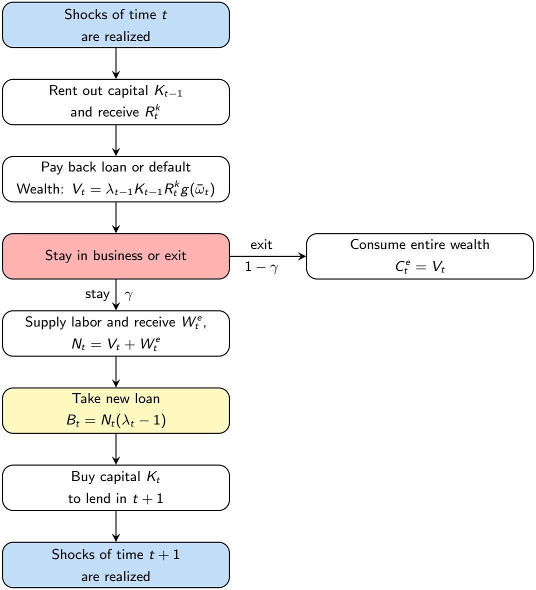
- Macroeconomic shocks have a substantial impact on credit risk in the baseline calibrated financial accelerator model.

  To test it properly on the data one needs to identify macro shocks first (changes in headline macro variables are bad measures of such shocks).

- Leverage constraints play an important role in the 'pass through' from macro shocks to credit risk in the extended model:
  - occasionally binding leverage constraint may increase the magnitude of spread jumps several times when underlying contractionary macro shocks are severe;
  - leverage constraints, when binding, change business cycle properties of credit-related variables.

  One needs to control for the interaction between macro shocks and leverage constraints in the empirical analysis of credit spreads.

Appendix: timeline for entrepreneur



Back to setup
Back to credit profile

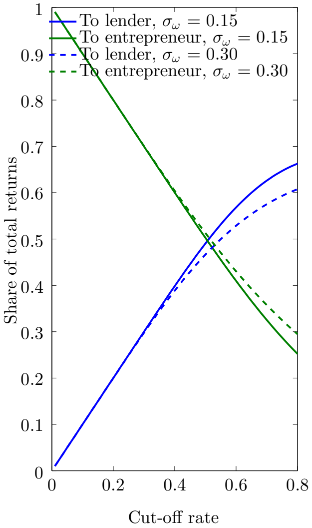
Appendix: returns sharing between lender and entrepreneur - theoretical

$$g(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} (\omega - \bar{\omega})\, dF(\omega),$$

$$h(\bar{\omega}) = \bar{\omega}\,(1 - F(\bar{\omega})) + (1 - \mu) \int_{0}^{\bar{\omega}} \omega dF(\omega).$$

Back to main Numerical example

Appendix: returns sharing between lender and entrepreneur - numerical



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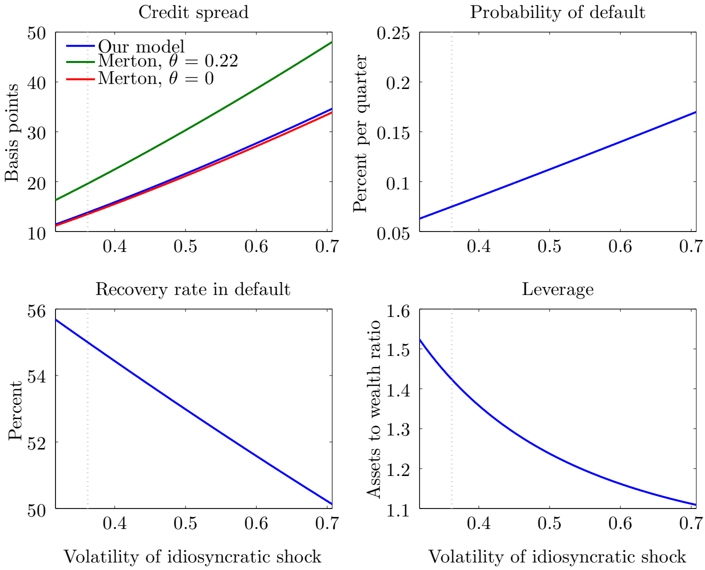
Appendix: comparative statics, changes in σ_ω



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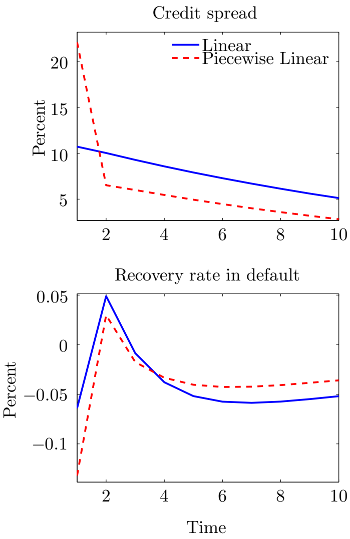
Appendix: impulse response to negative 2% tech shock



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters a and b are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 70 times steeper in this domain.

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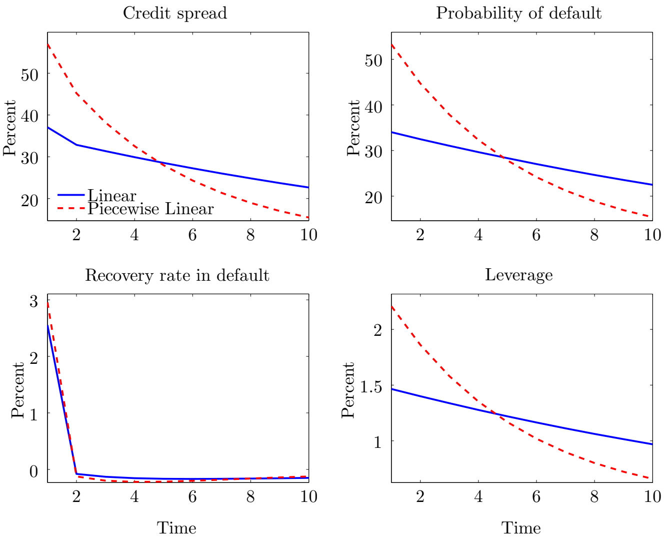
Appendix: impulse response to 10 b.p. rate jump (MCC contract)



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters a and b are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 7 times steeper in this domain.

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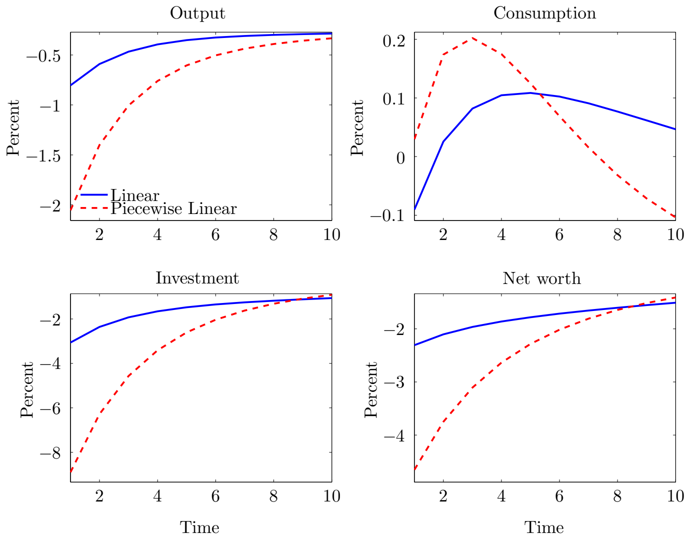
Appendix: impulse response to 10 b.p. rate jump (MCC contract, econ)



Quantities on vertical axes are percentage deviations from the corresponding deterministic steady states. Time is quarters. Parameters *a* and *b* are such that the leverage constraint binds if leverage jumps more than 0.4%. The leverage – external premium line becomes 7 times steeper in this domain.

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Expected loss contribution to credit spread in the data