Moral Hazard and Debt Maturity

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Motivation

It is difficult to establish any archetype for failure. Banks with high capital ratios imploded while those with lower ratios survived. Plain-vanilla retail banks blew up while some black-box trading shops prospered. Both small and big firms collapsed.

Yet there was a common ingredient in most failures: an over-reliance on (short-term) wholesale borrowing.

The Economist, September 5, 2009

Motivation

→ J. Tirole (AER 2003): *Inefficient Foreign Borrowing*

Should "dangerous forms of finance" be discouraged?

Borrowers design their financial structures to their own benefit, and one cannot presuppose that dangerous forms of debt constitute suboptimal liability structures.

Introduction

Issue

- Use of short-term wholesale financing $\rightarrow$ liquidity risk
- What is the upside?

This paper

- Costs and benefits of short-term debt
- Trade-off: Disciplining device vs. inefficient liquidation

Borrowing firm has attributes of bank

- Funds itself mostly by borrowing

  → Model of debt finance (no equity capital)

- Can easily modify risk profile of its assets

  → Model with moral hazard (risk-shifting) problem

- Invests in assets that cannot be redeployed to other sectors

  → Liquidation value related to expected continuation value

Preview of model

- Single bank + large number of wholesale investors
- Bank’s assets: Long-term risky investment
- Bank’s liabilities: Short-term (ST) or long-term (LT) debt
- Moral hazard problem in choice of risk
- Public signal on investment return at rollover date of ST debt

Preview of results

- ST debt may be the only way to secure funding

  → Because of positive incentive effects

- ST debt may dominate LT debt (when the latter is feasible)

  → Even if it involves inefficient liquidation

- Incentive effects of ST debt only obtain when it is risky

  → Positive probability of early liquidation

- ST debt may involve paying upfront dividend to shareholders

  → To ensure positive probability of early liquidation

Intuition for results

- Refer to moral hazard model of Stiglitz and Weiss (1981)

  "Higher loan rates induce firms to undertake projects with lower probabilities of success but higher payoffs when successful."

- Apply this argument to banks instead of firms

  "Higher borrowing costs induce banks to undertake investments with lower probabilities of success but higher payoffs when successful."

Intuition for results

- Difference in risk-shifting incentives between LT and ST debt

  → The relevant cost of bank's borrowing

- Cost of borrowing with LT debt

  → Reflects average probability of success

- Cost of borrowing with ST debt

  → Reflects average prob. of success conditional on rollover

  → Otherwise bank is liquidated and shareholders get nothing

Intuition for results

• Conditional probability greater than unconditional probability

→ Cost of borrowing will be higher with LT debt

→.Incentive to choose riskier investments

• Two caveats

→ Signal observed at $t = 1$ may be noisy (quality q)

→ Liquidating investment may be costly (recovery rate λ)

• ST debt will be better than LT debt when q and λ are high

Intuition for results

- Incentive effects of ST debt only obtain when it is risky

  → If ST debt is always rolled over

  → Conditional and unconditional probabilities will be equal

  → LT debt will be equivalent to (safe) ST debt

- ST debt may involve paying an upfront dividend to shareholders

  → Raise hurdle for continuation

  → Ensure positive probability of early liquidation

  → Positive incentive effects

Overview

- Model setup
- Long-term debt
- Short-term debt
- Numerical results
- Extensions

Part 1

Model setup

Model setup

- Three dates ($t = 0, 1, 2$)
- Large number of risk-neutral wholesale investors (the lenders)

  → Required return normalized to 0
- Single risk-neutral bank

  → Indivisible unit investment with random return at $t = 2$

  → Funded with debt (no capital)

  → LT debt (maturing at $t = 2$) or ST debt (rolled over at $t = 1$)

Model setup

→ F. Allen and D. Gale (2000): *Comparing Financial Systems*

• Return of investment at $t = 2$

$$R = \begin{cases} R_1 & \text{with probability } p \\ R_0 & \text{with probability } 1-p \end{cases}$$

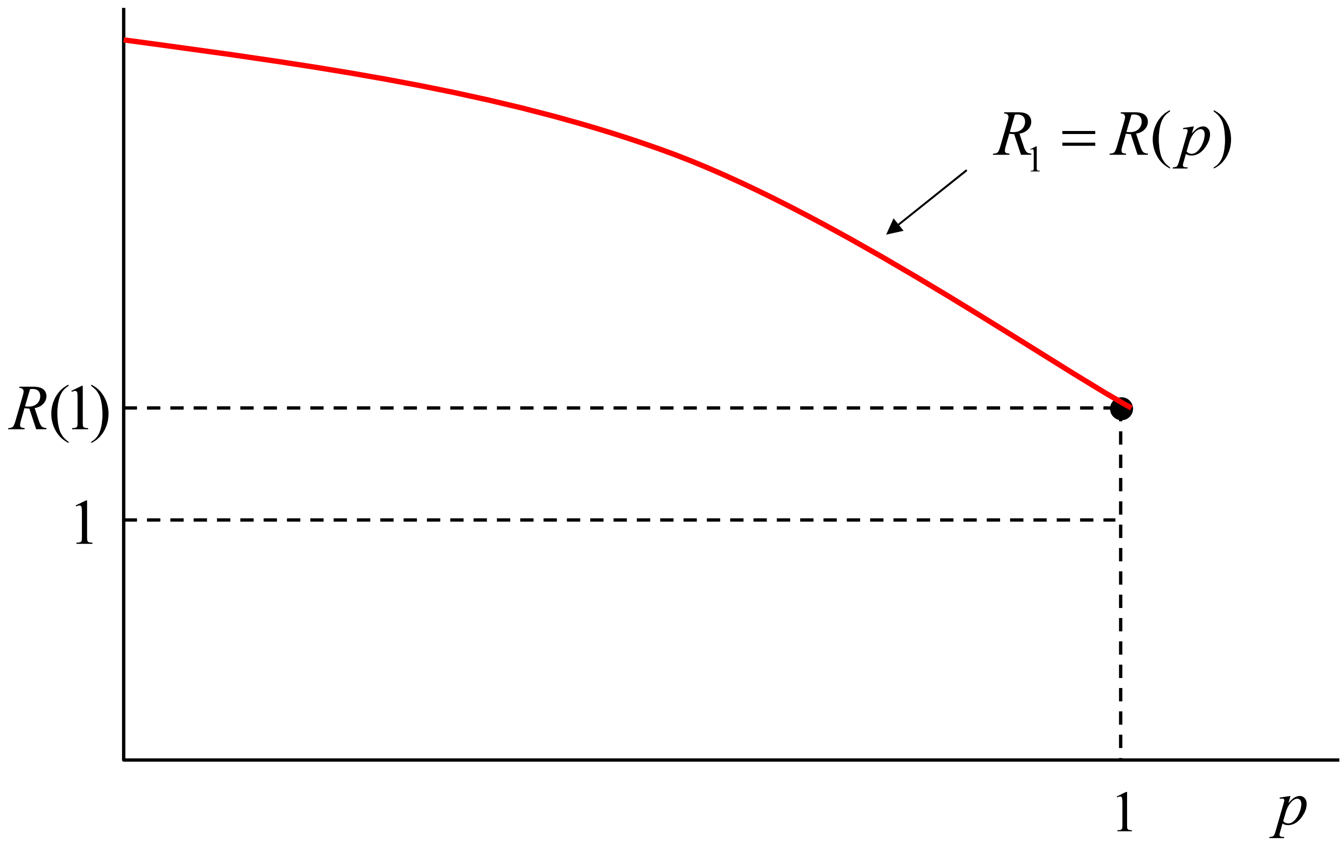
→ $p \in [0,1]$ is a risk parameter chosen by the bank at $t = 0$

→ Assume that $R_0 = 0$ and $R_1 = R(p)$

→ Assume that $R(p)$ is decreasing and concave, with $R(1) \geq 1$

• Liquidation value of investment at $t = 1$: L

Model setup



Model setup

- First-best level of risk

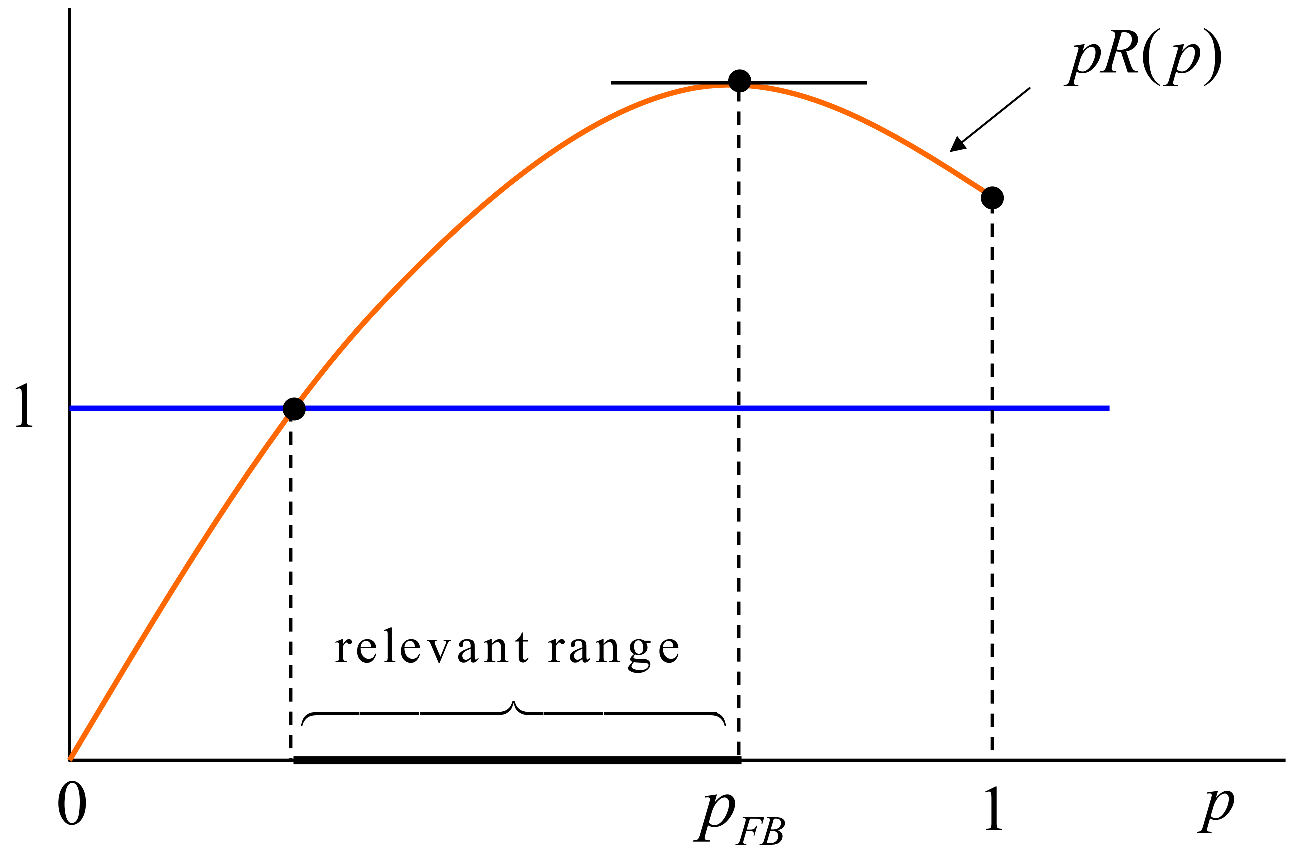
$$\max_p \left(pR(p) \right)$$

$\rightarrow$ First-order condition: $\left(pR(p) \right)' = 0$

$\rightarrow$ Since $pR(p)$ is concave a solution p_{FB} exists

$\rightarrow$ $p_{FB} R(p_{FB}) > 1$

Model setup



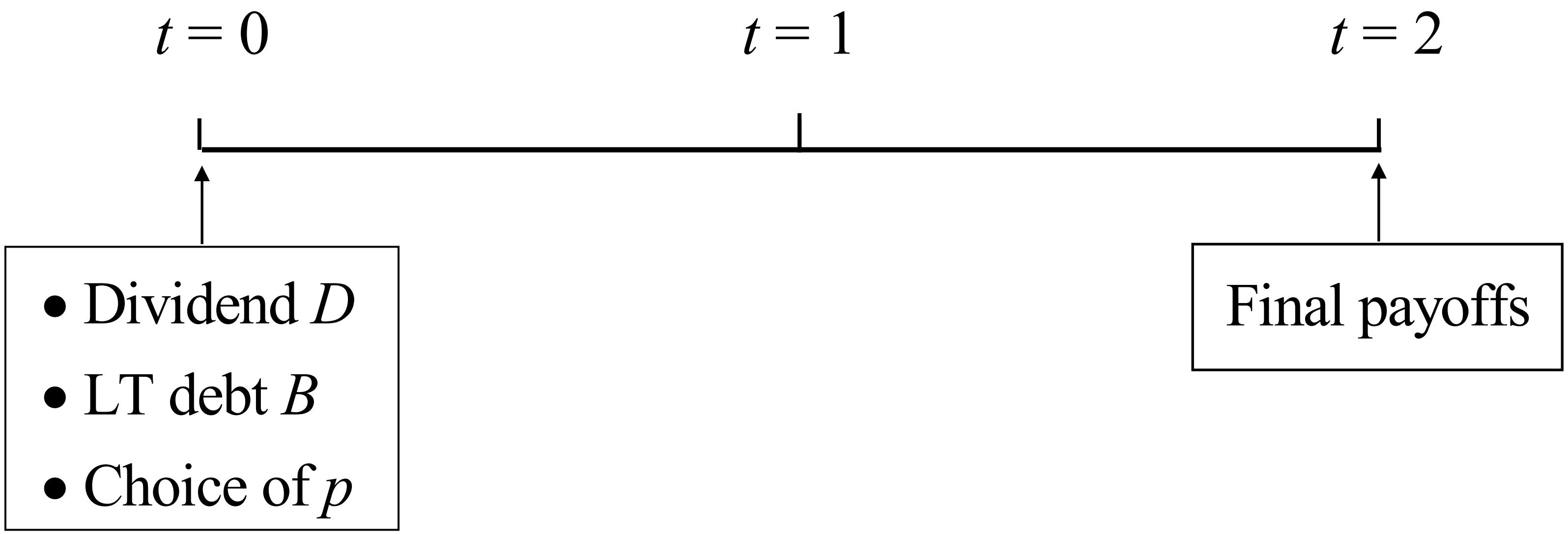
Part 2

Long-term debt

Long-term debt

- Suppose that the bank is funded at $t = 0$ with long-term debt

  → B is face value of debt payable at $t = 2$



Long-term debt

- Bank's choice of risk

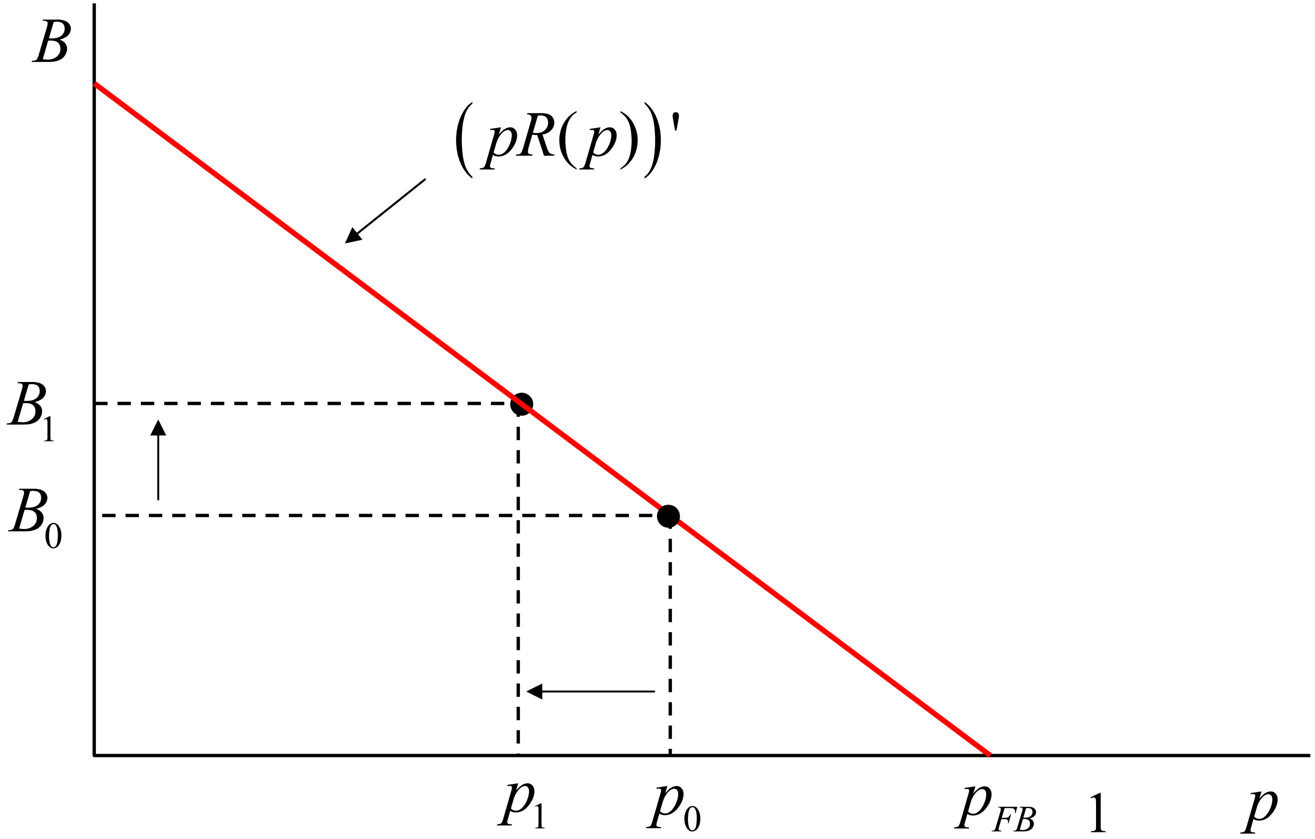
$$\max_p \ p\left(R(p) - B\right)$$

$\rightarrow$ First-order condition: $\left(pR(p)\right)' = B \ \rightarrow \ \dfrac{dp}{dB} < 0$

$\rightarrow$ For any $B > 0$ the bank chooses $p(B) < p_{FB}$

$\rightarrow$ Standard risk-shifting effect

Long-term debt



Long-term debt

Definition 1 A *contract* with LT debt specifies

(1) Initial dividend D paid to the bank at $t = 0$

(2) Face value B payable to lenders at $t = 2$

Such contract determines probability of success p chosen by bank

Long-term debt

Definition 2 An *optimal contract* with LT debt (D_{LT}, B_{LT}, p_{LT}) is a solution to problem:

$$\max_{(D,B,p)}[D + p(R(p) - B)]$$

subject to IC constraint:

$$p_{LT} = \arg\max_{p}[p(R(p) - B)]$$

and PC constraint:

$$pB \geq 1 + D$$

Long-term debt

Result 1 IC constraint: $\left(pR(p)\right)' = B$

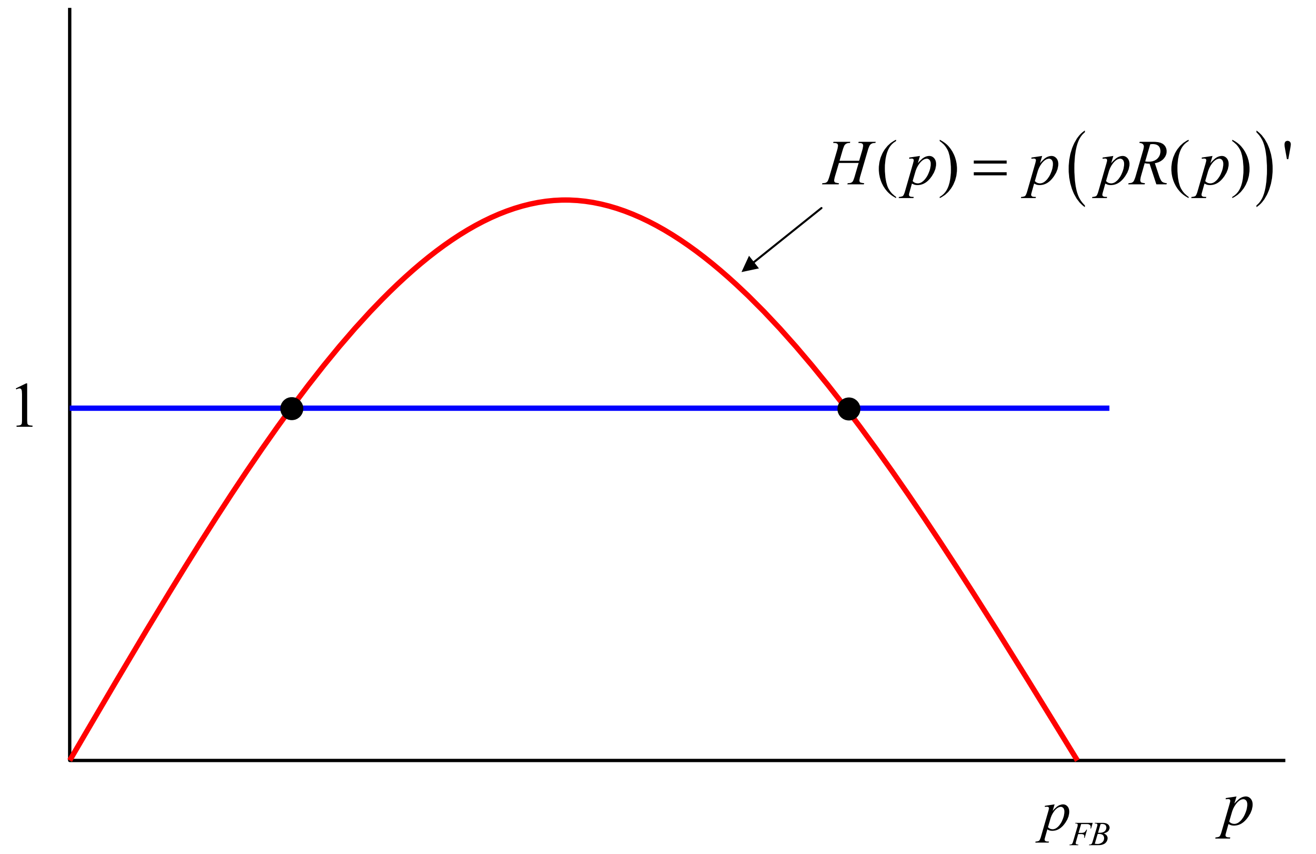
Result 2 PC constraint satisfied with equality: $pB = 1 + D$

Result 3 Initial dividend $D = 0$

Result 4 Substituting PC into IC:

$$\left(pR(p)\right)' = B = 1/p \quad \rightarrow \quad H(p) = p\left(pR(p)\right)' = 1$$

Long-term debt



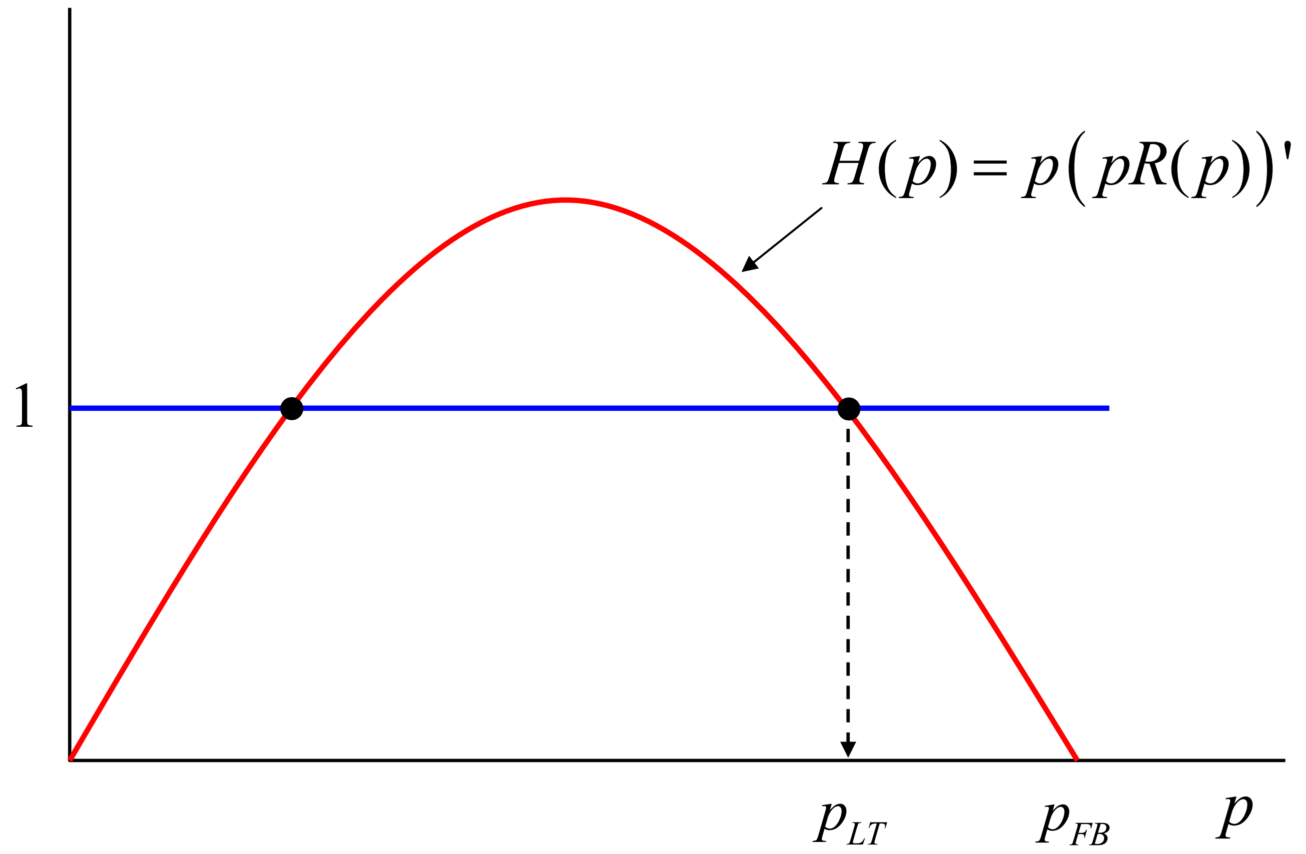
Long-term debt

Proposition 1 *LT debt is feasible if* $H(p) = 1$ *has a solution, in which case* $B_{LT} = 1/p_{LT}$ *and*

$$p_{LT} = \max\left\{ p \in (0, p_{FB}) \middle| H(p) = 1 \right\}$$

is the optimal contract with LT debt

Long-term debt



Long-term debt

- Example: $R(p) = a(2 - p)$

$$H(p) = 1 \;\;\rightarrow\;\; p_{LT} = \frac{1}{2}\left(1 + \sqrt{\frac{a-2}{a}}\right)$$

$\rightarrow$ LT debt requires $a \geq 2$

Part 3

Short-term debt

Short-term debt

- At $t = 1$ lenders observe non-verifiable signal $s \in \{s_0, s_1\}$
- Assume

$$\Pr(s_0 | R_0) = \Pr(s_1 | R_1) = q \in [1/2, 1]$$

→ q describes the *quality of information*

- Note that this is <u>not</u> signal about action (choice of risk)

→ It's a signal about consequences of action (future return)

- Liquidation value of investment at $t = 1$: $L = \lambda E(R_1 | s)$

→ $\lambda \in [0,1]$ is the *recovery rate*

Short-term debt

- By Bayes' law

$$\Pr(R_1 | s_0) = \frac{p(1-q)}{p+q-2pq} \quad \text{and} \quad \Pr(R_1 | s_1) = \frac{pq}{1-p-q+2pq}$$

- For $q = 1/2$ $\quad \Pr(R_1 | s_0) = \Pr(R_1 | s_1) = p$

  → Signal uninformative

- For $q = 1$ $\quad \Pr(R_1 | s_0) = 0$ and $\Pr(R_1 | s_1) = 1$

  → Signal completely reveals return of investment

- For $1/2 < q < 1$ $\quad \Pr(R_1 | s_0) < p < \Pr(R_1 | s_1)$

  → s_0 is bad state and s_1 is good state

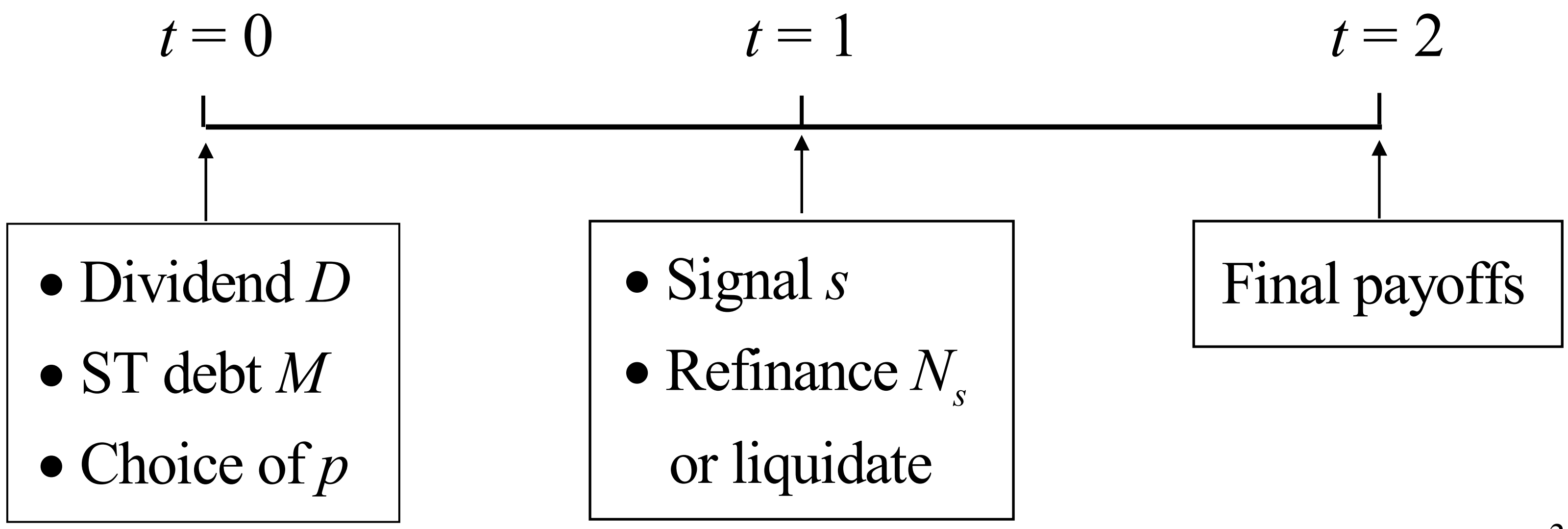
Short-term debt

- Suppose that the bank is funded at $t = 0$ with short-term debt

  → M is face value of debt payable at $t = 1$

  → N_s is face value of debt payable at $t = 2$

  when lenders decide to refinance in state s



Short-term debt

- Lenders' PC in state *s*:

$$\hat{E}(R_1 | s) \geq M$$

→ Notation: $\hat{E}(R_1 | s)$ is posterior probability based on prior $\hat{p}$

→ Since lenders do not observe bank's choice of *p*

- Face value of interim debt in state *s*:

$$N_s = \frac{M}{\hat{P}r(R_1 | s)}$$

Short-term debt

- Decision to refinance initial debt in state *s*:

$$I(x) = \begin{cases} 1, \text{ if } x = \hat{E}(R_1 | s) - M \geq 0 \\ 0, \text{ otherwise} \end{cases}$$

- Initial lenders' PC:

$$\varphi(M, \hat{p}) = \sum_{s=s_0,s_1} \hat{P}r(s)\Big[I(x)M + (1 - I(x))\lambda \hat{E}(R_1 | s)\Big] = 1 + D$$

- Bank's expected payoff

$$\pi(D, M, p, \hat{p}) = D + \sum_{s=s_0,s_1} Pr(s)I(x)Pr(R_1 | s)\max\{R(p) - N_s, 0\}$$

Short-term debt

Definition 3 A *contract* with ST debt specifies

(1) Initial dividend D paid to the bank at $t = 0$

(2) Face value M of initial debt payable to lenders at $t = 1$

Such contract determines probability of success p chosen by bank and face value of interim debt N_s (if initial debt is rolled over)

Short-term debt

Definition 2 An *optimal contract* with ST debt (D_{ST}, M_{ST}, p_{ST}) is a solution to problem:

$$\max_{(D,B,p)} \pi(D, M, p, \hat{p})$$

subject to IC constraint:

$$p_{ST} = \arg\max_{p} \pi(D, M, p, \hat{p})$$

PC constraint:

$$\varphi(M, \hat{p}) = 1 + D$$

and rational expectations constraint: $\hat{p} = p_{ST}$

Short-term debt

- Two possible types of ST debt
  - Safe ST debt (no liquidation in bad state s_0)
  - Risky ST debt (liquidation in bad state s_0)

Part 3.1

Safe short-term debt

Safe short-term debt

- Lenders' PC becomes

$$\varphi(M, \hat{p}) = M = 1 + D$$

- Bank's expected payoff becomes

$$\pi(D, M, p, \hat{p}) = D + p\left(R(p) - \frac{M}{\hat{p}} \right)$$

Result 1 IC + PC give:

$$\left(pR(p) \right)' = \frac{M}{p} = \frac{1+D}{p} \quad \rightarrow \quad H(p) = p\left(pR(p) \right)' = 1 + D$$

•**Result 2** Initial dividend $D = 0 \ \rightarrow \ M = 1$

Safe short-term debt

Constraint Initial debt refinanced in bad state s_0:

$$\hat{E}(R_1 \mid s_0) \geq 1 \quad \rightarrow \quad q \leq q(p)$$

Special cases

- $q = 1/2$ $\quad \Pr(R_1 \mid s_0) = \Pr(R_1 \mid s_1) = p$

  $\rightarrow$ Constraint $E(R_1 \mid s_0) \geq 1$ is always satisfied

- $q = 1$ $\quad \Pr(R_1 \mid s_0) = 0$

  $\rightarrow$ Constraint $\hat{E}(R_1 \mid s_0) \geq 1$ is never satisfied

Safe short-term debt

Proposition 2 *Safe ST debt is feasible if LT debt is feasible and* $q \leq q(p_{LT})$, *in which case* $(1, p_{LT})$ *is the optimal contract.*

$\rightarrow$ Safe ST debt does not add anything relative to LT debt

Part 3.2

Risky short-term debt

Risky short-term debt

- Lenders' PC becomes

$$\varphi(M,\hat{p}) = \hat{P}r(s_0)\lambda\hat{E}(R_1 | s_0) + \hat{P}r(s_1)M = 1 + D$$

- Bank's payoff becomes

$$\pi(D,M,p,\hat{p}) = D + \hat{P}r(s_1)\hat{P}r(R_1 | s_1)[R(p) - N_1]$$

Result 1 IC + PC give:

$$H(p) = F(p,q,\lambda,D)$$

Risky short-term debt

Constraint Initial debt <u>not</u> refinanced in bad state s_0:

$$\hat{E}(R_1 | s_0) \leq M \quad \rightarrow \quad G(p, q, \lambda) \leq 1 + D$$

Risky short-term debt

Proposition 3 *Risky ST debt is feasible if*

$$H(p) = F(p, q, \lambda, D)$$

has a solution for some $D \geq 0$ *that satisfies* $G(p, q, \lambda) \leq 1 + D$

in which case (D_{ST}, M_{ST}, p_{ST}) *where*

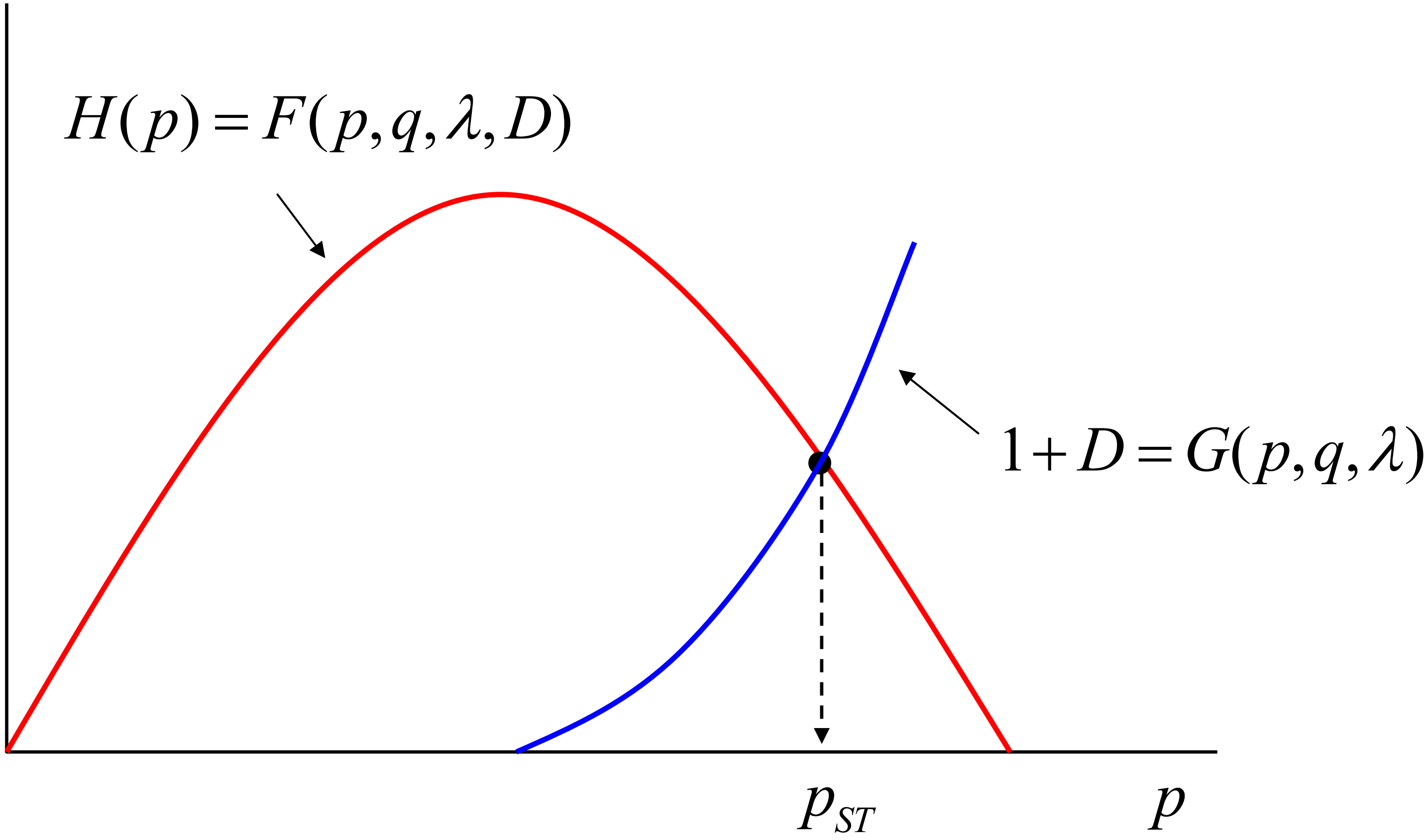
$$p_{ST} = \max\left\{ p \in (0, p_{FB}) \middle| H(p) = F(p, q, \lambda, D) \textit{ and } G(p, q, \lambda) \leq 1 + D \right\}$$

$$D_{ST} = \max\left\{ G(p_{ST}, q, \lambda) - 1, 0 \right\}$$

$$M_{ST} = \frac{1 + D_{ST} - \lambda(1-q) p_{ST} R(p_{ST})}{1 - p_{ST} - q + 2 p_{ST} q}$$

is the optimal contract with risky ST debt.

Risky short-term debt



Part 4

Numerical results

Parameterization

- Suppose that $R(p) = a(2 - p)$

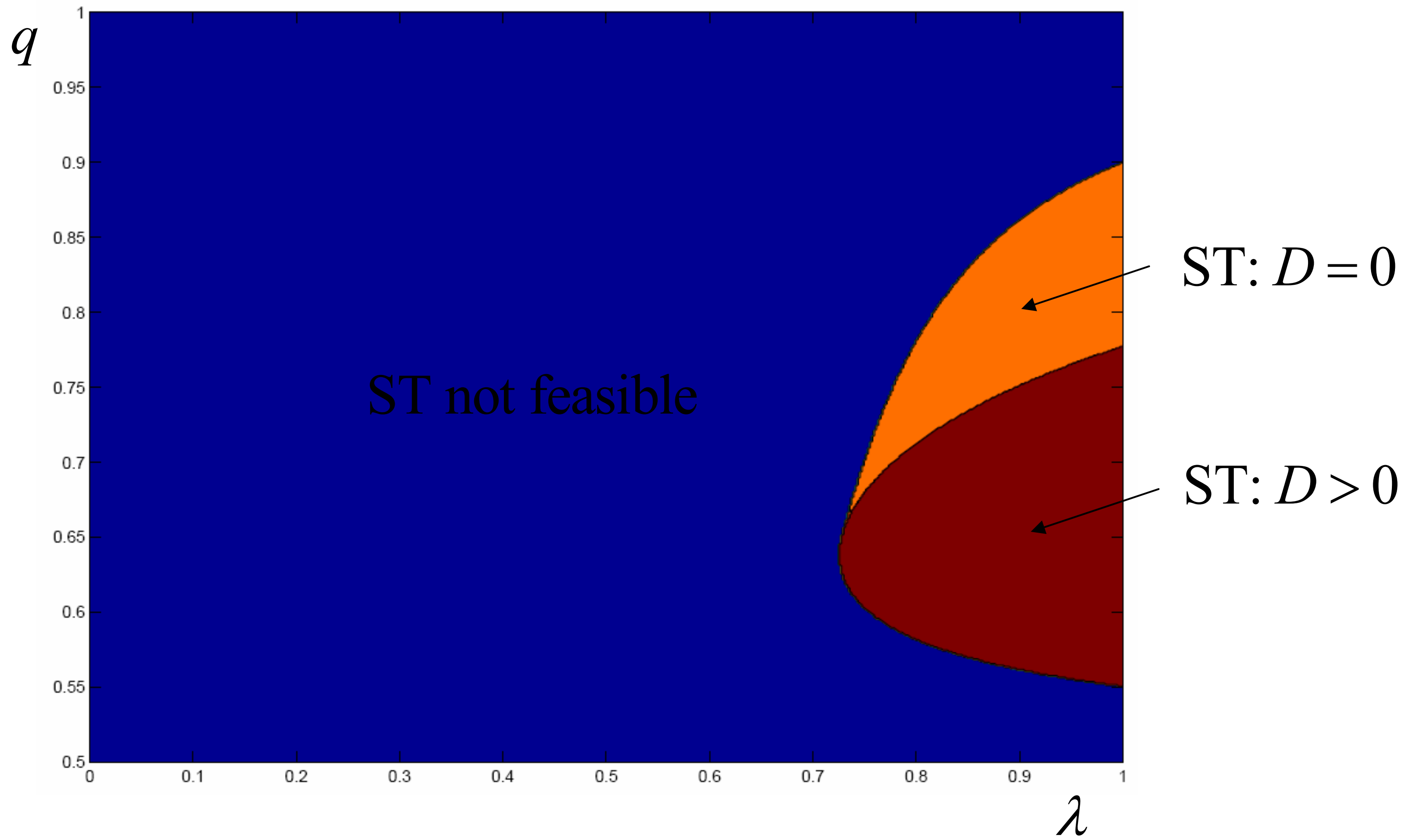
  → a measures the profitability of the investment project

  → LT debt requires $a \geq 2$

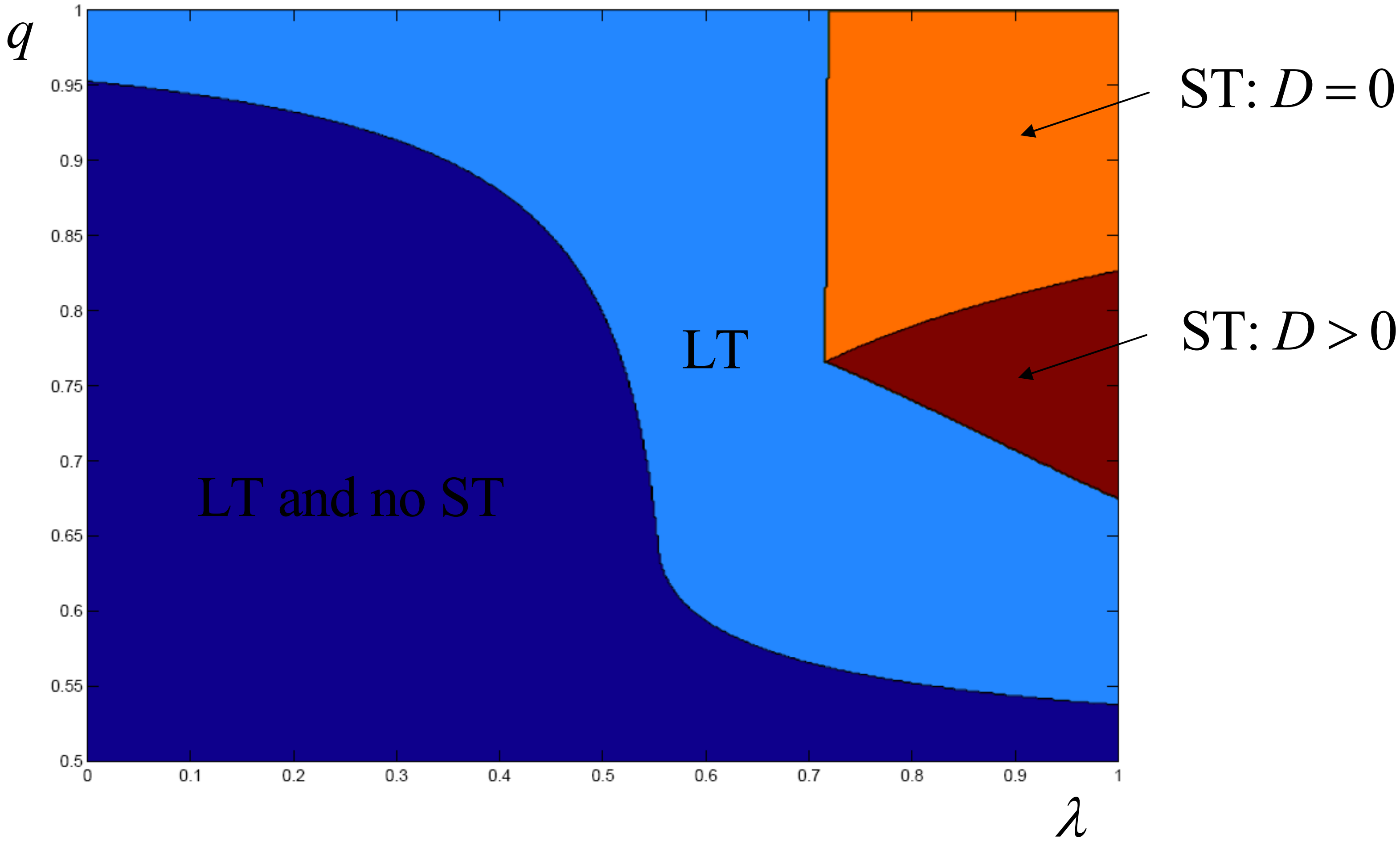
Numerical results

- Solve for optimal contract with risky ST debt for
  - Quality of the lenders' information $q \in [1/2, 1]$
  - Recovery rate the investment $\lambda \in [0,1]$
- Three cases
  - Low profitability: $a = 1.9 < 2$ $\rightarrow$ LT debt is not feasible
  - Medium profitability: $a = 2.1 > 2$ $\rightarrow$ LT debt is feasible
  - High profitability: $a = 3.125 > 2$ $\rightarrow$ LT debt is feasible

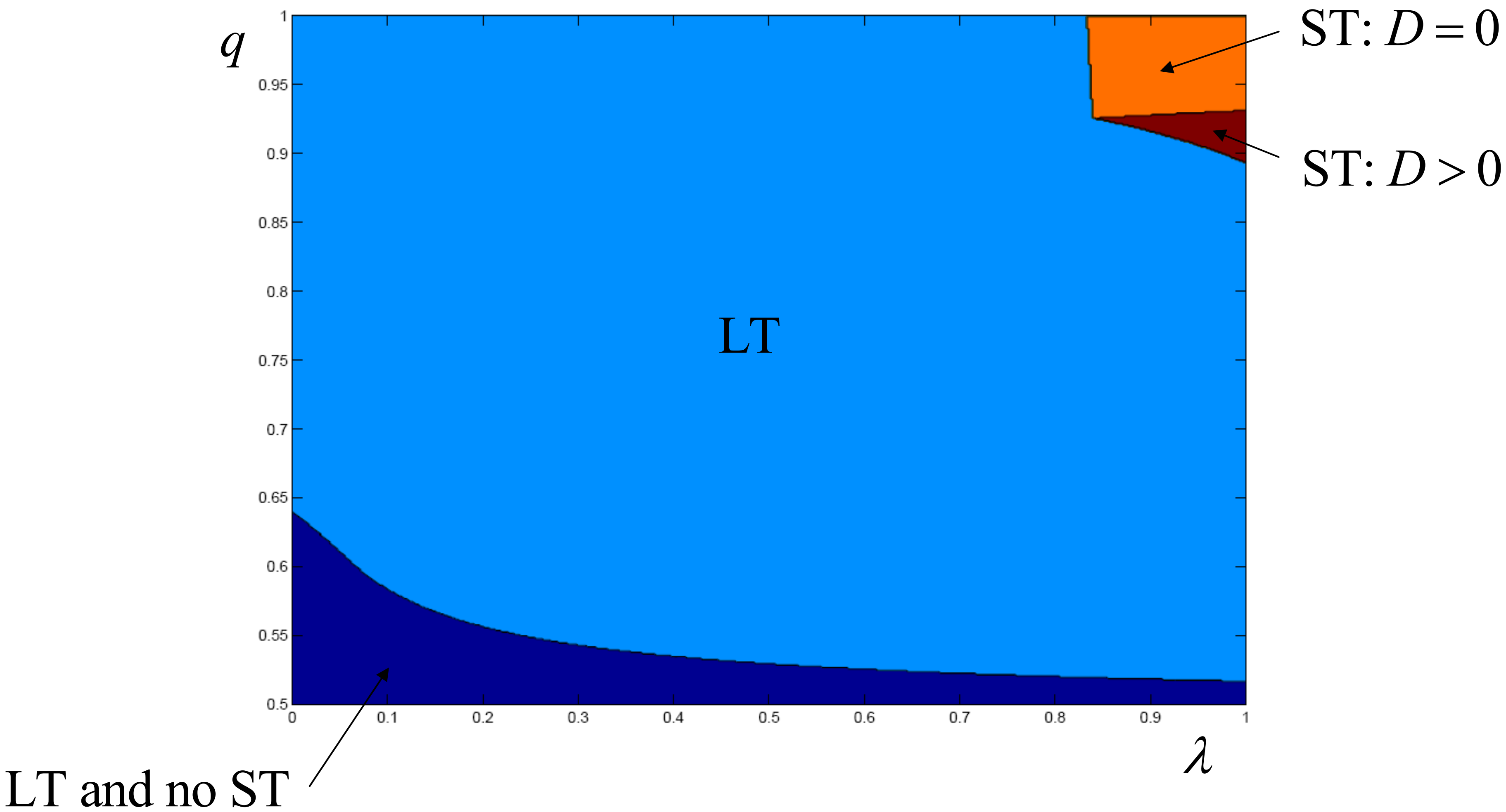
Case 1: Low profitability (*a* = 1.9)



Case 2: Medium profitability (a = 2.1)



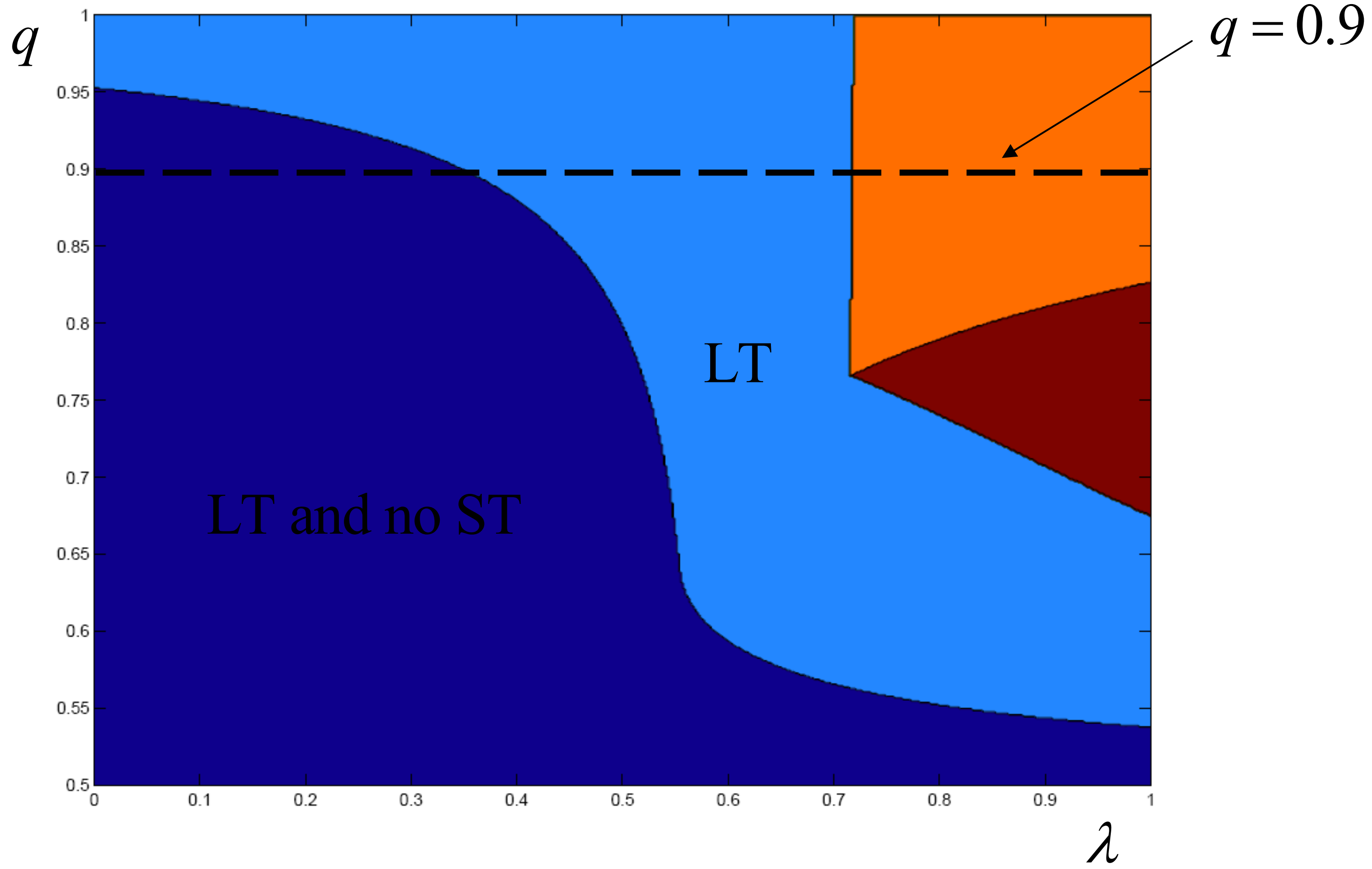
Case 3: High profitability (*a* = 3.125)



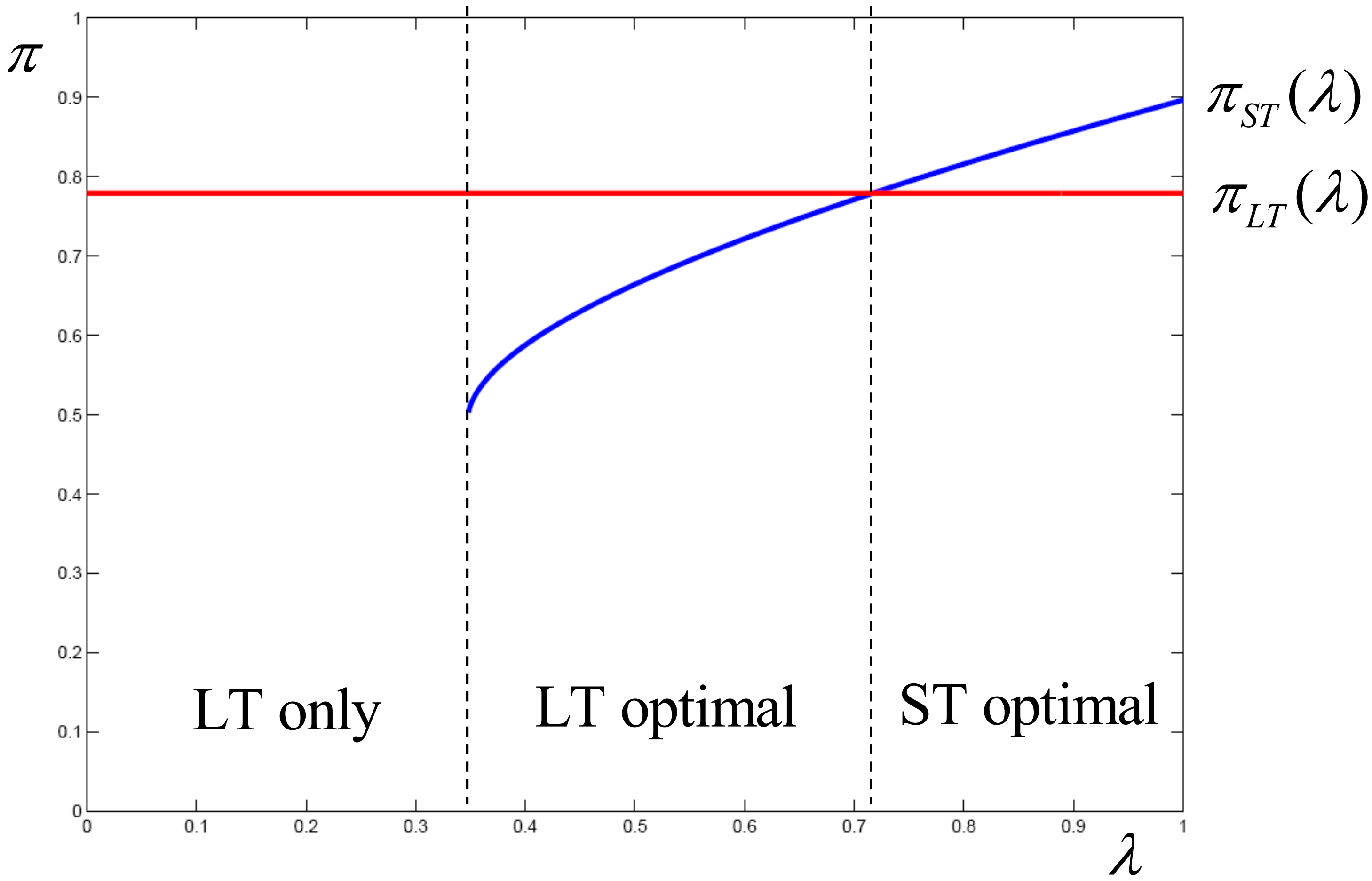
Summing up

- ST debt may be the only way to secure funding: $1.65 \leq a < 2$
- ST debt may dominate LT debt (when latter is feasible)
- ST debt is more likely to be optimal when
  - Profitability a is low (highly competitive environments)
  - Quality of information q and recovery rate λ are high
- ST debt involves upfront dividend when
  - Quality of information q is not too high

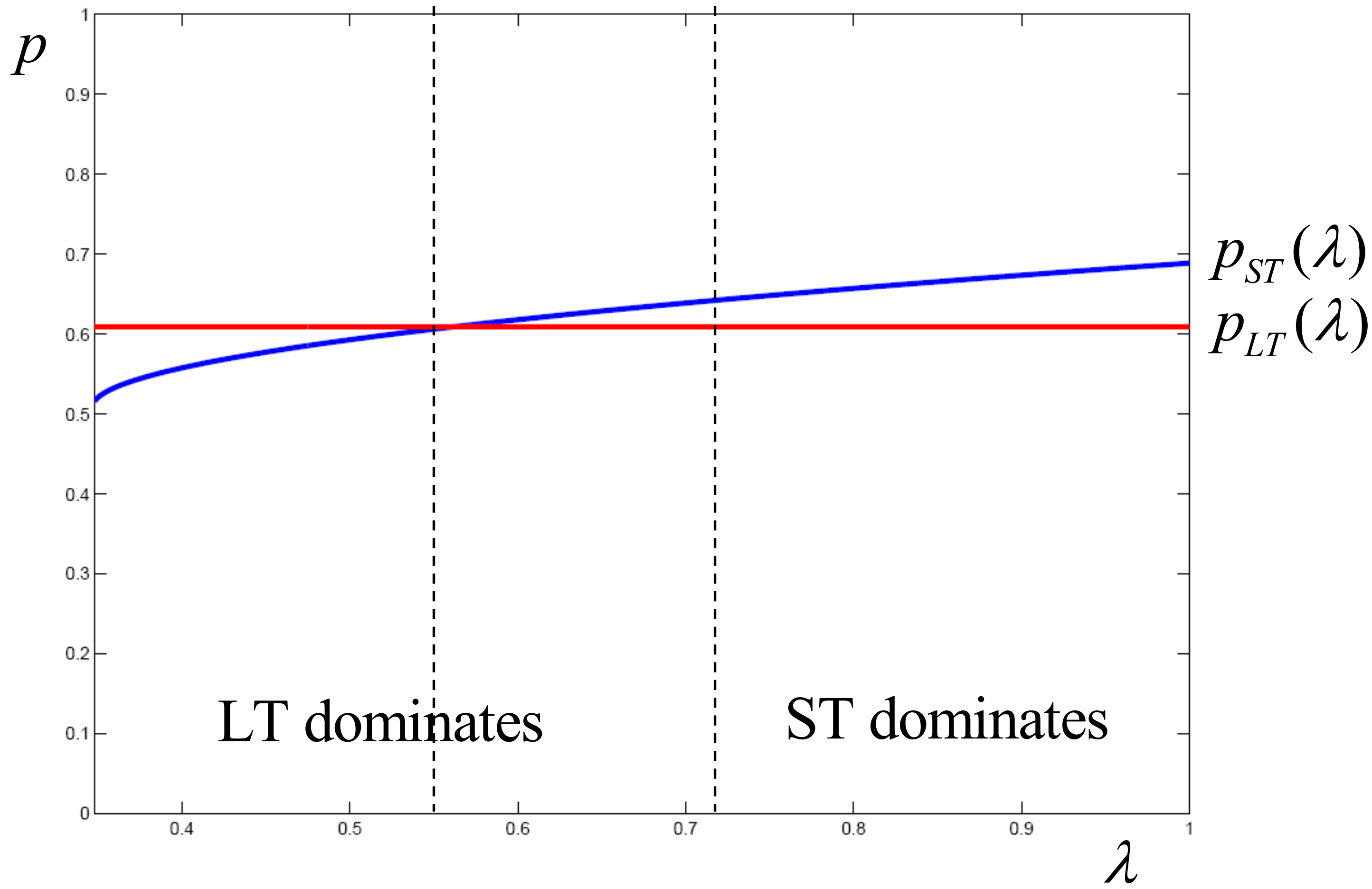
Effect of changes in recovery rate λ



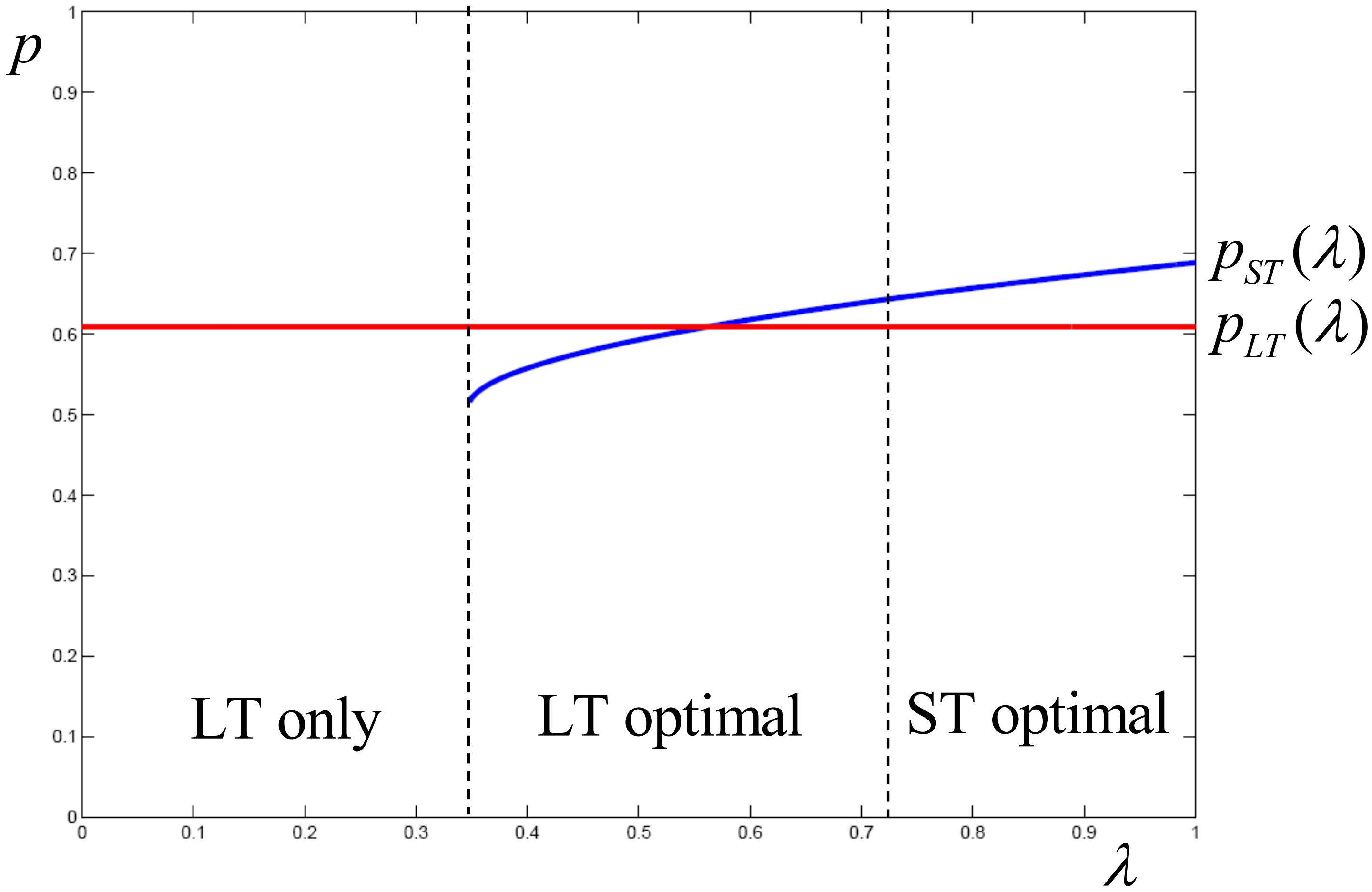
Effect of λ on bank's expected payoff



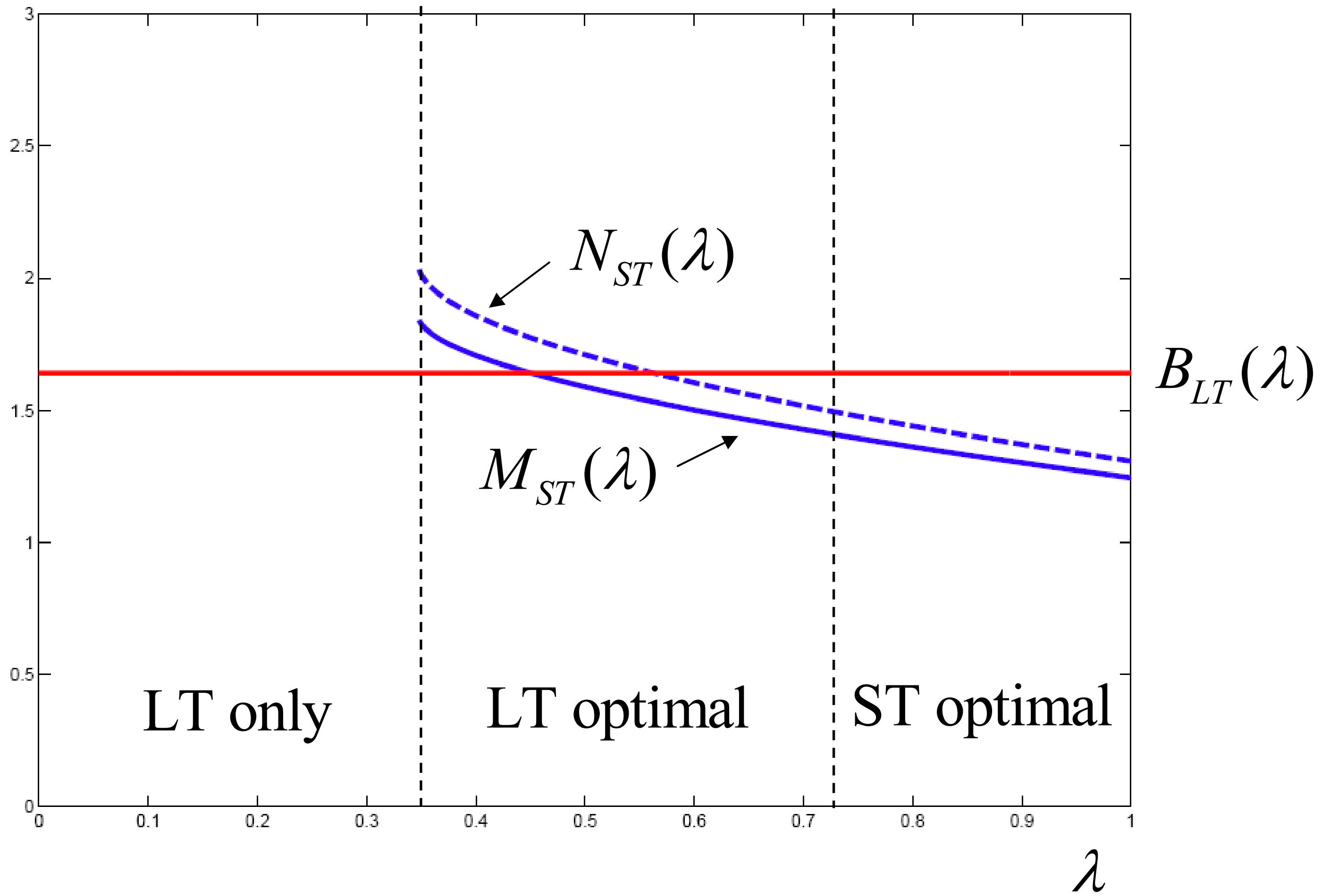
Effect of λ on success probabilities



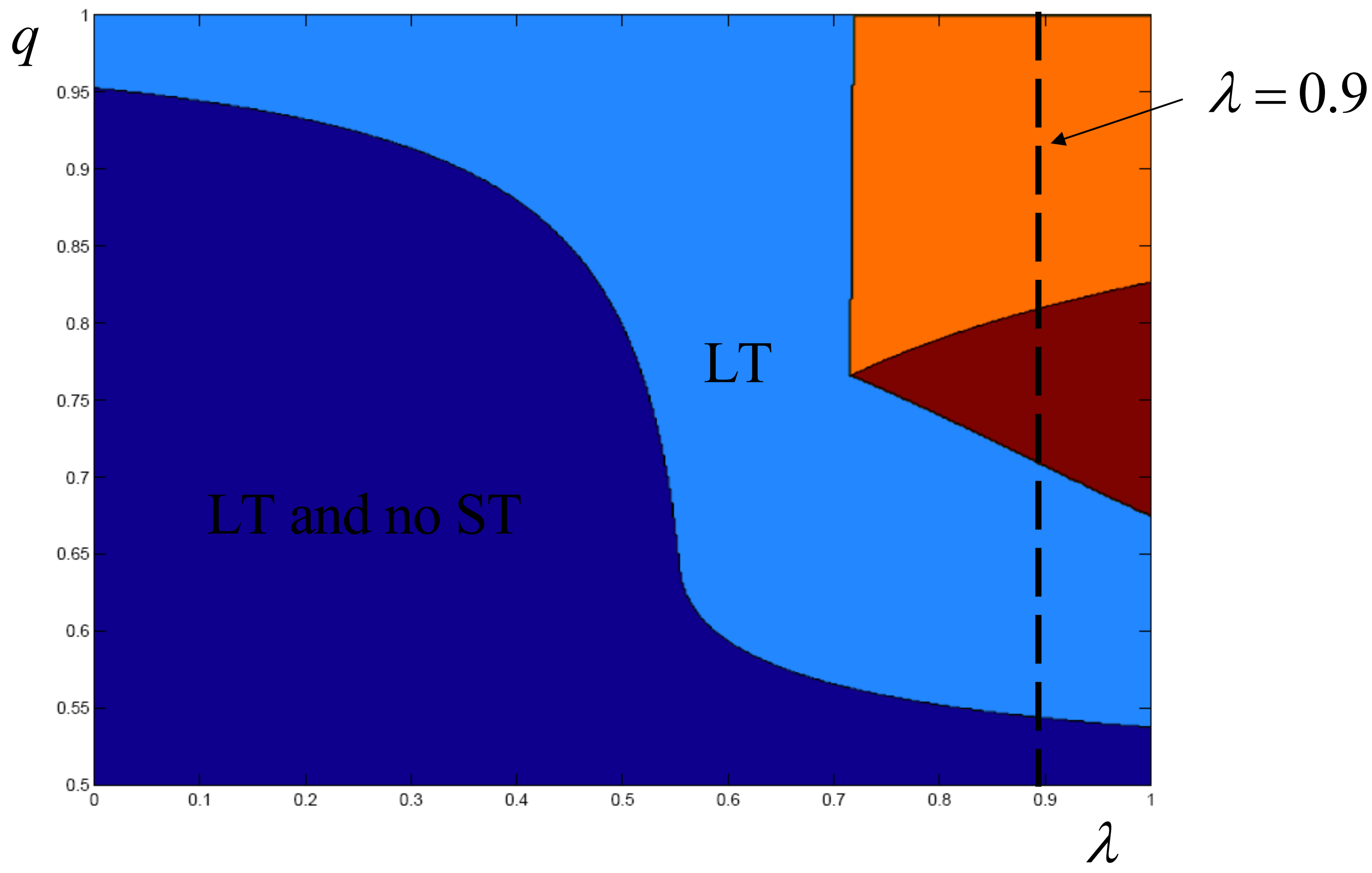
Effect of λ on success probabilities



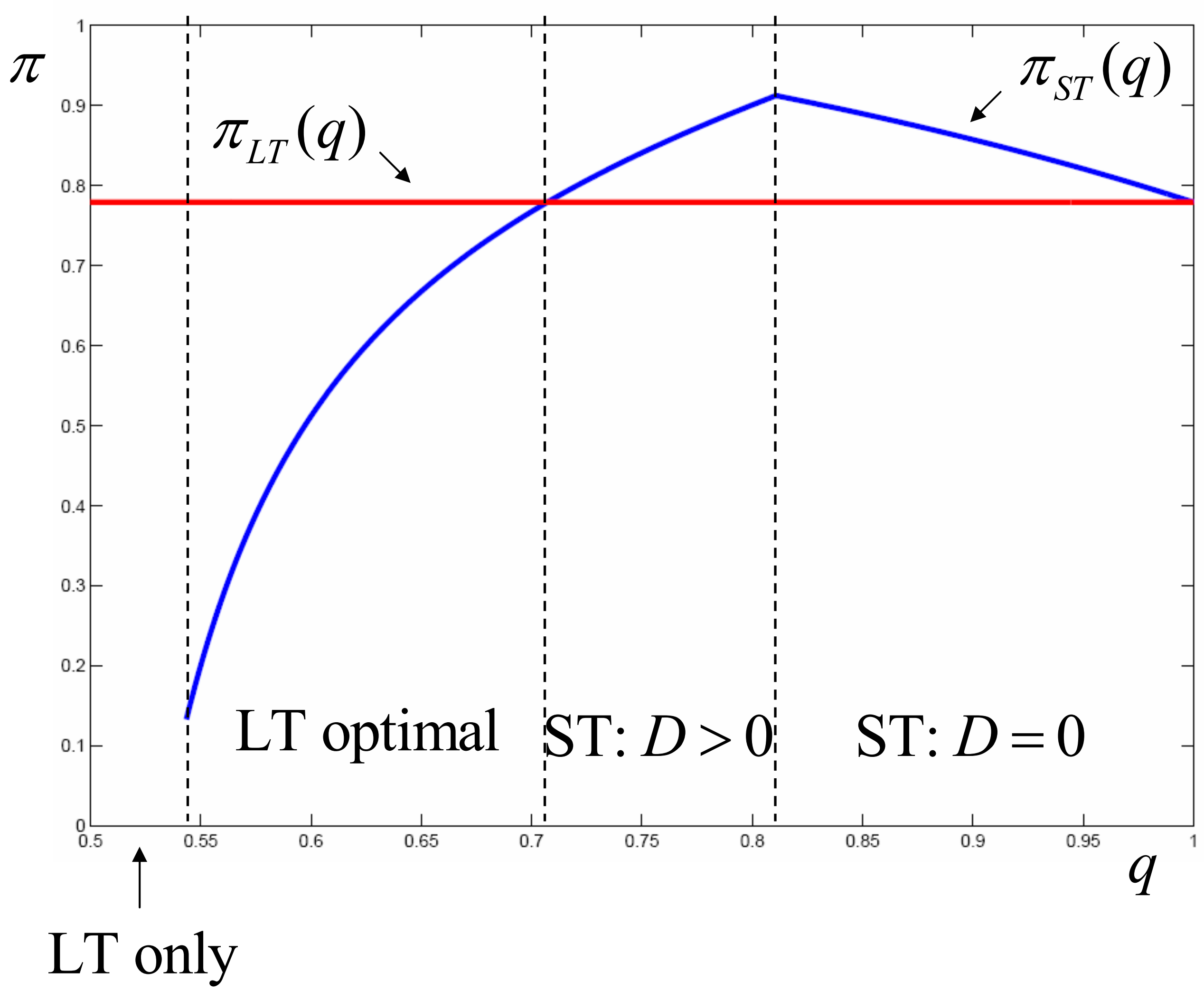
Effect of λ on interest rates



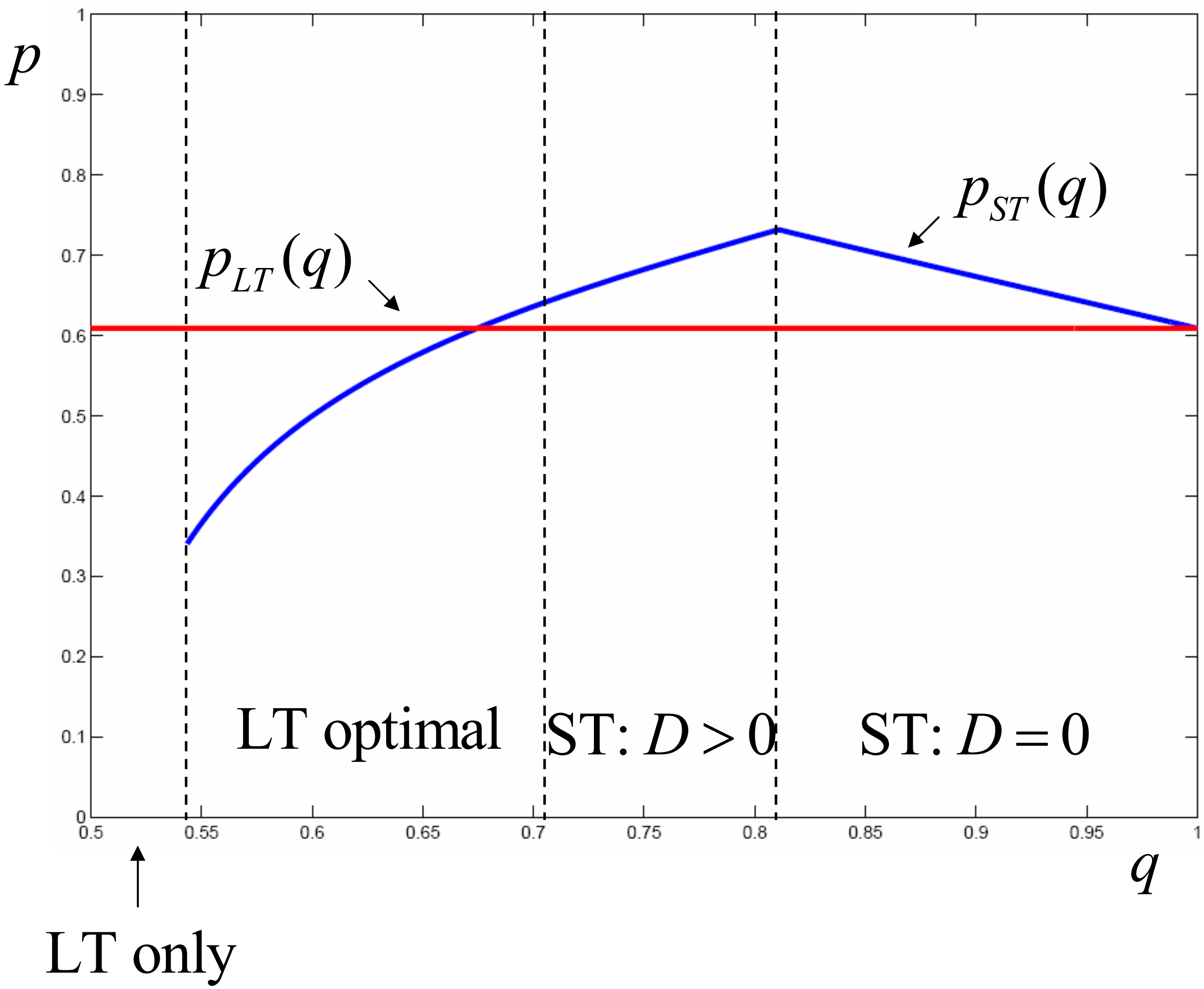
Effect of changes in quality of signal *q*



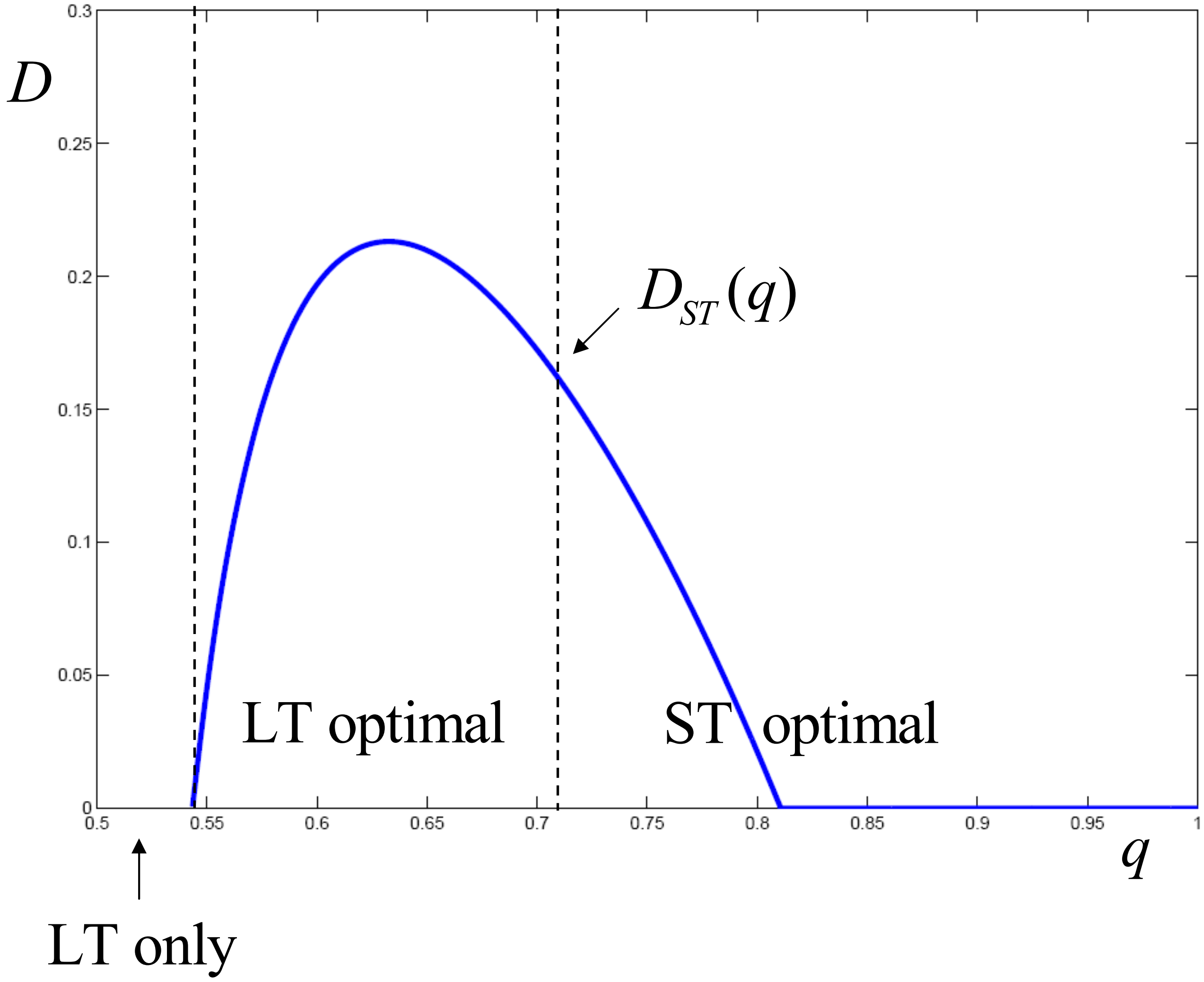
Effect of *q* on bank's expected profits



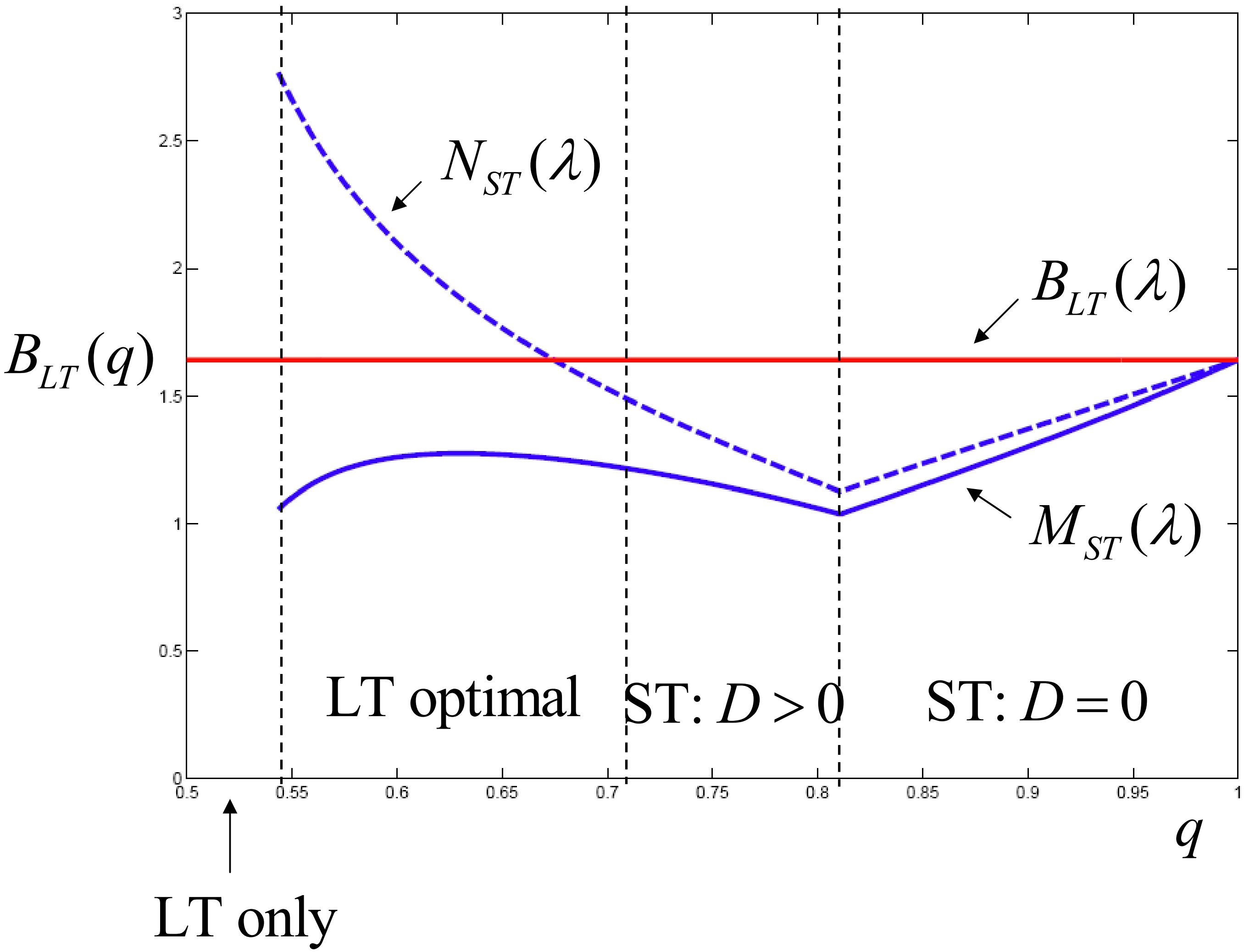
Effect of *q* on success probabilities



Effect of *q* on upfront dividend



Effect of *q* on interest rates



Part 5

Extensions

Extensions

- Model with mixed (ST and LT) debt
- Insured vs. uninsured debt
- Monetary policy (changes in return required by lenders)
- Liquidity requirement

Liquidity requirement

- Introduce liquid asset with zero return
- Suppose bank is required to match ST debt with liquid asset

  → Liquidity Coverage Ratio in Basel Committee (2009)
- Result: Only feasible contract equivalent to LT debt

  → Disciplining effects of ST debt are lost

  → May imply riskier portfolio (lower p)

Liquidity requirement

→ M. Flannery (AER 1994) *Optimally Financing Banking Firms*

"If short-funding bank assets provides important incentive benefits, regulations that limit a bank's ability to employ this funding device may reduce social welfare."

Conclusion

- Costs and benefits of ST debt

  → Disciplining device vs. inefficient liquidation

- Benefits may be greater than costs

  → When transparency q and recovery rate λ are high

- ST debt appears to be “cheaper” than LT dent

  → Because of positive incentive effects, not by assumption

- Liquidity requirements eliminate disciplining effect of ST debt

  → Risk of inefficient regulation