Monetary independence and rollover crises

Javier Bianchi (Federal Reserve Bank of Minneapolis & NBER)
Jorge Mondragon (University of Minnesota)

NBER Summer Institute

Eurozone Debt Crisis

- Concerns about **rollover crises** and sovereign defaults
  - Lenders refuse to rollover $\Rightarrow$ Liquidity problem for govt....
  - Liquidity problem $\Rightarrow$ Govt. default $\Rightarrow$ Lenders don't rollover...

Eurozone Debt Crisis

- Concerns about **rollover crises** and sovereign defaults
  - Lenders refuse to rollover $\Rightarrow$ Liquidity problem for govt....
  - Liquidity problem $\Rightarrow$ Govt. default $\Rightarrow$ Lenders don't rollover...

You have large parts of the euro area in what we call a "bad equilibrium", namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios.

Mario Draghi, President of the ECB, 2012 Speech

Eurozone Debt Crisis

- Concerns about **rollover crises** and sovereign defaults
  - Lenders refuse to rollover $\Rightarrow$ Liquidity problem for govt....
  - Liquidity problem $\Rightarrow$ Govt. default $\Rightarrow$ Lenders don't rollover...
- Members of the Eurozone unable to conduct independent monetary policy
  - Argument that this was exacerbating recession and debt crisis
  - Fears of potential break-up of monetary union

Eurozone Debt Crisis

- Concerns about **rollover crises** and sovereign defaults
  - Lenders refuse to rollover $\Rightarrow$ Liquidity problem for govt....
  - Liquidity problem $\Rightarrow$ Govt. default $\Rightarrow$ Lenders don't rollover...
- Members of the Eurozone unable to conduct independent monetary policy
  - Argument that this was exacerbating recession and debt crisis
  - Fears of potential break-up of monetary union

How does the lack of monetary autonomy affect the vulnerability of a government to a rollover crisis?

This Paper

Inability to use monetary policy for macroeconomic stabilization leaves a government more vulnerable to a rollover crisis

This Paper

Inability to use monetary policy for macroeconomic stabilization leaves a government more vulnerable to a rollover crisis

- Theory: Model of sovereign default and rollover crisis with:
  - Downward nominal wage rigidity $\Leftarrow$ Macro-stabilization
  - Foreign currency debt $\Leftarrow$ No role for inflating away

This Paper

Inability to use monetary policy for macroeconomic stabilization leaves a government more vulnerable to a rollover crisis

- Theory: Model of sovereign default and rollover crisis with:
  - Downward nominal wage rigidity $\Leftarrow$ Macro-stabilization
  - Foreign currency debt $\Leftarrow$ No role for inflating away

Key insight: Investors pessimism can trigger a demand driven recession $\Rightarrow$ default more attractive $\Rightarrow$ investors more prone to run

This Paper (ctd): Quantitative Results

- Flexible exchange rate: govt. almost immune to rollover crises
  - Defaults mostly due to fundamentals
- In a monetary union, large fraction of defaults explained by rollover crises

This Paper (ctd): Quantitative Results

- Flexible exchange rate: govt. almost immune to rollover crises
  - Defaults mostly due to fundamentals
- In a monetary union, large fraction of defaults explained by rollover crises

Welfare implications:

- Large costs from joining a monetary union, mostly coming from default exposure, not output losses
- Lender-of-last resort can substantially decreases these costs

Related Literature

Classic papers on rollover crises: Sachs (1984); Alesina, Pratti and Tabellini (1989); Cole and Kehoe (2000)

Recent quantitative models on rollover crises: Chatterjee and Eygunoor (2012); Bocola and Dovis (2016); Aguiar, Chatterjee, Cole and Stangebye (2016); Roch and Uhlig (2018); Conesa and Kehoe (2015)

Other types of multiplicity in sovereign debt: Calvo (1988); Lorenzoni and Werning (2013); Ayres, Navarro, Nicolini and Teles (2015), Aguiar and Amador (2018)

Monetary models with domestic currency debt: Calvo (1988); Da Rocha, Gimenez and Lores (2013); Araujo, Leon and Santos (2016); Aguiar, Amador, Farhi and Gopinath (2013; 2016); Corsetti and Dedola (2016); Camous and Cooper (2014); Bacchetta, Perazzi and van Wincoop (2015)

Sovereign default model with nominal rigidities: Na, Schmitt-Grohe, Uribe and Yue (2018); Bianchi, Ottonello and Presno (2016), Arellano, Bai and Mihalache (2018), Bianchi and Sosa-Padilla (2018)

Elements of the model

Small open economy (SOE) populated by households, firms and a government

- Tradable goods:
  - Law of one price holds: $P_t^T = P_t^* e_t$
    - Foreign price P_t^* assumed to be constant, normalized to one
  - Stochastic endowment y^T
- Non-tradable goods:
  - Market must clear domestically
  - Produced with labor $y^N = F(h)$, subject to wage rigidity
- Government borrows without commitment

Households

$$\max_{\{c_t^T, c_t^N\}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t) \right]$$

$$c = [\omega (c^T)^{-\mu} + (1-\omega)(c^N)^{-\mu}]^{-1/\mu}$$

- Budget constraint in domestic currency

$$e_t c_t^T + P_t^N c_t^N = e_t y_t^T + \phi_t^N + W_t h_t - T_t e_t$$

- ϕ^N firms' profits, T_t taxes. No direct access to external credit.
- Endowment of hours $\bar{h}$

Households

$$\max_{\{c_t^T, c_t^N\}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t) \right]$$

$$c = [\omega (c^T)^{-\mu} + (1-\omega)(c^N)^{-\mu}]^{-1/\mu}$$

- Budget constraint in domestic currency

$$e_t c_t^T + P_t^N c_t^N = e_t y_t^T + \phi_t^N + W_t h_t - T_t e_t$$

- ϕ^N firms' profits, T_t taxes. No direct access to external credit.
- Endowment of hours $\bar{h}$

Firms

- Produce using labor: $y^N = F(h)$
- Profit maximization

$$\phi_t^N = \max_{h_t} \left\{ P_t^N F(h_t) - W_t h_t \right\}$$

Prelude: Equilibrium real wage

- Household's and firms's optimality conditions

$$\frac{P_t^N}{e_t} = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{1+\mu} \qquad \& \qquad \frac{W_t}{e_t} = \frac{P_t^N}{e_t}F'(h_t)$$

- Nontradable market clearing implies $c_t^N = F(h_t)$
- For any equilibrium (c^T, h_t), wages (in tradable units) are

$$\mathcal{W}\left(c_t^T, h_t\right) \equiv \frac{1-\omega}{\omega}\left(\frac{c_t^T}{F(h_t)}\right)^{1+\mu} F'(h_t)$$

Prelude: Equilibrium real wage

- Household's and firms's optimality conditions

$$\frac{P_t^N}{e_t} = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{1+\mu} \qquad \& \qquad \frac{W_t}{e_t} = \frac{P_t^N}{e_t} F'(h_t)$$

- Nontradable market clearing implies $c_t^N = F(h_t)$
- For any equilibrium (c^T, h_t), wages (in tradable units) are

$$\mathcal{W}\left(c_t^T, h_t\right) \equiv \frac{1-\omega}{\omega}\left(\frac{c_t^T}{F(h_t)}\right)^{1+\mu} F'(h_t)$$

Increasing in tradable consumption c^T and decreasing in labor h

Downward nominal wage rigidity

Wages in *domestic currency* cannot fall below $\overline{W}$:

$$W_t \geq \overline{W}$$

Downward nominal wage rigidity

Wages in *domestic currency* cannot fall below $\overline{W}$:

$$W_t \geq \overline{W}$$

- If market clearing wage is *lower* than $\overline{W} \Rightarrow$ unemployment
  - Employment is demand determined: $h_t = F'^{-1}\left(\frac{\overline{W}}{P_t^N}\right)$

Downward nominal wage rigidity

Wages in *domestic currency* cannot fall below $\overline{W}$:

$$W_t \geq \overline{W}$$

- If market clearing wage is *lower* than $\overline{W} \Rightarrow$ unemployment
  - Employment is demand determined: $h_t = F'^{-1}\left(\frac{\overline{W}}{P_t^N}\right)$

Inside a monetary union, wages in foreign currency w_t must satisfy

$$w_t \geq \overline{w}$$

Government

- Long maturity bond denominated in foreign currency
  - Coupon payments decrease at rate $1 - \delta$
- Budget constraint in repayment (in units of T):

$$\delta b_t = q_t[b_{t+1} - b_t(1 - \delta)] + T_t$$

  q is a bond price schedule

- If default:
  - Government suffers utility loss and temporary exclusion
  - Investors get zero

Government (ctd)

- Focus on two exchange rate regimes
  - Flexible: optimal choice of e_t
    - Depreciate currency to achieve $\mathcal{W}(c^T, \overline{h})e \geq W$
  - Fixed: $e_t = \overline{e}$ for all t
    - Equivalent to a single (small) economy within a currency union

Government (ctd)

- Focus on two exchange rate regimes
  - Flexible: optimal choice of e_t
    - Depreciate currency to achieve $\mathcal{W}(c^T, \overline{h})e \geq W$
  - Fixed: $e_t = \overline{e}$ for all t
    - Equivalent to a single (small) economy within a currency union
- Abstract here from gains of fixing exchange rate
  - See appendix

International Lenders

- Unit mass of atomistic risk-neutral lenders
- No-arbitrage condition between long-term government bond and a one-period risk-free asset with interest rate r

$$q_t(1+r) = \mathbb{E}_t[(1-d_{t+1})(\delta + (1-\delta)q_{t+1})]$$

Where are we going?

- Find "crisis zone": zone in which repayment/default depends on investors' beliefs
    - Characterize value function of repayment in optimistic/pessimistic cases
- Examine how wage rigidity and monetary policy affects size of crisis zone

Markov equilibrium: Recursive Government Problem

- States: $(b, \mathbf{s}) \quad \mathbf{s} = \left(y^T, \zeta\right)$
  - ζ is a sunspot, assumed to be iid
- Government problem in good credit standing

$$V(b, \mathbf{s}) = \max \left\{ V_D(y^T), V_R(b, \mathbf{s}) \right\}$$

- Repayment/default decision is made at the end of the period
  - Cole-Kehoe timing

Multiplicity of Equilibria

Notation for value functions:

- Optimistic: If lenders are willing to rollover, government obtains value V_R^+ under repayment
- Pessimistic: If lenders refuse to rollover, government obtains value V_R^- under repayment

If $V_R^- < V_D < V_R^+$, equilibrium depends on beliefs (Cole-Kehoe):

Multiplicity of Equilibria

Notation for value functions:

- Optimistic: If lenders are willing to rollover, government obtains value V_R^+ under repayment
- Pessimistic: If lenders refuse to rollover, government obtains value V_R^- under repayment

If $V_R^- < V_D < V_R^+$, equilibrium depends on beliefs (Cole-Kehoe):

- If each investor expects others to lend to the government, s/he also lends & govt. repays

Multiplicity of Equilibria

Notation for value functions:

- Optimistic: If lenders are willing to rollover, government obtains value V_R^+ under repayment
- Pessimistic: If lenders refuse to rollover, government obtains value V_R^- under repayment

If $V_R^- < V_D < V_R^+$, equilibrium depends on beliefs (Cole-Kehoe):

- If each investor expects others to lend to the government, s/he also lends & govt. repays
- If each investor expects others not to lend to the government, s/he doesn't lend & govt. defaults

Value of repayment for the Govt.

$$V_R(b,\ \mathbf{s}\ ) = \max_{b', c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[\quad V\left(b', \mathbf{s}'\right)\quad\right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b + q(b', b, \mathbf{s})\left[b' - (1-\delta)b\right]$$

$$\mathcal{W}\left(c^T, h\right)\overline{e} \geq \overline{W}$$

$\downarrow c^T \rightarrow \downarrow h$

Value of repayment for the Govt.

$$V_R(b,\ \mathbf{s}\ ) = \max_{b', c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[\quad V\left(b', \mathbf{s}'\right)\quad\right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b + q(b', b, \mathbf{s})\left[b' - (1-\delta)b\right]$$

$$\mathcal{W}\left(c^T, h\right)\overline{e} \geq \overline{W}$$

Value of repayment for the Govt.

$$V_R(b,\ \mathbf{s}\ ) = \max_{b', c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[\quad V\left(b', \mathbf{s}'\right)\quad\right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b + q(b', b, \mathbf{s})\left[b' - (1-\delta)b\right]$$

$$\mathcal{W}\left(c^T, h\right) \overline{e} \geq \overline{W}$$

Optimal exchange rate eliminates wage rigidity $\downarrow c^T \rightarrow \downarrow h$

Value of repayment for the Govt. if investors lend

$$V_R^+(b, y^T) = \max_{b', c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[\quad V\left(b', \mathbf{s}'\right) \quad \right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b + \tilde{q}(b', y^T)\left[b' - (1-\delta)b\right]$$

$$\mathcal{W}\left(c^T, h\right)\overline{e} \geq \overline{W}$$

Value of repayment for the Govt. if investors do not lend

$$V_R^-(b, y^T) = \max_{c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[V\left((1-\delta)b, \mathbf{s}'\right)\right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b + \cancel{\tilde{q}(b', y^T)\left[b' - (1-\delta)b\right]}$$

$$\mathcal{W}\left(c^T, h\right) \overline{e} \geq \overline{W}$$

Value of repayment for the Govt. if investors do not lend

$$V_R^-(b, y^T) = \max_{c^T, h \leq \overline{h}} \left\{ u\left(c^T, F(h)\right) + \beta \mathbb{E}\left[V\left((1-\delta)b, \mathbf{s}'\right)\right] \right\}$$

$$\text{s.t. } c^T = y^T - \delta b$$

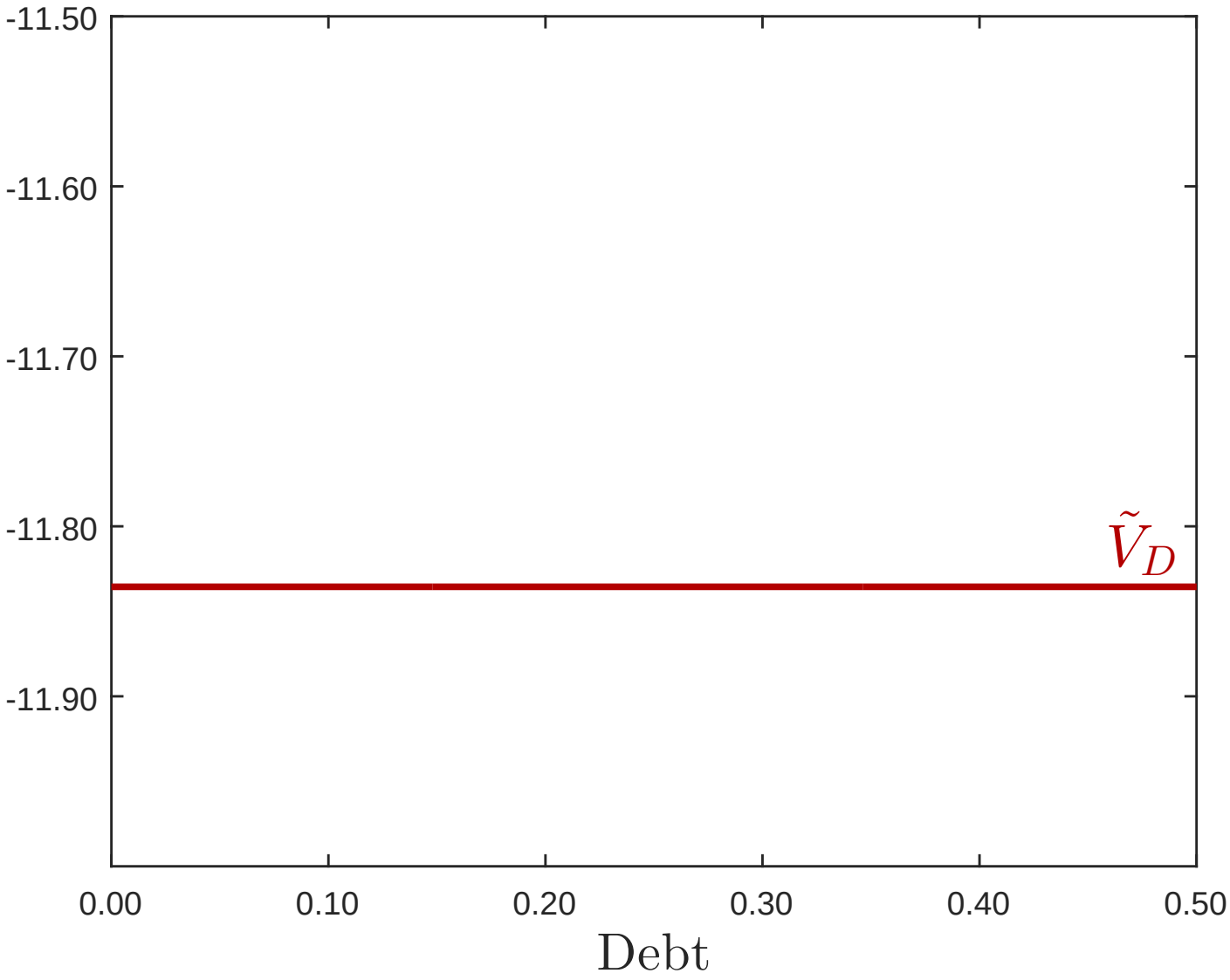
$$\mathcal{W}\left(\underset{+}{c^T}, \underset{-}{h}\right) \overline{e} \geq \overline{W}$$

Inability to issue debt makes rigidity more binding $\downarrow c^T \Rightarrow \downarrow h$

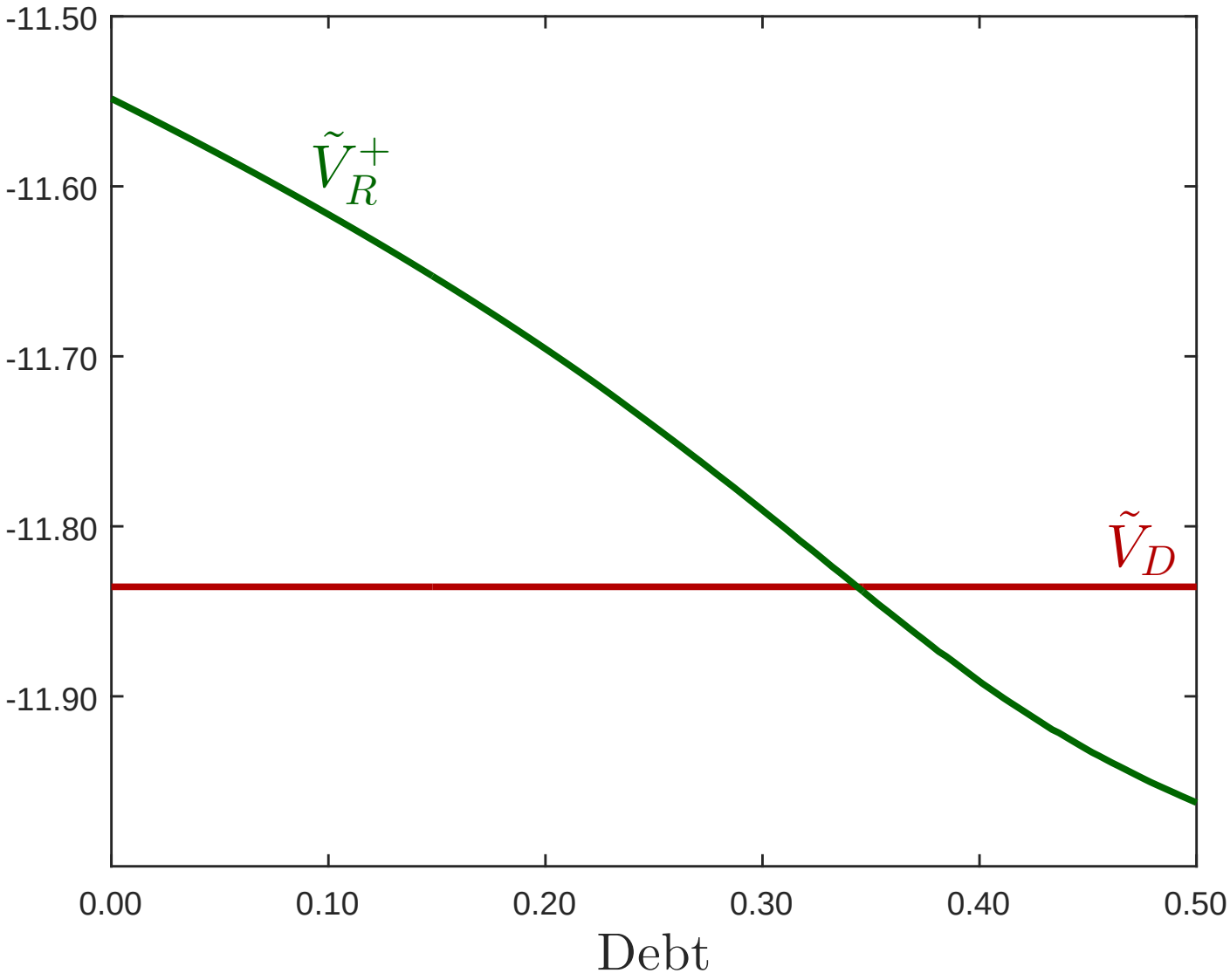
Crisis Region under Flexible Wages

(fix a value of y^T)

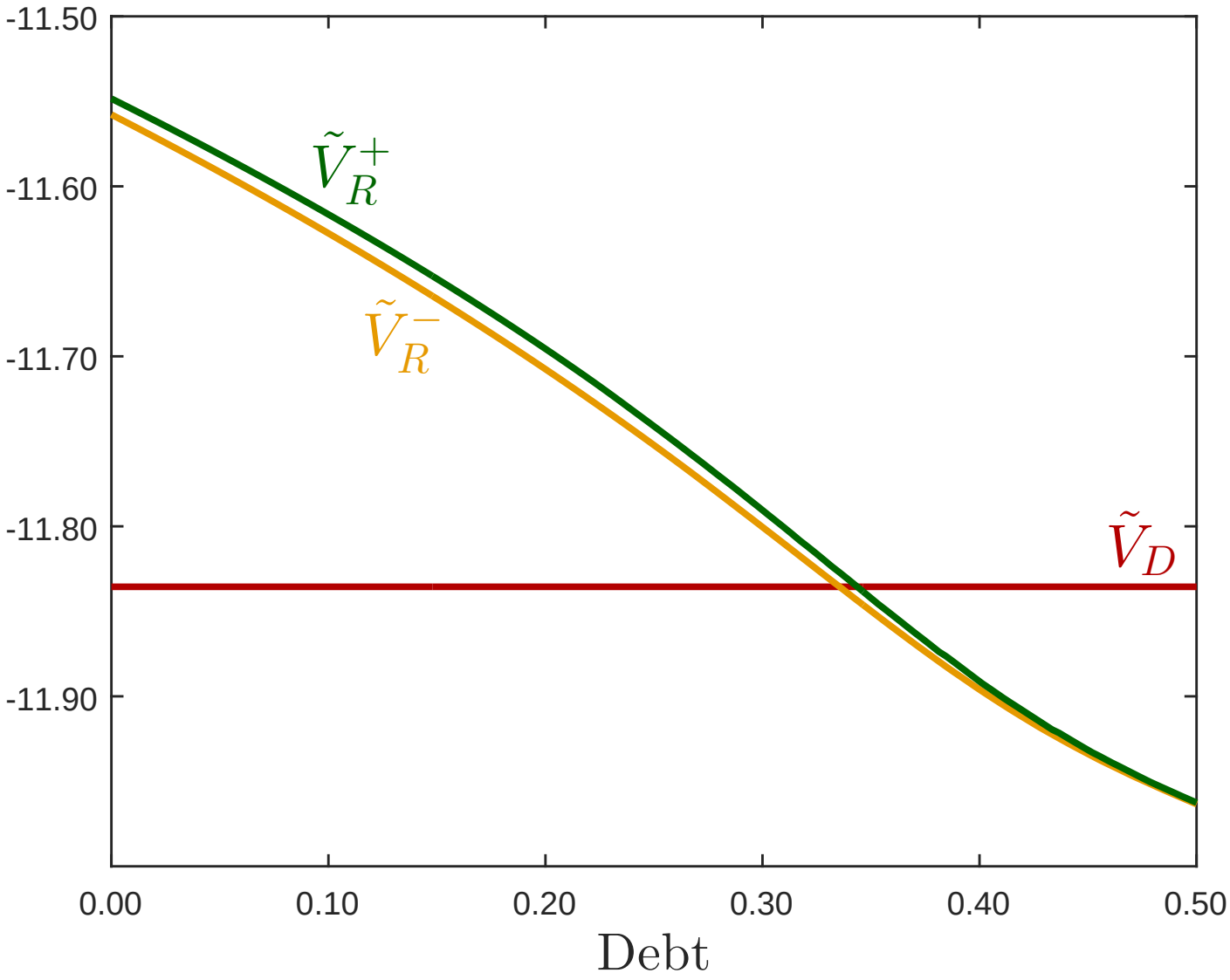
Value Functions: Flexible Wages



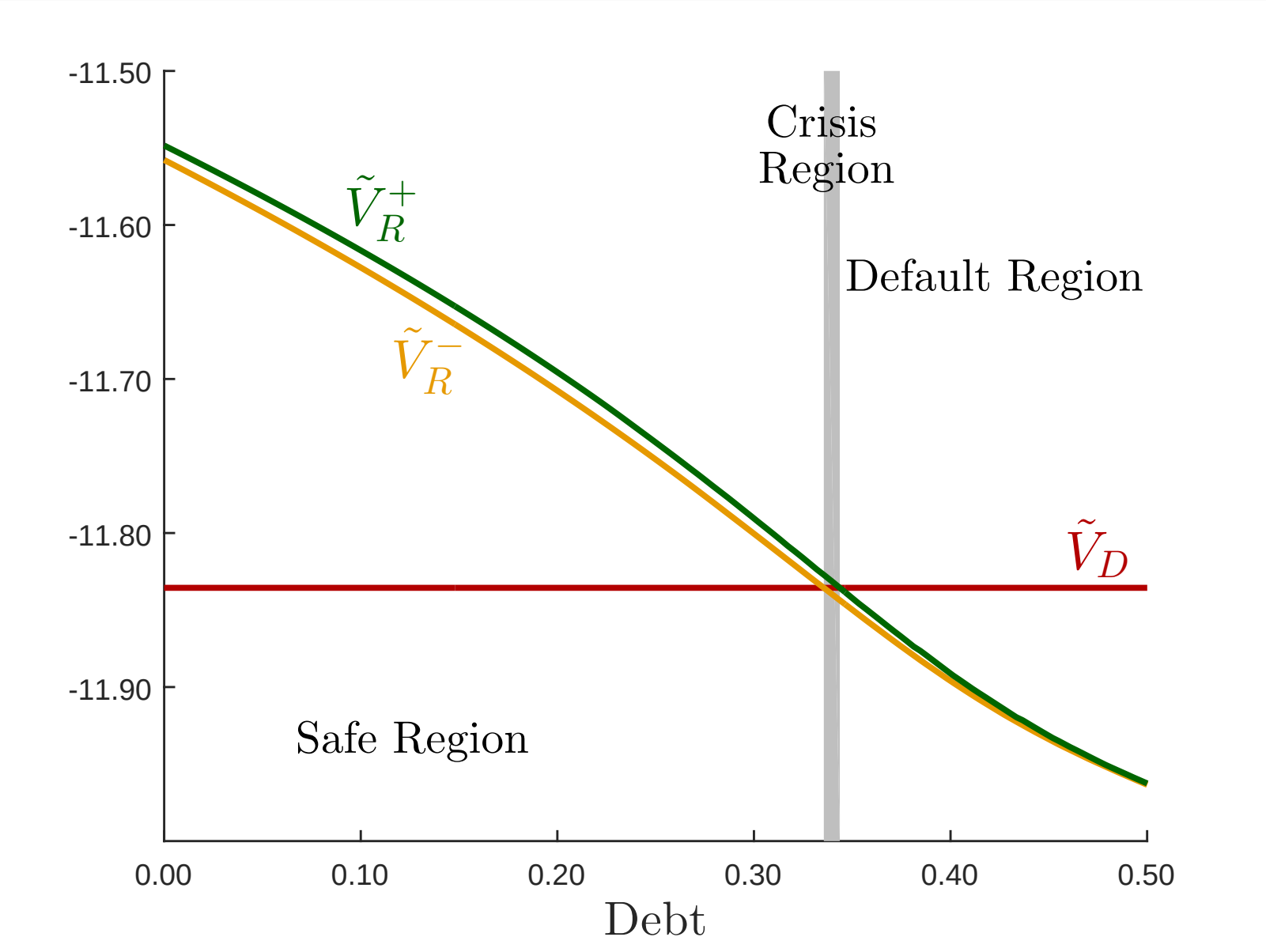
Value Functions: Flexible Wages



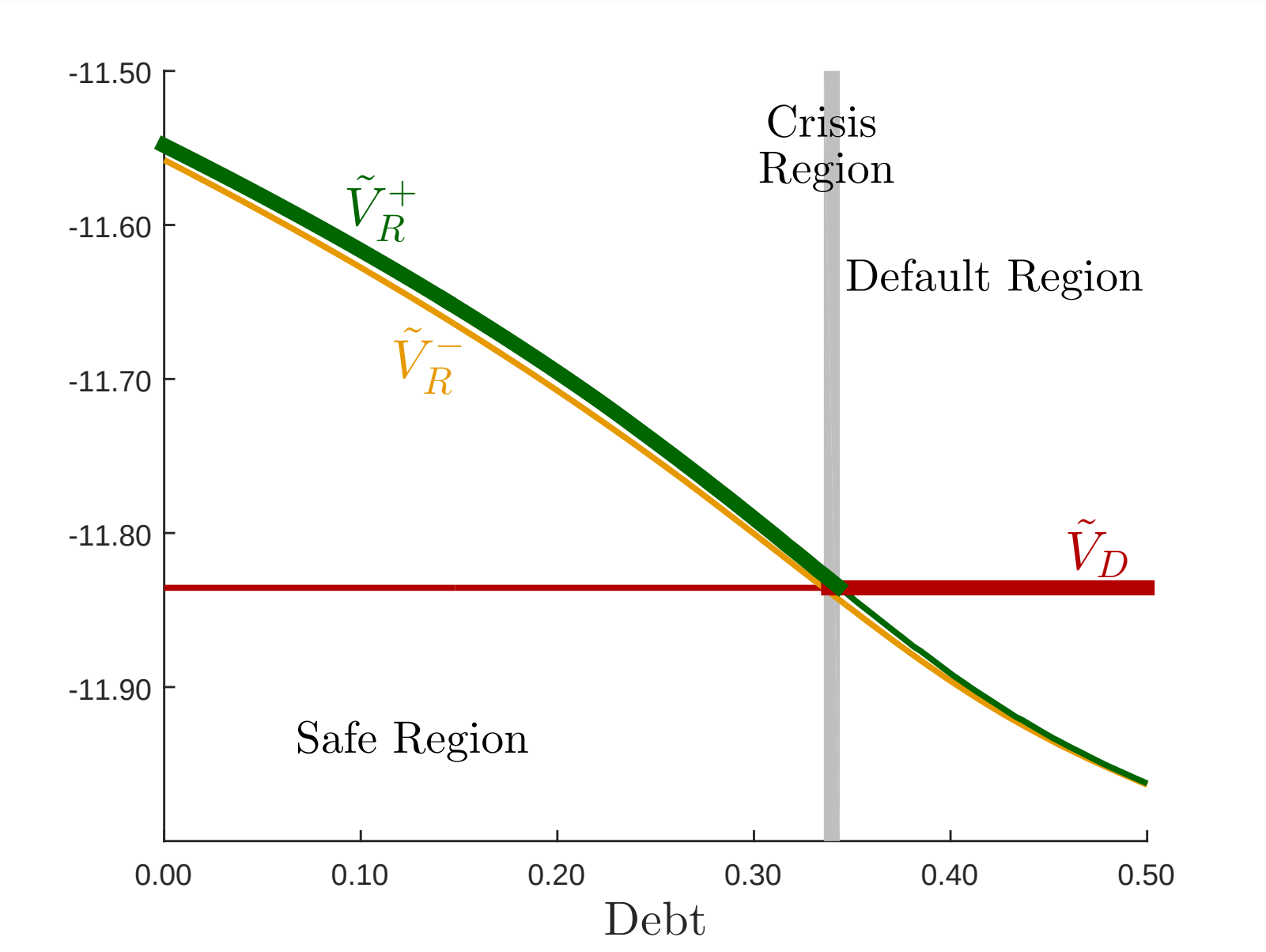
Value Functions: Flexible Wages



Value Functions: Flexible Wages



Value Functions: Flexible Wages - Equilibrium



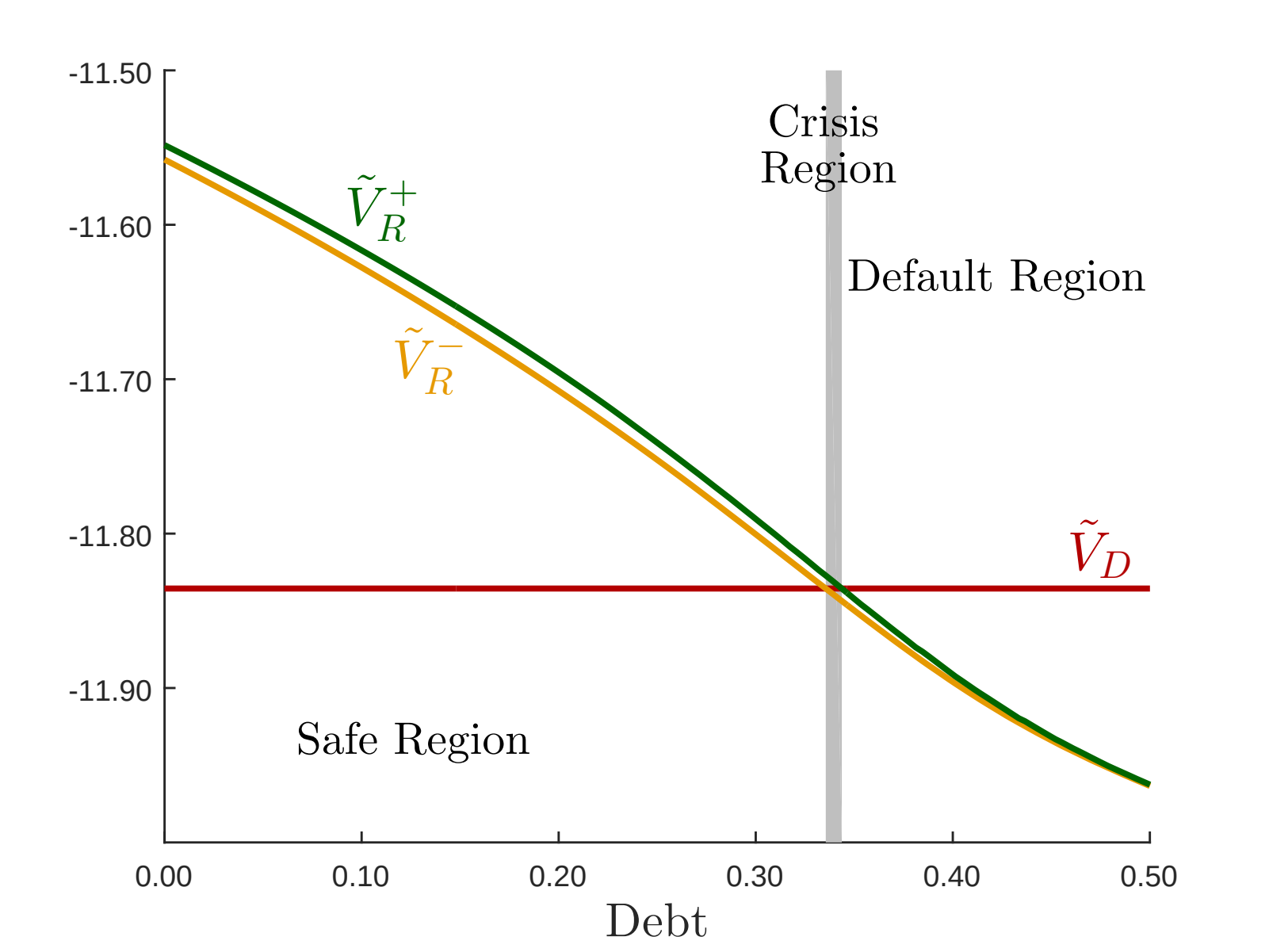
"Comparative Statics": Flexible vs. Sticky Wages

- Start by assuming that rigidity in place for *only one period*
    - Same continuation values and bond price schedule
- How do three zones change with $\overline{w_t} \equiv \overline{W}/\overline{e_t}$?

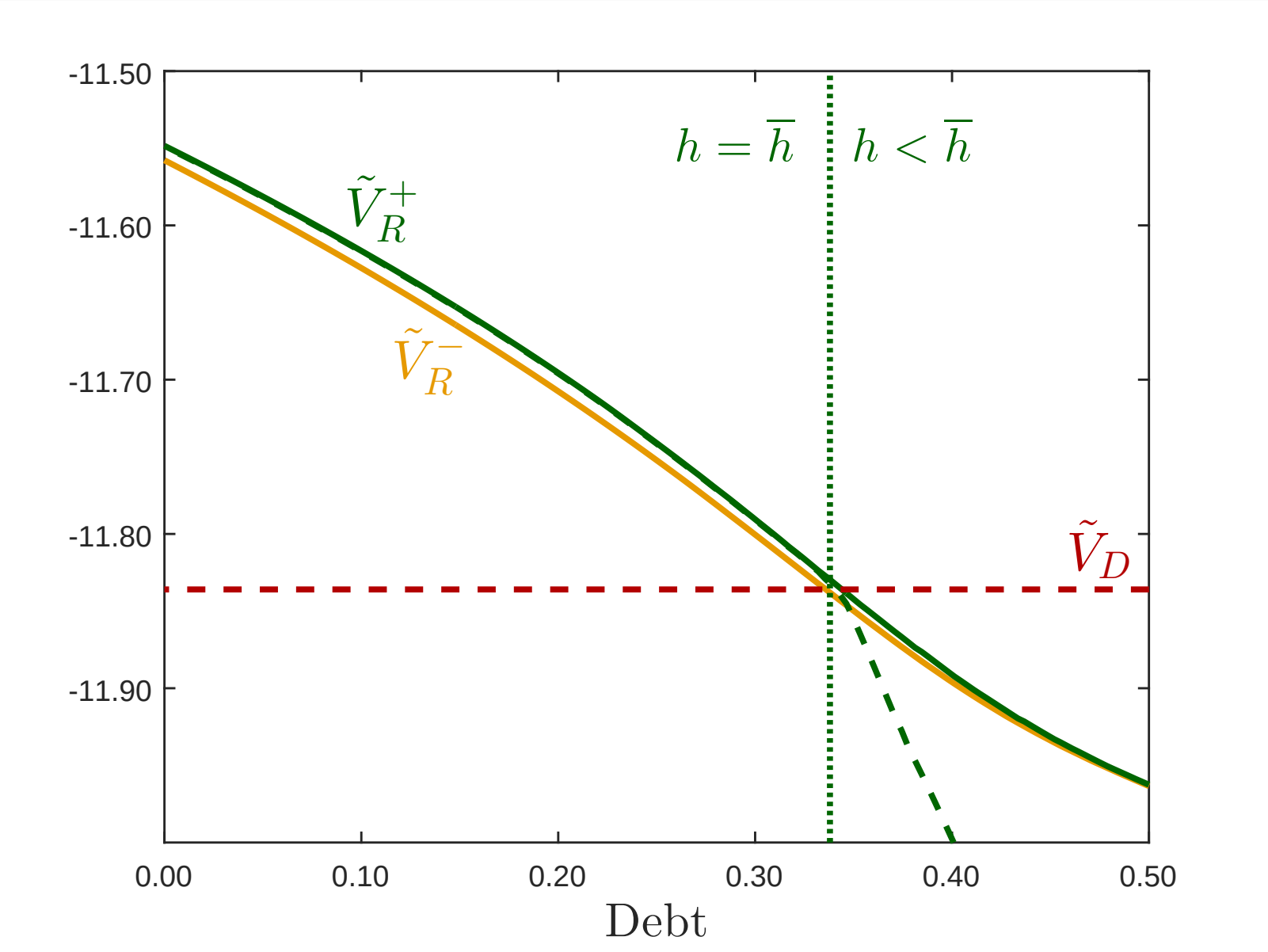
"Comparative Statics": Flexible vs. Sticky Wages

- Start by assuming that rigidity in place for *only one period*
    - Same continuation values and bond price schedule
- How do three zones change with $\overline{w_t} \equiv \overline{W}/\overline{e_t}$?
- Denote by $\tilde{V}(b, \mathbf{s}; \bar{w})$ current values

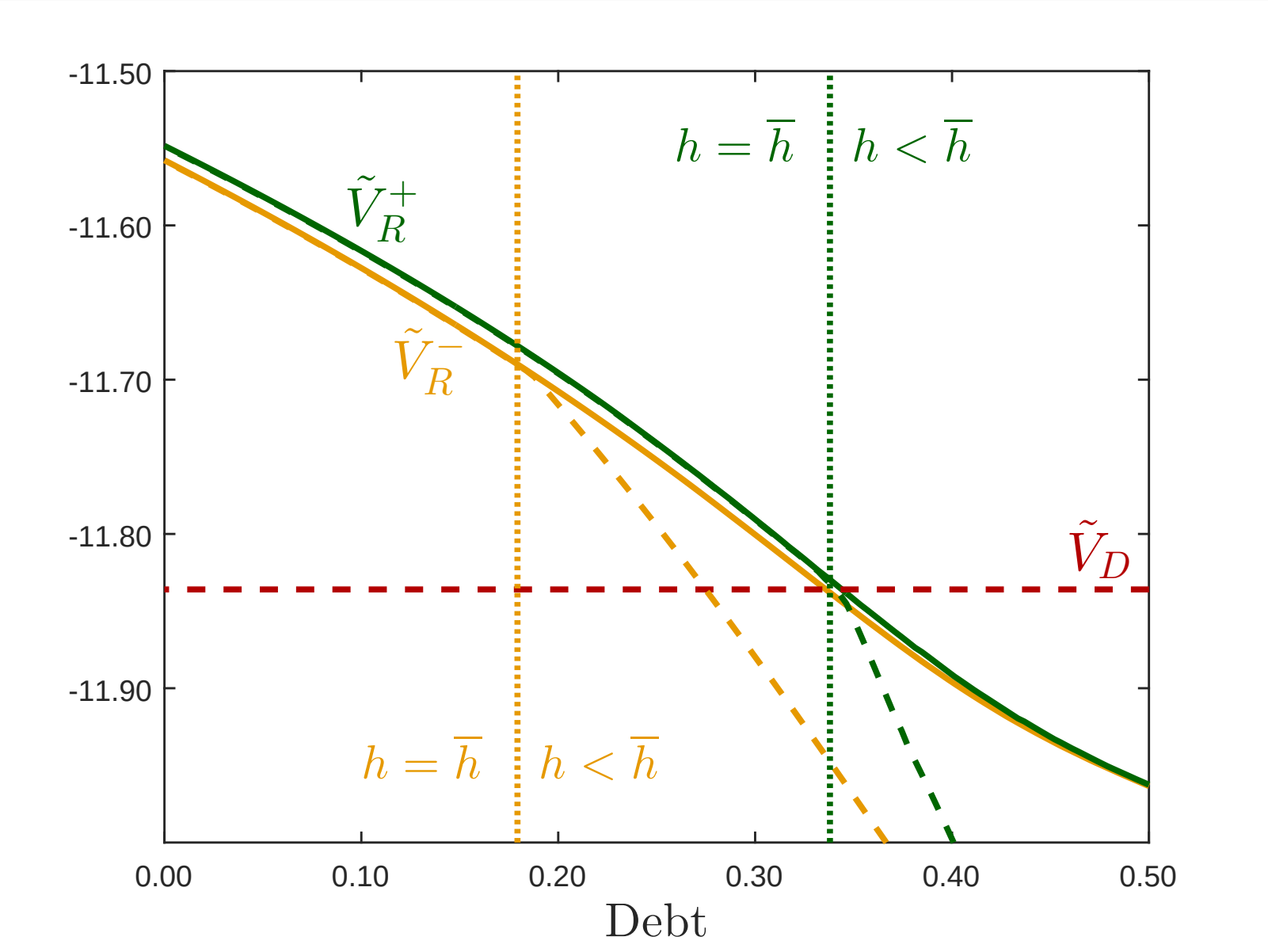
Recall crisis zone with flexible wages



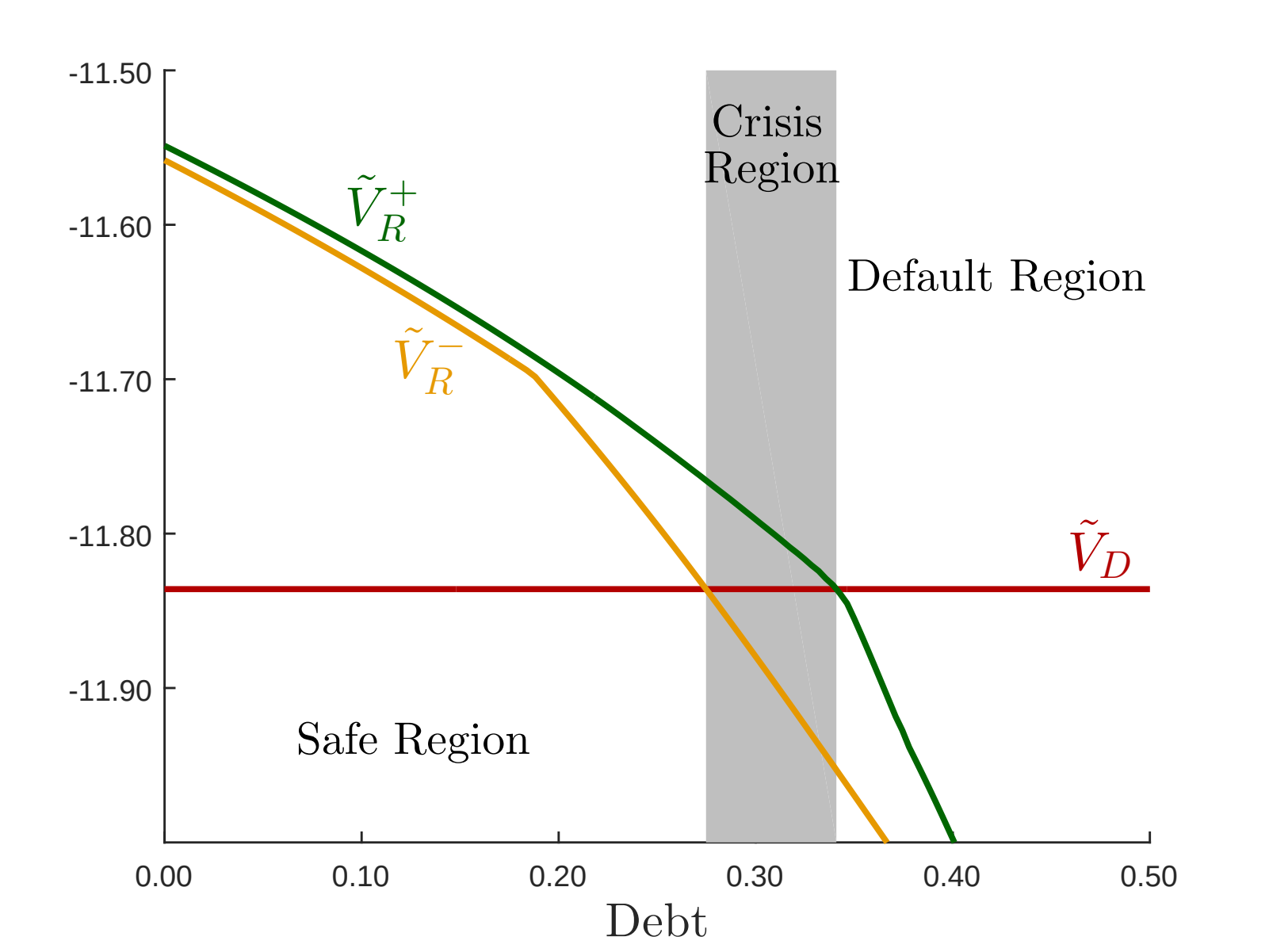
V^+ is reduced with $\overline{w}_{low}$



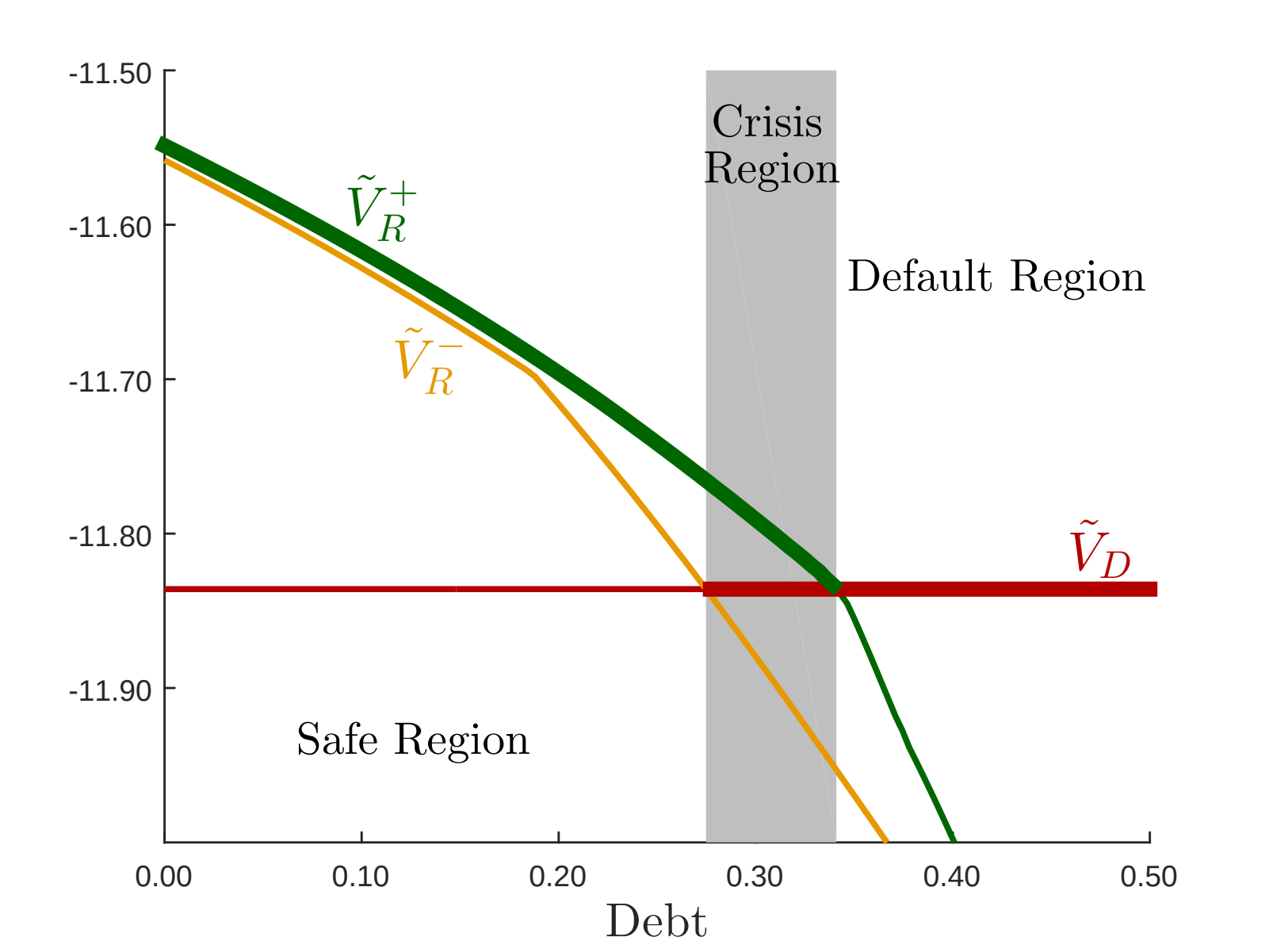
V^- is reduced by more than V^+



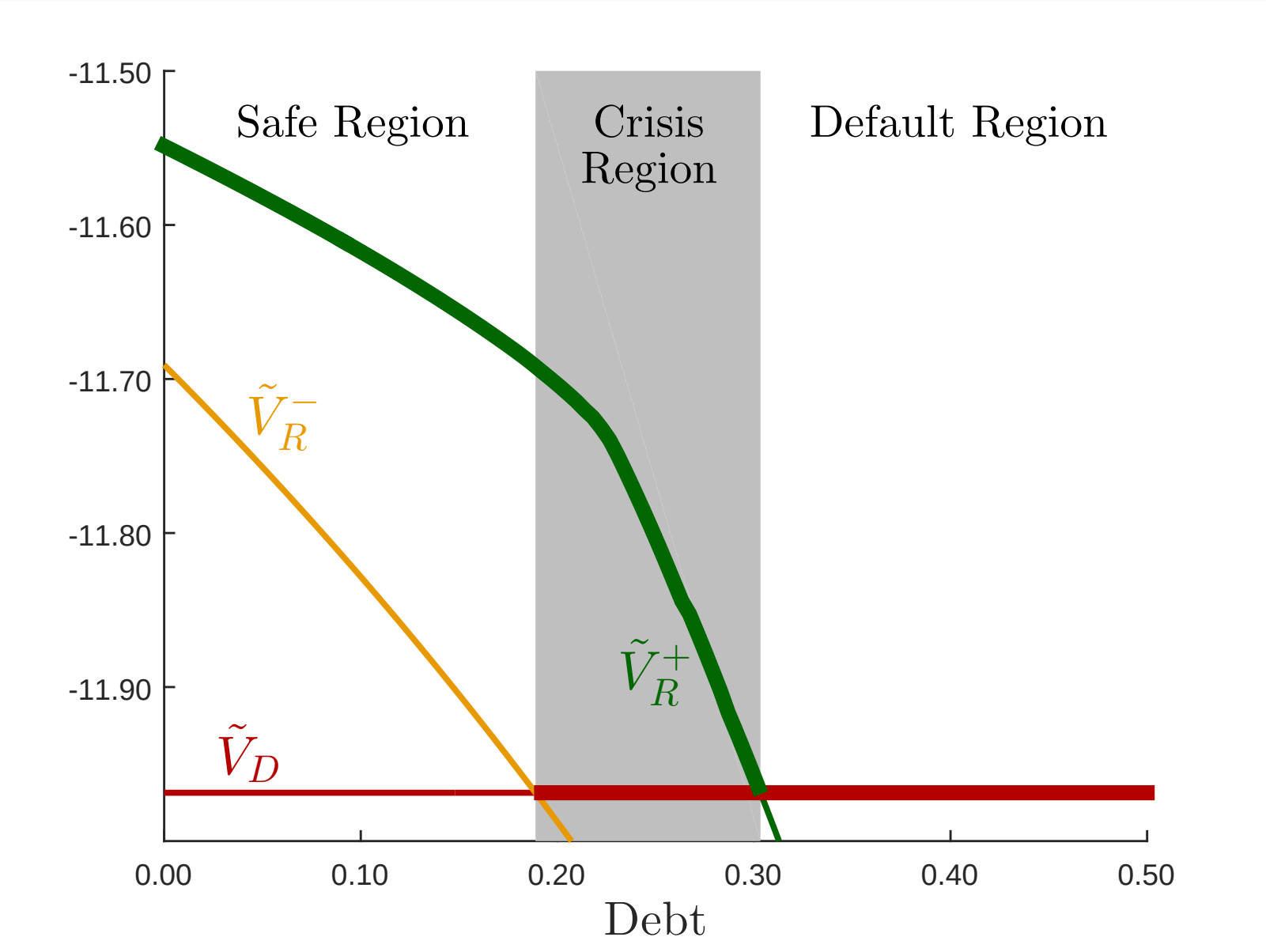
Increase in Crisis Region (Default Region Unaffected)



Increase in Crisis Region (Default Region Unaffected)



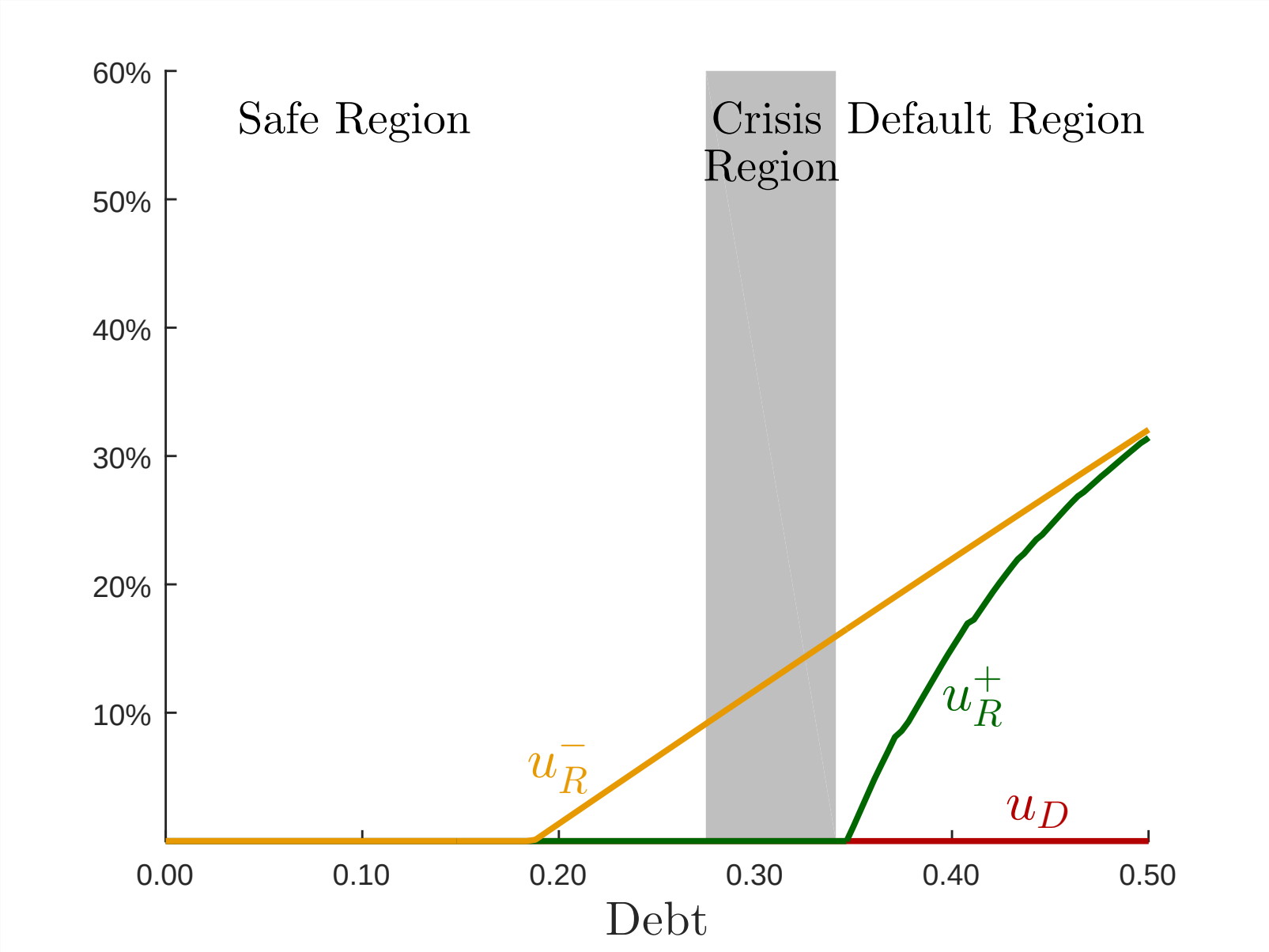
Increase in Crisis Region and Default Region



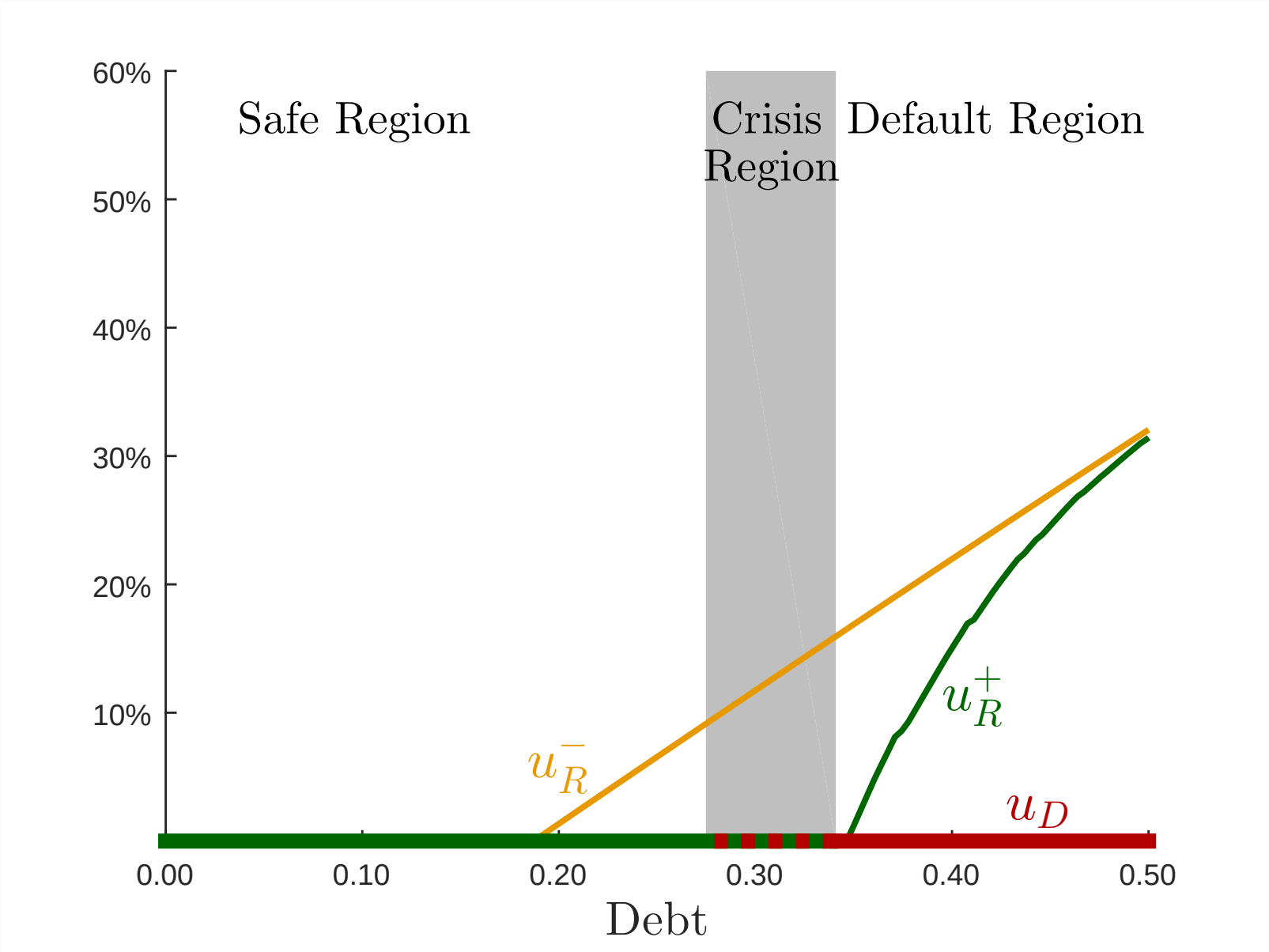
The role of unemployment

▸ Zones

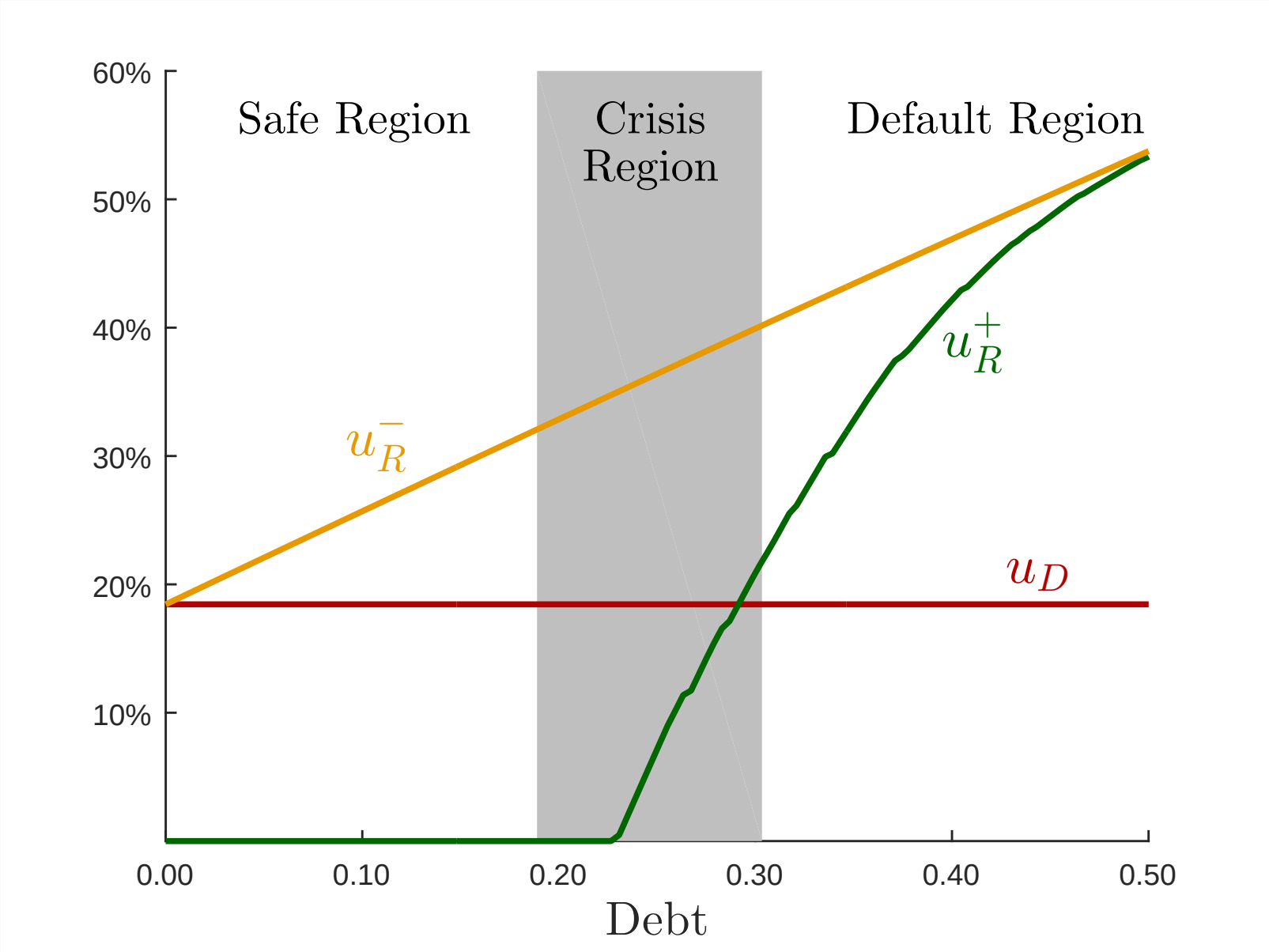
Unemployment with $\overline{w}_{low}$



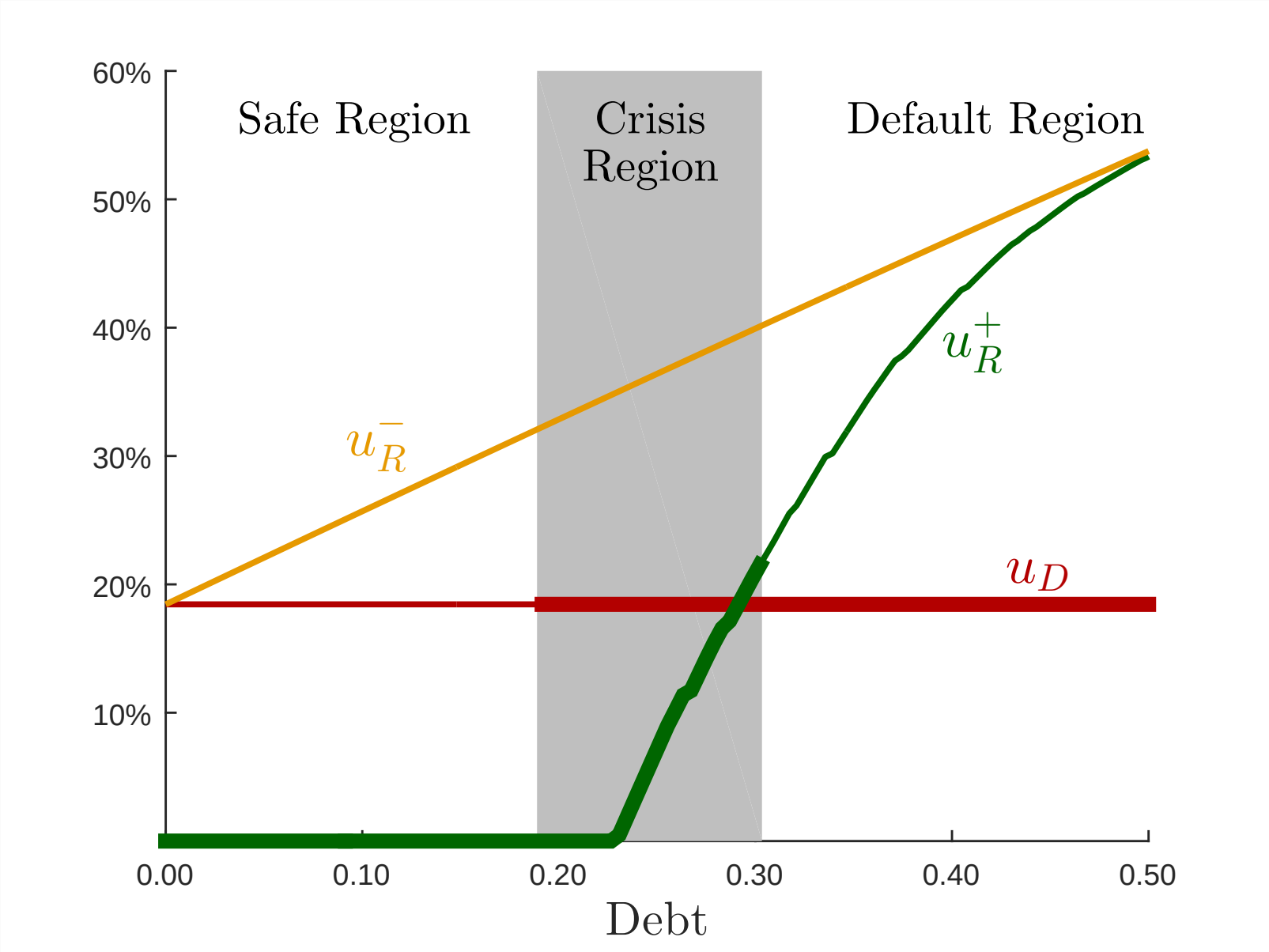
Unemployment with $\overline{w}_{low}$ - Equilibrium



Unemployment with $\overline{w}_{high}$



Unemployment with $\overline{w}_{high}$ - Equilibrium



Theoretical Characterization

Paper characterizes thresholds that separates three regions and how they depend on rigidities

Main result:

- When wage rigidity increases, safe region contracts
  $\Rightarrow$ Government vulnerable with lower levels of debt

Theoretical Characterization

Paper characterizes thresholds that separates three regions and how they depend on rigidities

Main result:

- When wage rigidity increases, safe region contracts
  $\Rightarrow$ Government vulnerable with lower levels of debt

Results can be generalized substantially:

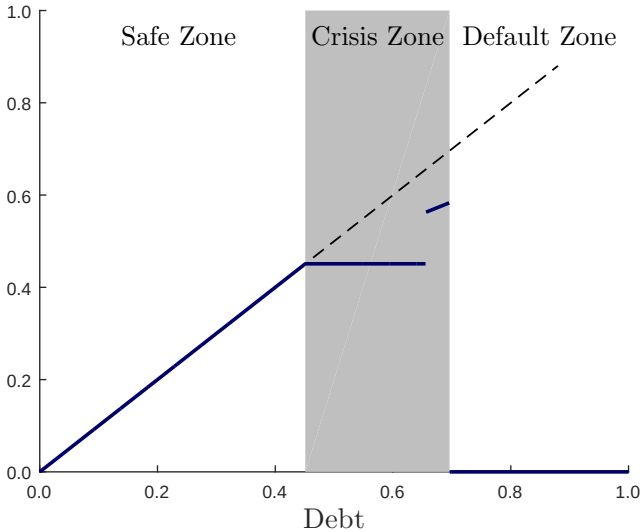
- Price rigidity, costs of depreciating exchange rate, nominal debt, maturity structure, and other monetary policy regimes

Simple Example: Gambling for redemption

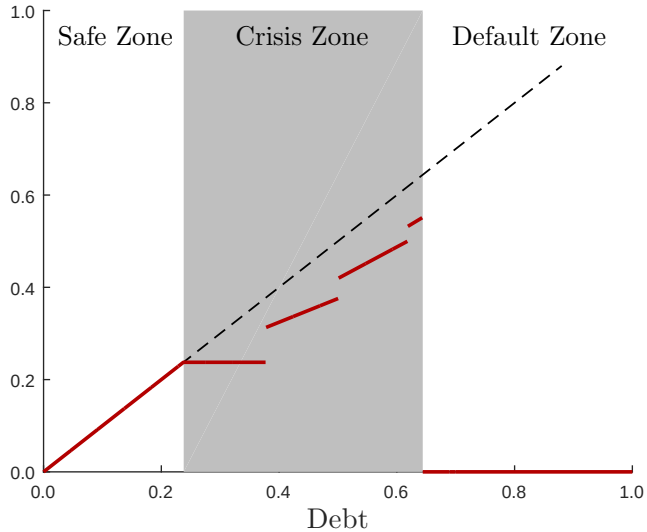
- Constant income, one-period debt $\beta R = 1$

  $\rightarrow$ Government eventually leaves crisis zone

Flexible exchange rate: b'



Fixed exchange rate: b'



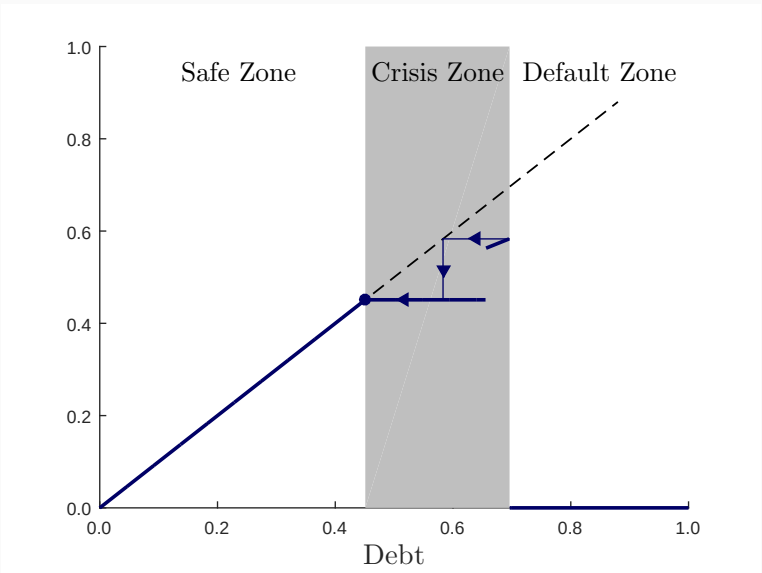
Government stays longer in crisis zone under fixed exchange rate

Simple Example: Gambling for redemption

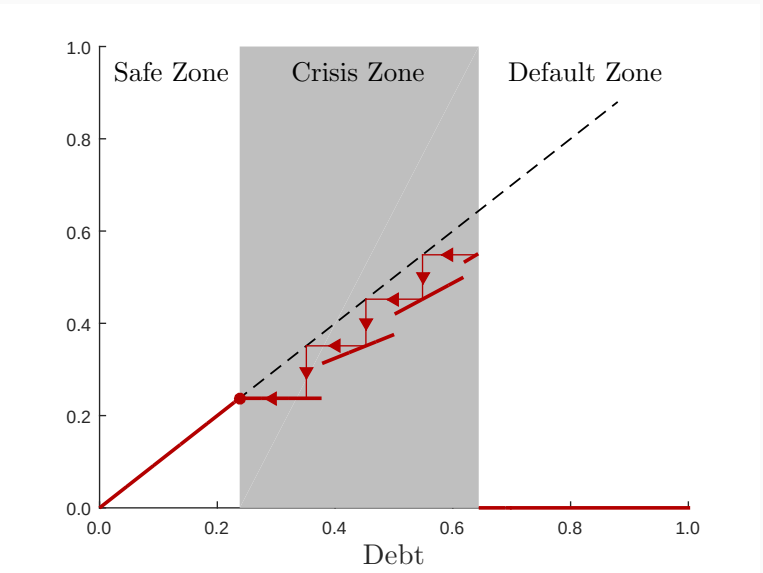
- Constant income, one-period debt $\beta R = 1$

  $\rightarrow$ Government eventually leaves crisis zone

Flexible exchange rate: b'



Fixed exchange rate: b'



Government stays longer in crisis zone under fixed exchange rate

Taking stock

- Under fixed, crisis zone is larger and government stays longer
  - Investors anticipate that government is more prone to default so they are more likely to run
  - Saving away can trigger recession today, take longer to exit

Taking stock

- Under fixed, crisis zone is larger and government stays longer
  - Investors anticipate that government is more prone to default so they are more likely to run
  - Saving away can trigger recession today, take longer to exit
- Next, quantitative simulations calibrated to Spain:
  - How important are rollover crises and how does this depend on the exchange rate regime?
  - How large are the welfare costs from lack of monetary independence?

Benchmark Calibration: Spain 1995-2015

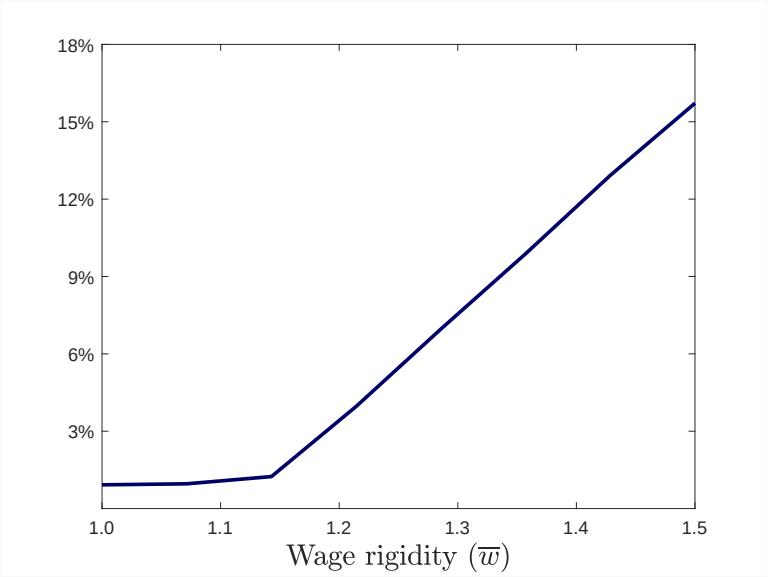
Parameter	Value		Description
$\overline{h}$	1.000		Normalization
σ	2.000		Standard risk aversion
ω	0.197		Share of tradable GDP
μ	1.000		Elasticity of substitution between T-NT$= 1/2$
ρ	0.777		Persistence of tradable income
σ_y	0.029		Std. of tradable output
α	0.750		Labor share in nontradable sector
r	0.020		German 6-year government bond yield
δ	0.141		Spanish bond maturity 6 years
ψ	0.240		Re-entry to financial markets probability
π	0.030		Sunspot probability
Calibration	Flexible	Fixed	Target
β	0.914	0.908	Average external debt-GDP ratio 29.05%
κ_0	0.101	0.315	Average spread 2.01%
κ_1	0.759	3.273	Standard deviation interest rate spread 1.42%
$\overline{w}$	-	2.493	Δ unemployment rate 2.00%

Benchmark Calibration: Spain 1995-2015

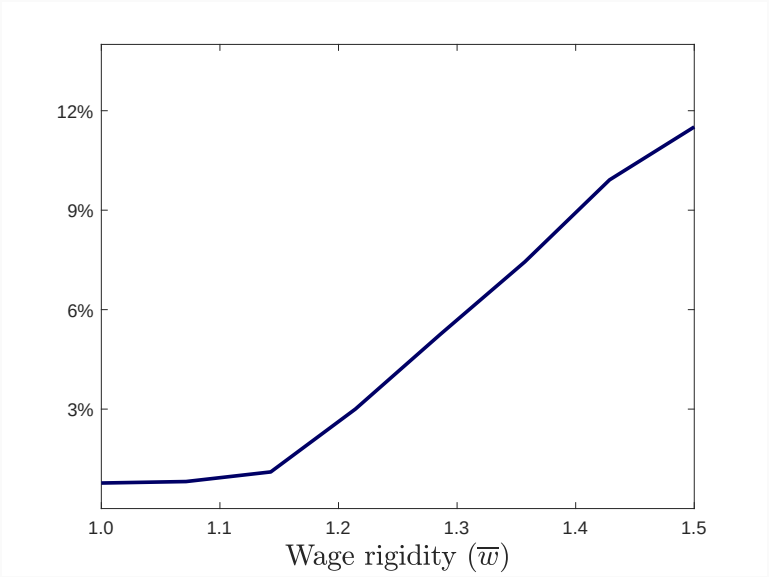
Parameter	Value		Description
$\overline{h}$	1.000		Normalization
σ	2.000		Standard risk aversion
ω	0.197		Share of tradable GDP
μ	1.000		Elasticity of substitution between T-NT$= 1/2$
ρ	0.777		Persistence of tradable income
σ_y	0.029		Std. of tradable output
α	0.750		Labor share in nontradable sector
r	0.020		German 6-year government bond yield
δ	0.141		Spanish bond maturity 6 years
ψ	0.240		Re-entry to financial markets probability
π	0.030		Sunspot probability
Calibration	Flexible	Fixed	Target
β	0.914	0.908	Average external debt-GDP ratio 29.05%
κ_0	0.101	0.315	Average spread 2.01%
κ_1	0.759	3.273	Standard deviation interest rate spread 1.42%
$\overline{w}$	-	2.493	Δ unemployment rate 2.00%

Quantitative Simulations: Exposure to Rollover Crises

Defaults due to Rollover

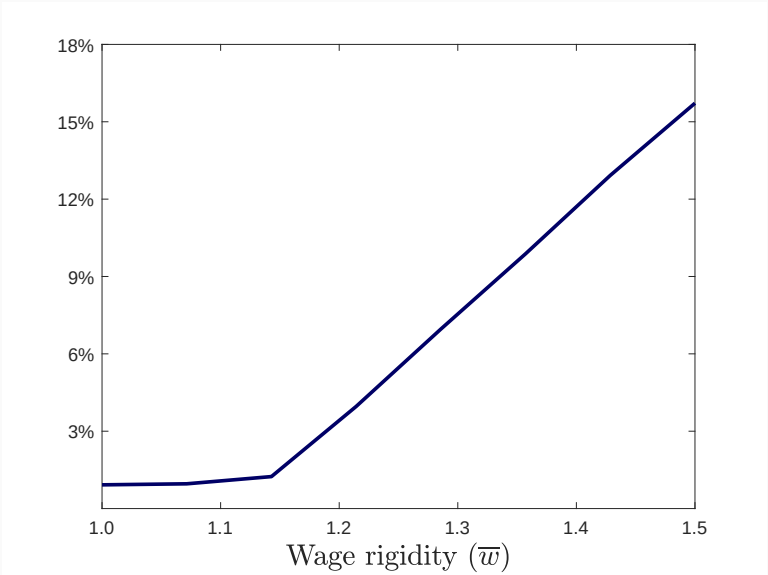


Time in Crisis Zone

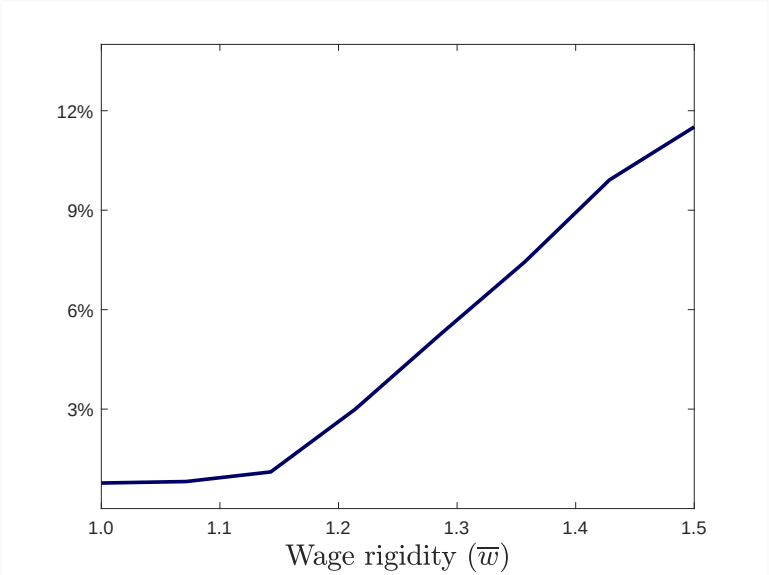


Quantitative Simulations: Exposure to Rollover Crises

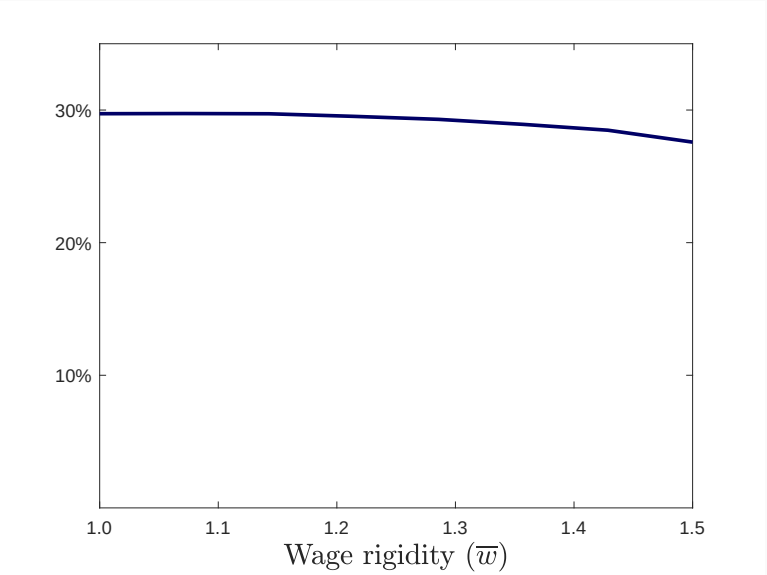
Defaults due to Rollover



Time in Crisis Zone



Average Debt



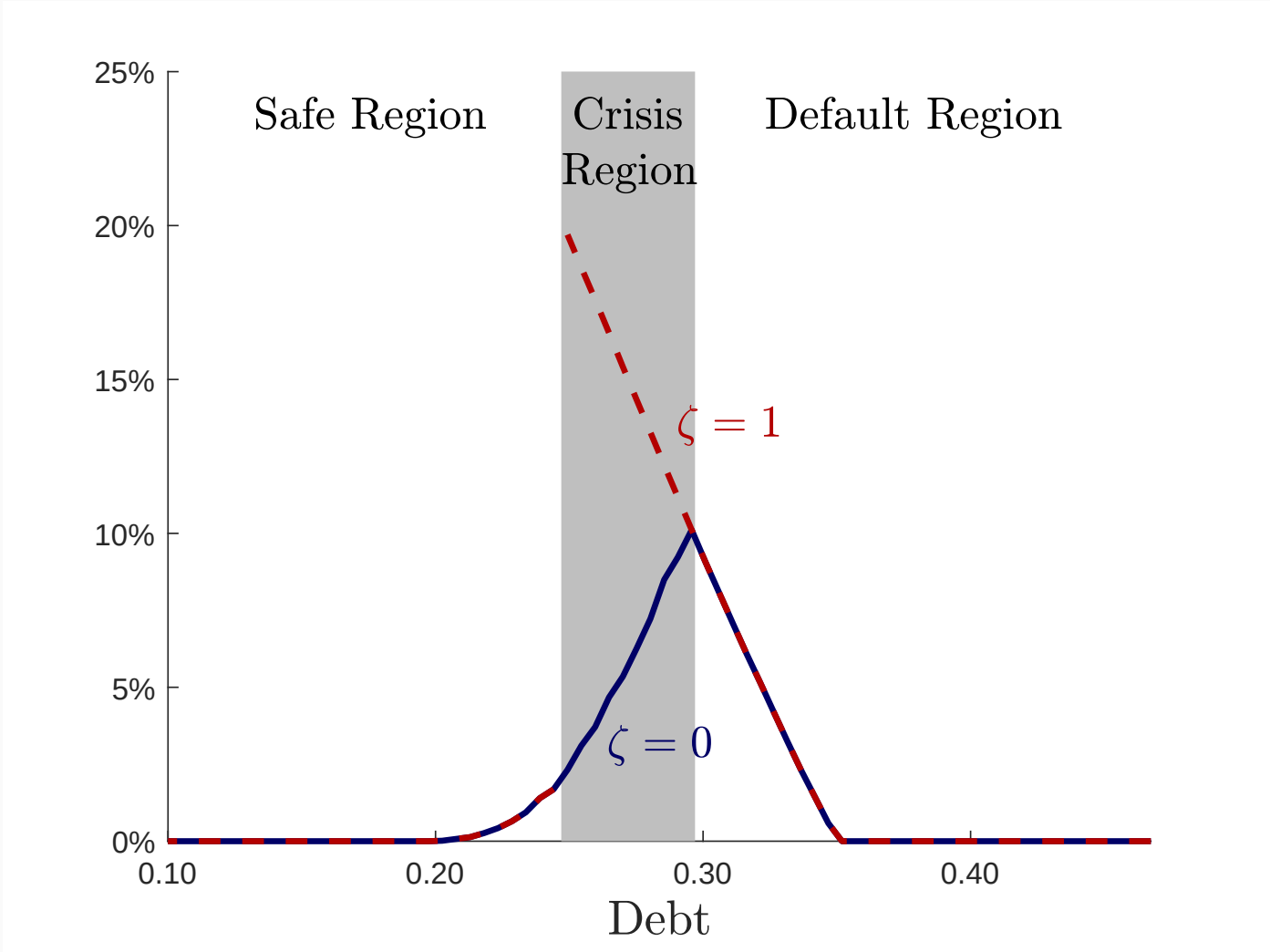
Simulations: Fixed vs. Flexible (recalibrated)

Statistic	Data	Flexible	Fixed
Average spread (%)	2.01	2.46	1.43
Average debt-income (%)	29.05	29.73	31.33
Spread volatility (%)	1.42	1.33	1.60
Unemployment Increase (%)	2.00	0.00	1.83
$\rho(y, c)$	0.98	0.97	0.94
$\rho(y, spread)$	0.38	0.87	0.77
$\sigma(\hat{c})/\sigma(\hat{y})$	1.10	1.55	1.33
Fraction of time in crisis region (%)	-	0.77	2.59
Fraction of defaults due to rollover crisis (%)	-	0.92	6.53

▸ Sunspot probability

Welfare Cost of a Monetary Union

Benefits from a one-period devaluation for different b



The Path to Spain's Rollover Crisis

Simulation of Spain 2000-2010

- Start economy with 2000's external debt
- Feed income shocks through 2000-2012
- Feed sunspot shocks

The Path to Spain's Rollover Crisis

Simulation of Spain 2000-2010

- Start economy with 2000's external debt
- Feed income shocks through 2000-2012
- Feed sunspot shocks

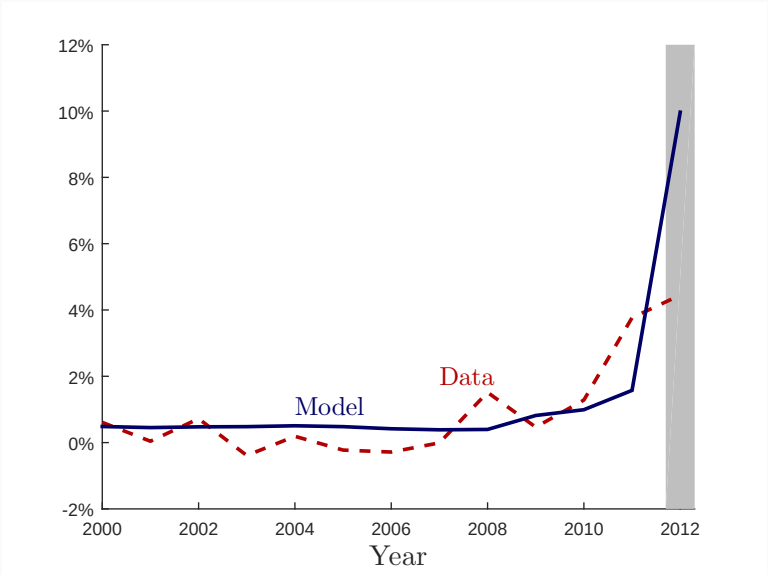
Predictions of the model:

1. Spain falls in crisis region in 2012
2. Exiting the Euro, would take Spain to safe zone
3. About 60% of welfare losses from lack of monetary independence can be eliminated by a lender of last resort

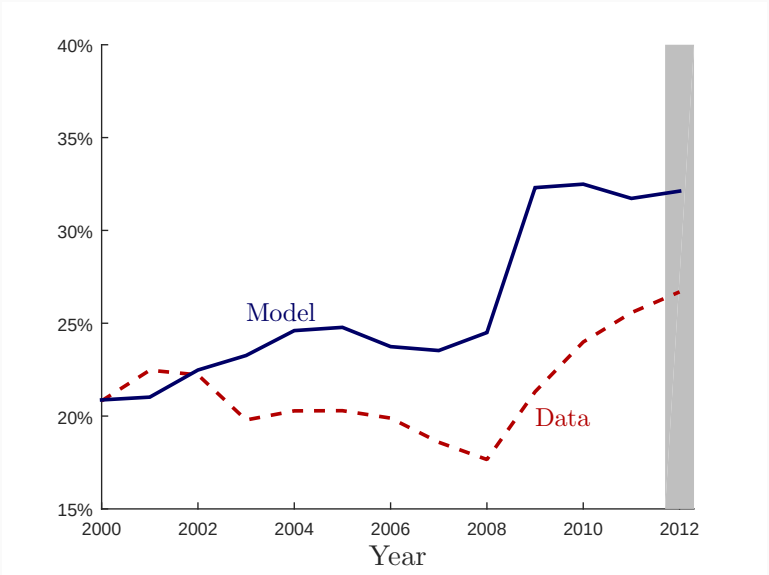
Abstract from gains of monetary union

The Path to Spain's Rollover Crisis

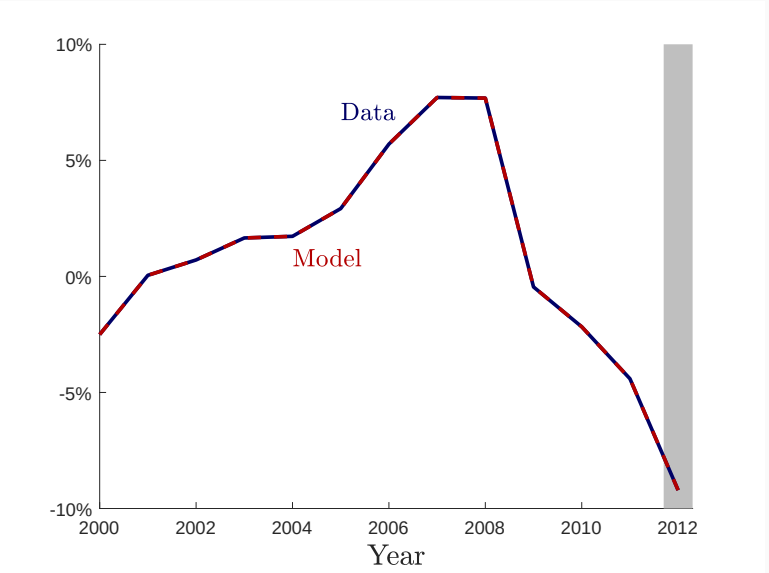
Spread



Debt

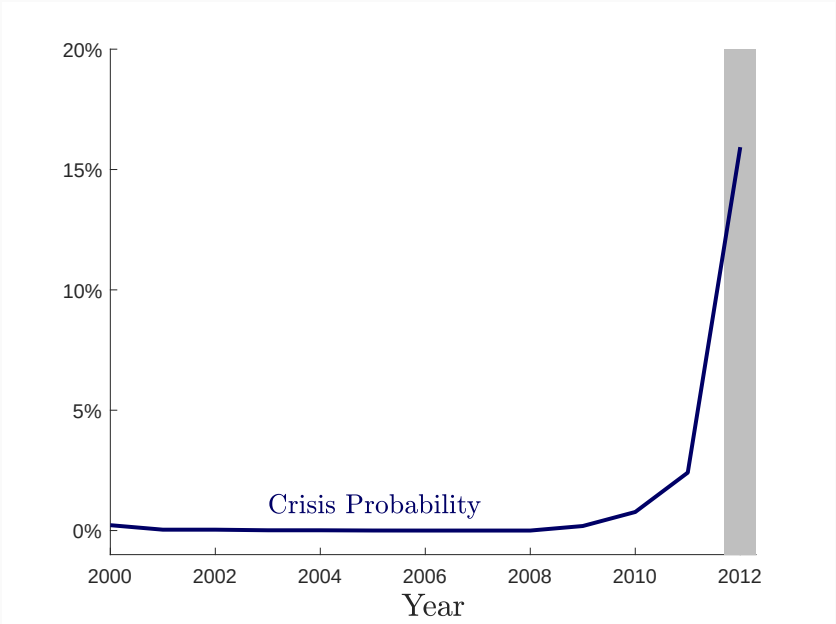


Income process

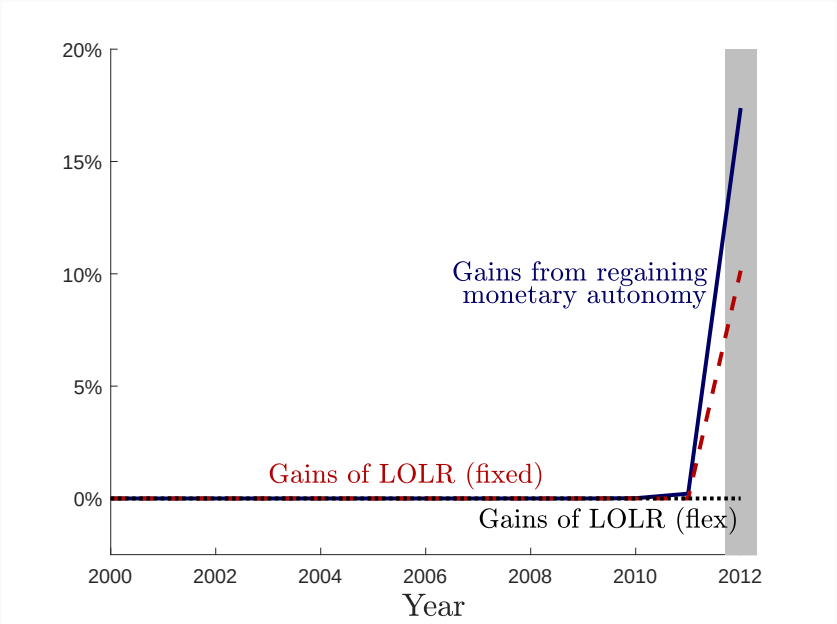


The Path to Spain's Rollover Crisis

Probability Crisis Zone



Welfare (one-period)



Conclusion

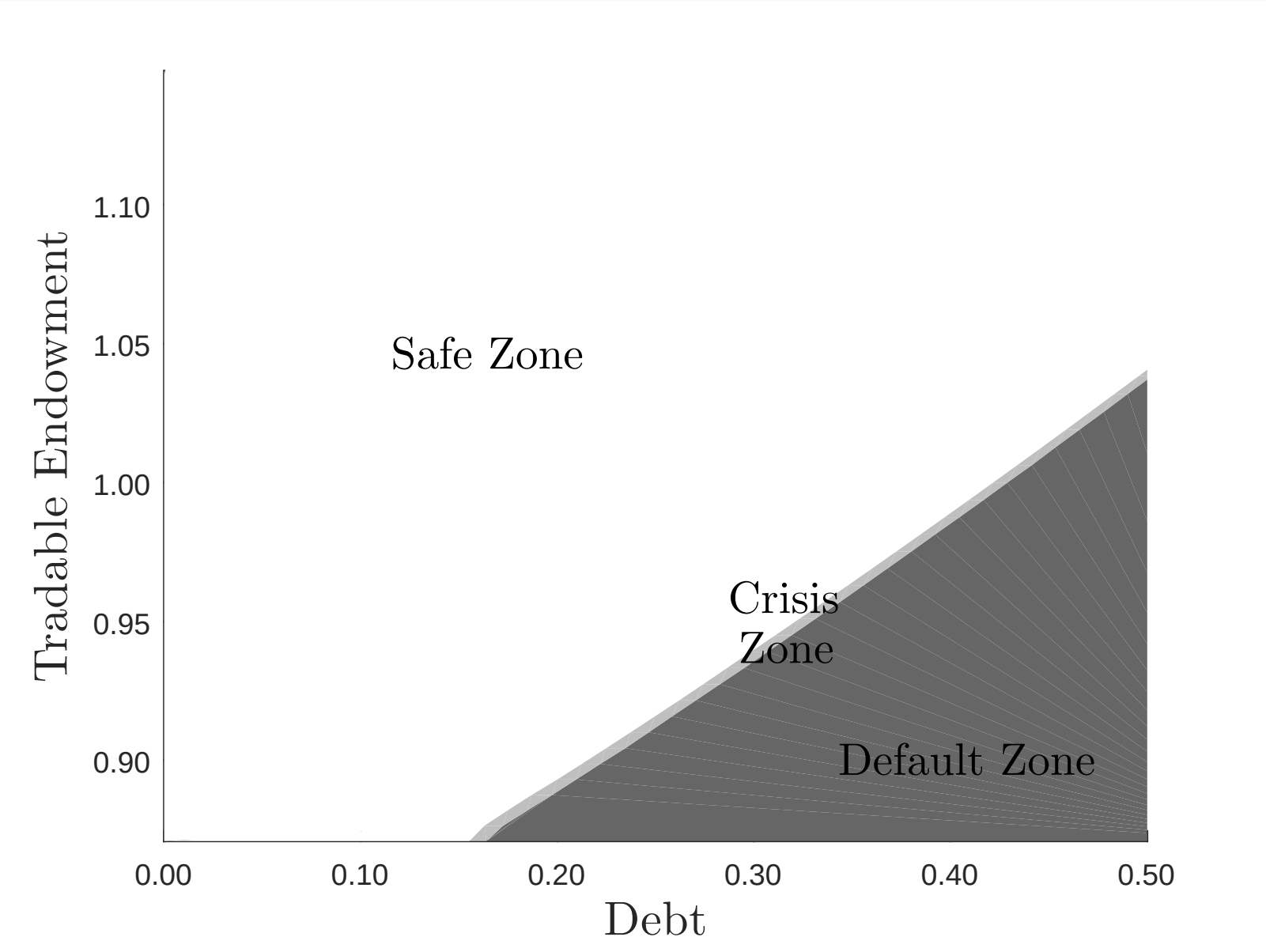
- Inability to use monetary policy for macroeconomic stabilization increases the vulnerability to a rollover crisis
    - Uncover new cost from monetary unions
- Lender of last resort critical for monetary unions and economies with limited exchange rate flexibility
    - For economies with flexible exchange rate, moral hazard likely to outweigh benefits

Conclusion

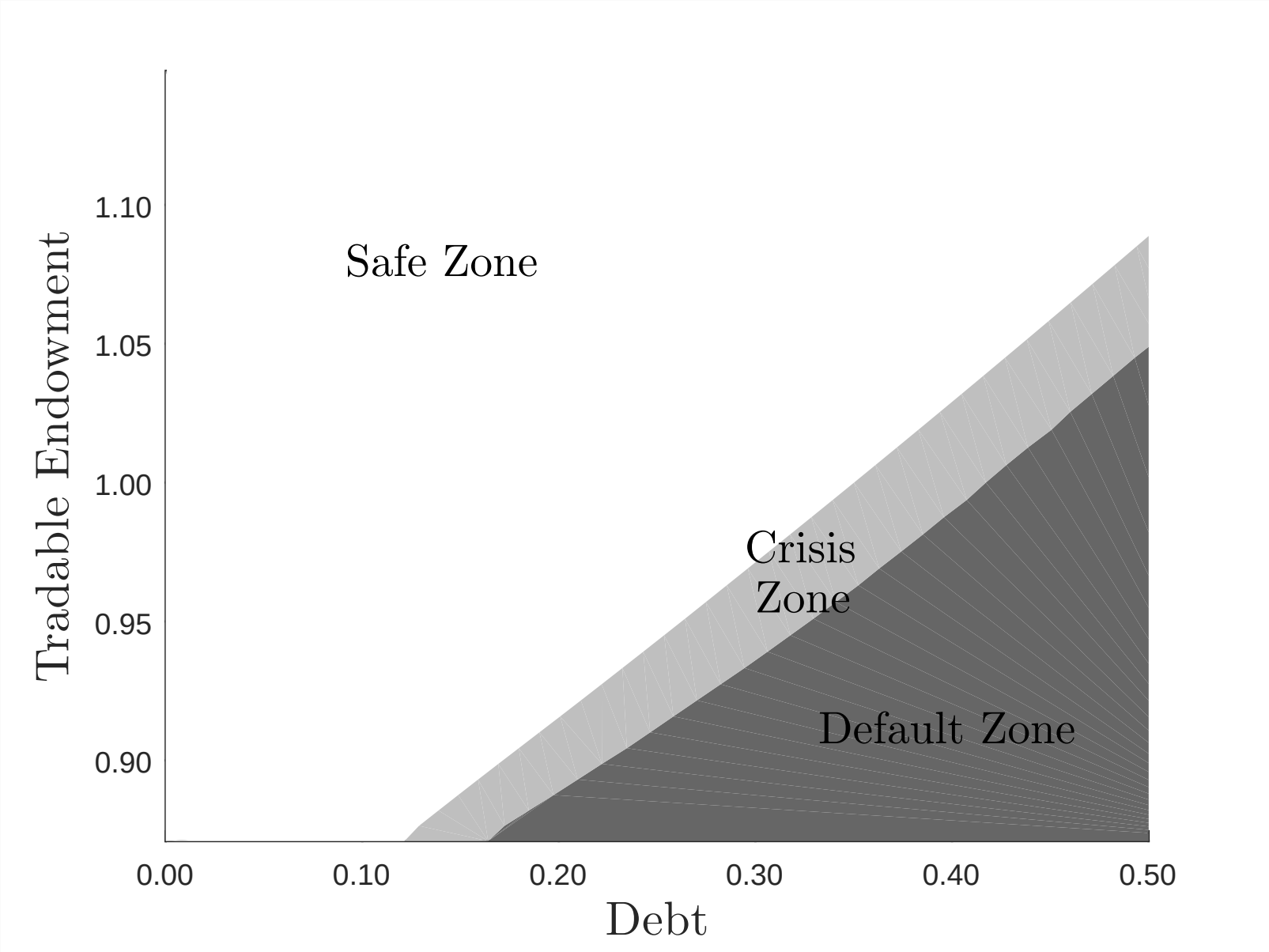
- Inability to use monetary policy for macroeconomic stabilization increases the vulnerability to a rollover crisis
    - Uncover new cost from monetary unions
- Lender of last resort critical for monetary unions and economies with limited exchange rate flexibility
    - For economies with flexible exchange rate, moral hazard likely to outweigh benefits

EXTRAS

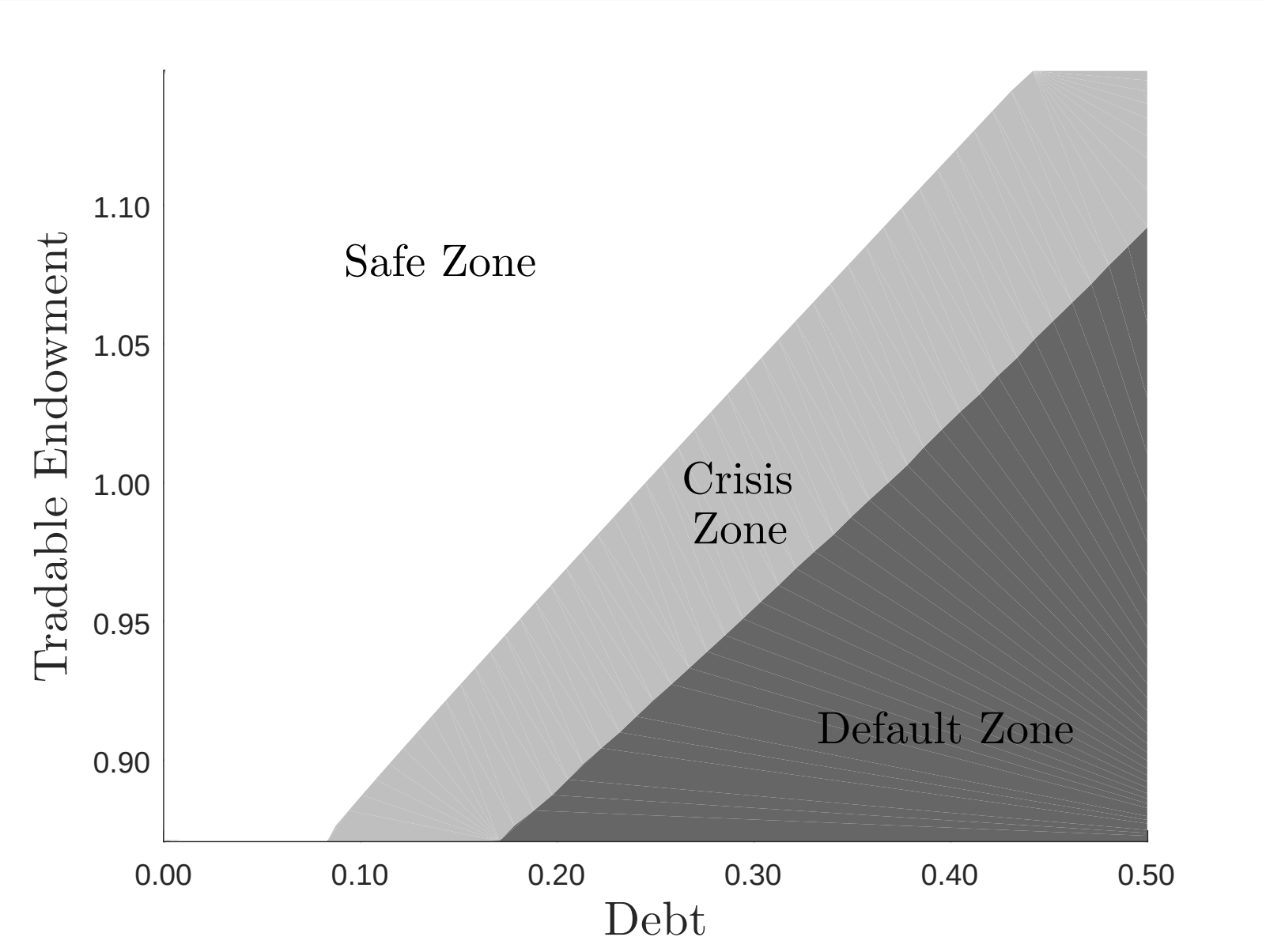
Three Zones: Flexible Wages



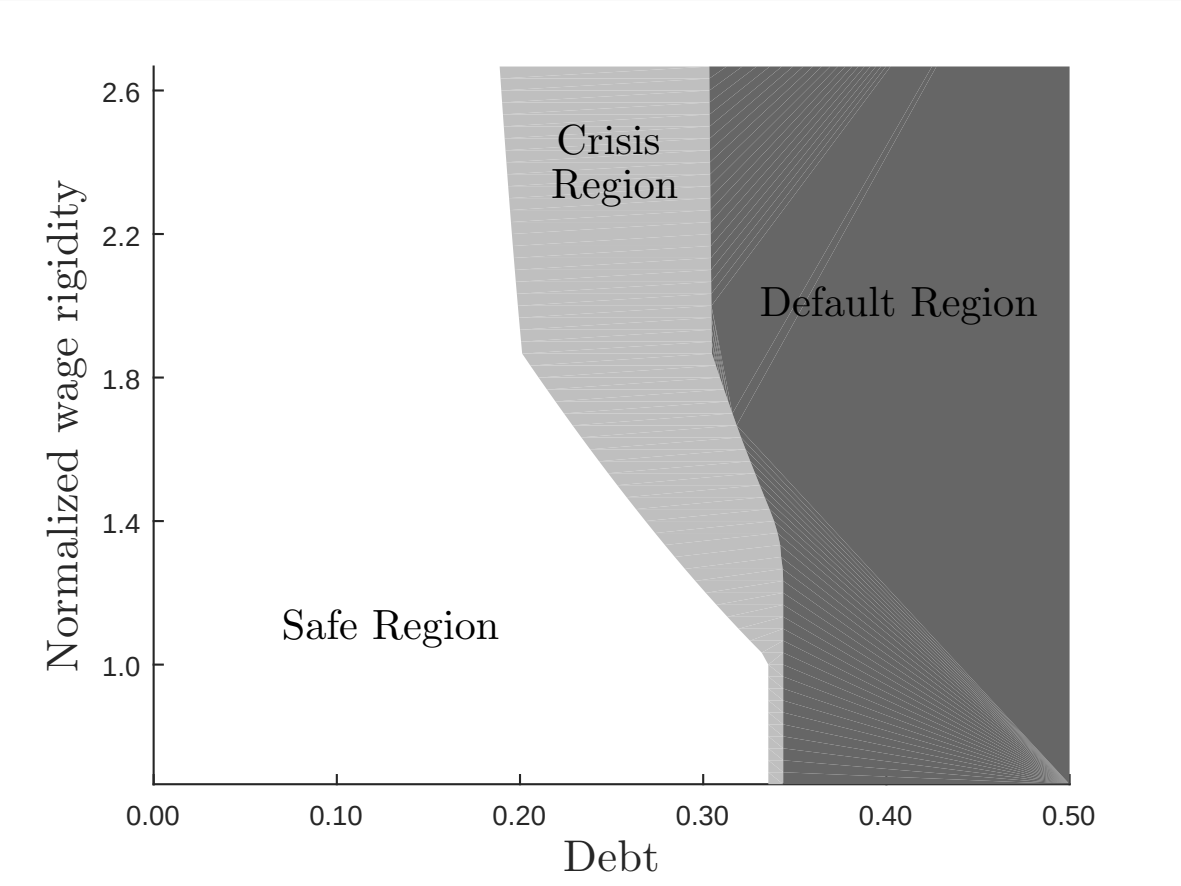
Three Zones: Low Wage Rigidity



Three Zones: High Wage Rigidity



Safe region, crisis region, and default regions



▸ Back

Markov Perfect Equilibrium

A *Markov perfect equilibrium* is defined by value functions $\{V(b, \mathbf{s}), V_R(b, \mathbf{s}), V_D(y^T)\}$, policy functions $\{d(b, \mathbf{s}), c^T(b, \mathbf{s}), b'(b, \mathbf{s}), h(b, \mathbf{s})\}$, and a bond price schedule $q(b', b, \mathbf{s})$ such that

i. Given the bond price schedule, the policy functions solve the government problem

ii. The bond price schedule satisfies no arbitrage given future government policies

▸ Back

Sensitivity to Sunspot Probability

Sunspot probability	$\pi = 3\%$		$\pi = 10\%$		$\pi = 20\%$	
(percentage %)	Flexible	Fixed	Flexible	Fixed	Flexible	Fixed
Average spread	2.46	1.43	2.45	1.47	2.46	1.53
Average debt-income	29.73	31.33	29.58	29.29	29.37	28.53
Spread volatility	1.33	1.60	1.30	1.72	1.31	1.75
Unemployment Increase	0.00	1.83	0.00	1.80	0.00	1.35
Fraction of time in crisis region	0.77	2.59	0.68	1.93	0.58	1.41
Fraction of defaults due to rollover crisis	0.92	6.53	3.70	11.80	6.20	19.80

▸ Back

Long-Run Simulation Statistics: Fixed vs. Flexible

Statistic	Data	Flexible	Fixed
Average spread (%)	2.01	2.46	1.43
Average debt-income (%)	29.05	29.73	31.33
Spread volatility (%)	1.42	1.33	1.60
Unemployment Increase (%)	2.00	0.00	1.83
$\rho(y, c)$	0.98	0.97	0.94
$\rho(y, spread)$	0.38	0.87	0.77
$\sigma(\hat{c})/\sigma(\hat{y})$	1.10	1.55	1.33
Fraction of time in crisis region (%)	-	0.77	2.59
Fraction of defaults due to rollover crisis (%)	-	0.92	6.53

Sensitivity to Sunspot Probability

Sunspot probability	$\pi = 3\%$		$\pi = 10\%$		$\pi = 20\%$	
(percentage %)	Flexible	Fixed	Flexible	Fixed	Flexible	Fixed
Average spread	2.46	1.43	2.45	1.47	2.46	1.53
Average debt-income	29.73	31.33	29.58	29.29	29.37	28.53
Spread volatility	1.33	1.60	1.30	1.72	1.31	1.75
Unemployment Increase	0.00	1.83	0.00	1.80	0.00	1.35
Fraction of time in crisis region	0.77	2.59	0.68	1.93	0.58	1.41
Fraction of defaults due to rollover crisis	0.92	6.53	3.70	11.80	6.20	19.80

Three Zones

- Safe zone (govt. always repays)

$$\mathcal{S} \equiv \left\{ (b, y^T) : \quad V_D(y^T) \leq V_R^-(b, y^T) \right\}$$

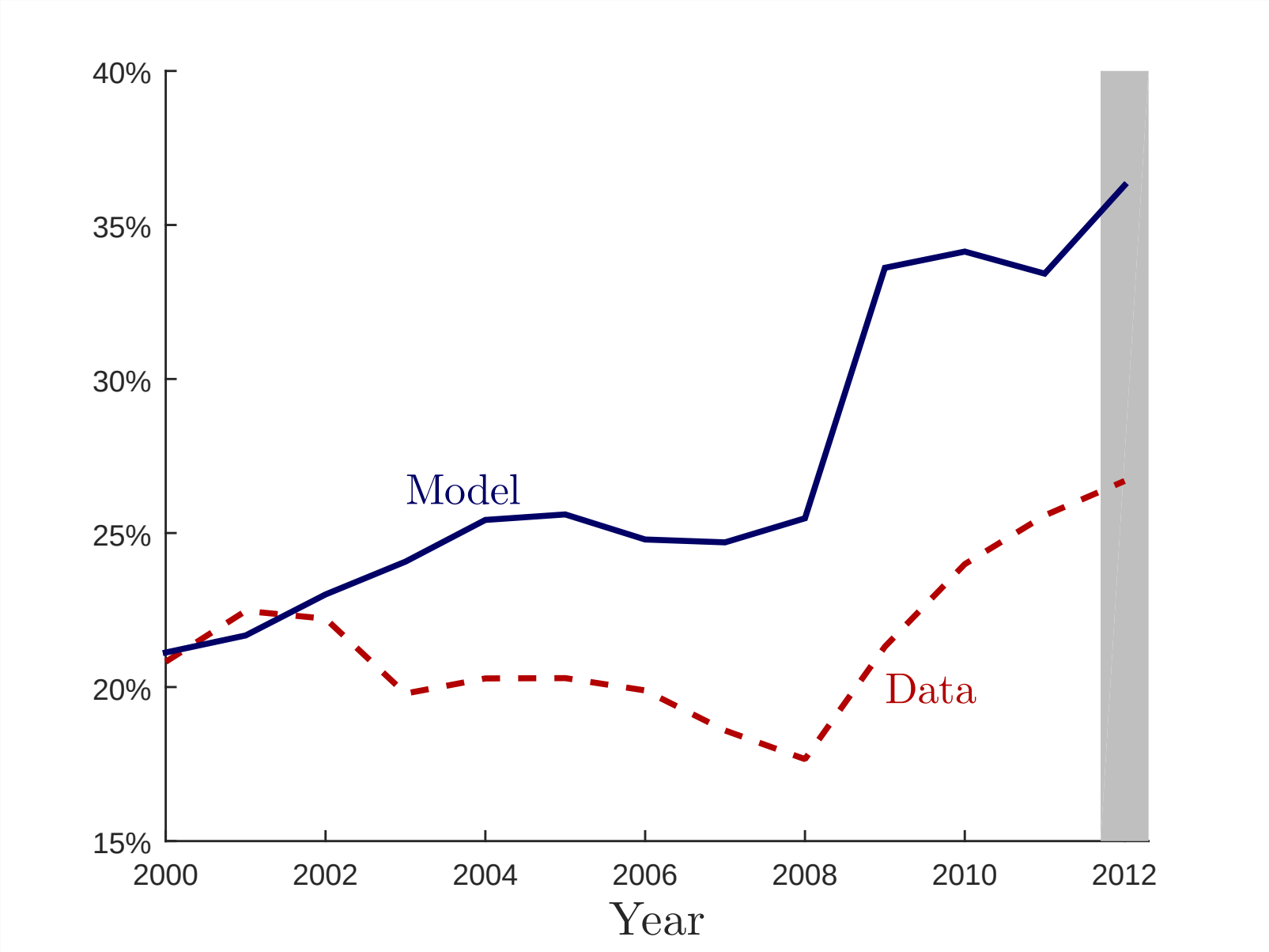
- Default zone (govt. always defaults)

$$\mathcal{D} \equiv \left\{ (b, y^T) : \quad V_D(y^T) > V_R^+(b, y^T) \right\}$$

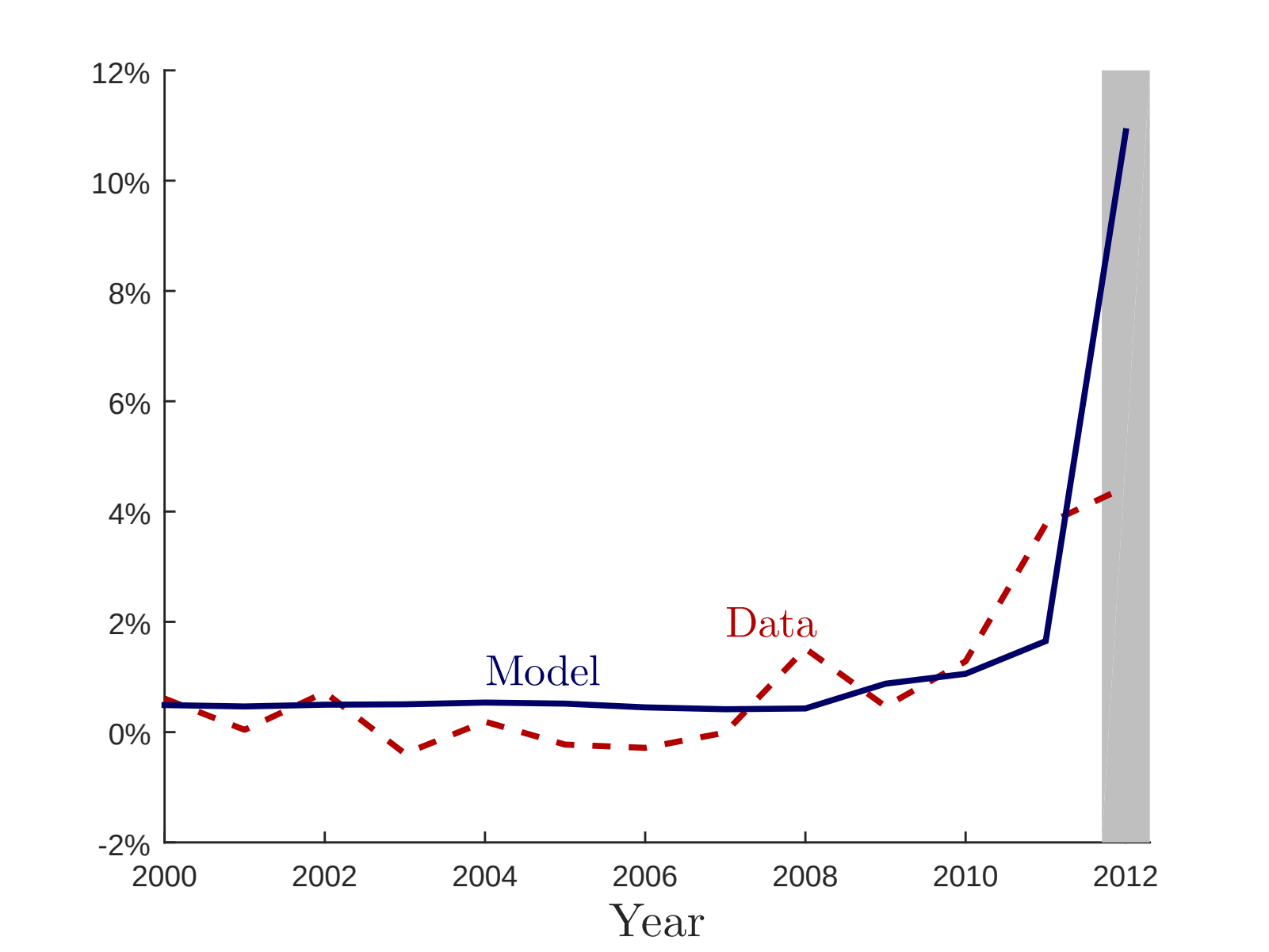
- Crisis zone (govt. repayment depends on beliefs)

$$\mathcal{C} \equiv \left\{ (b, y^T) : \quad V_D(y^T) > V_R^-(b, y^T) \right.$$
$$\left. \& \quad V_D(y^T) \leq V_R^+(b, y^T) \right\}$$

Debt-GDP ratio: Data vs Model



Interest rate spreads: Data vs Model



Definition: Competitive eq. given govt. policies

Given b_0, and govt. policy $\{e_t, b_{t+1}, d_t\}_{t=0}^{\infty}$, a *competitive equilibrium* is given by households and firms' allocations $\{c_t^T, c_t^N, h_t\}_{t=0}^{\infty}$, and prices $\{P_t^N, W_t, q_t\}_{t=0}^{\infty}$, such that

i. Households and firms solve their optimization problems

ii. Government budget constraint holds

iii. Bond pricing schedule satisfies investors' optimality

iv. NT market clears $c_t^N = y_t^N$ and resource constraint for T

$$c_t^T - q_t \left(b_{t+1} - (1-\delta)b_t\right) = y_t^T - \delta(1-d_t)b_t$$

v. Labor market equilibrium conditions hold

Markov Perfect Equilibrium

A *Markov perfect equilibrium* is defined by value functions $\{V(b, \mathbf{s}), V_R(b, \mathbf{s}), V_D(y^T)\}$, policy functions $\{d(b, \mathbf{s}), c^T(b, \mathbf{s}), b'(b, \mathbf{s}), h(b, \mathbf{s})\}$, and a bond price schedule $q(b', b, \mathbf{s})$ such that

i. Given the bond price schedule, the policy functions solve the government problem

ii. The bond price schedule satisfies no arbitrage given future government policies

Safe and Default Zones and $\bar{w}$

Proposition. *(Safe zone shrinks with $\bar{w}$)*
There exist a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, the safe zone compresses $\mathcal{S}(\bar{w}_2) \subset \mathcal{S}(\bar{w}_1)$.

Safe and Default Zones and $\bar{w}$

Proposition. *(Safe zone shrinks with $\bar{w}$)*
There exist a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, the safe zone compresses $\mathcal{S}(\bar{w}_2) \subset \mathcal{S}(\bar{w}_1)$.

Proposition. (*Default zone expands with $\bar{w}$*)
There exist a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, the default zone expands $\mathcal{D}(\bar{w}_1) \subset \mathcal{D}(\bar{w}_2)$.

Safe and Default Zones and $\bar{w}$

Proposition. *(Safe zone shrinks with $\bar{w}$)*
There exist a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, the safe zone compresses $\mathcal{S}(\bar{w}_2) \subset \mathcal{S}(\bar{w}_1)$.

Proposition. (*Default zone expands with $\bar{w}$*)
There exist a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, the default zone expands $\mathcal{D}(\bar{w}_1) \subset \mathcal{D}(\bar{w}_2)$.

Next, results on **crisis zone**

Crisis zone expands with $\bar{w}$

- For every y^T, there is an interval of debt in crisis region

$$\mathcal{C}_{y^T} \equiv \left(\bar{B}^S_{y^T}, \bar{B}^D_{y^T}\right] \qquad \& \qquad \Delta\mathcal{C}_{y_T} \equiv \bar{B}^D_{y^T} - \bar{B}^S_{y^T}$$

$\bar{B}^S_{y^T}, \bar{B}^D_{y^T}$ are the thresholds for the default and safe zones

Assumption. Autarchy after default, i.i.d. shock for y^T, and *one-period* wage rigidity shock $\bar{w} > 0$

Proposition. There exists a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, then, for all y_T, $\Delta\mathcal{C}_{y_T}$ increases and $\frac{d\bar{B}^S_{y_T}}{d\bar{w}} \leq 0$

Crisis zone expands with $\bar{w}$

- For every y^T, there is an interval of debt in crisis region

$$\mathcal{C}_{y^T} \equiv \left(\bar{B}^S_{y^T}, \bar{B}^D_{y^T}\right] \qquad \& \qquad \Delta\mathcal{C}_{y_T} \equiv \bar{B}^D_{y^T} - \bar{B}^S_{y^T}$$

$\bar{B}^S_{y^T}, \bar{B}^D_{y^T}$ are the thresholds for the default and safe zones

Assumption. Autarchy after default, i.i.d. shock for y^T, and *one-period* wage rigidity shock $\bar{w} > 0$

Proposition. There exists a $\bar{w}^*$ such that for every $\bar{w}_1, \bar{w}_2 \in [0, \bar{w}^*]$, if $\bar{w}_2 > \bar{w}_1$, then, for all y_T, $\Delta\mathcal{C}_{y_T}$ increases and $\frac{d\bar{B}^S_{y_T}}{d\bar{w}} \leq 0$

Starting from w^{FLEX}, crisis region expands with higher $\bar{w}$

Why crisis region expands with $\bar{w}$?

$$V^R(\mathbf{S}) = \max_{c^T\ h, b'} \left\{ u(c) + \beta \mathbb{E}\left[V\left(b', \mathbf{s}'\right)\right]\right\}$$

subject to

$$c = \left(\omega \left(c^T\right)^{-\mu} + (1-\omega)\left(F(h)\right)^{-\mu}\right)^{-\frac{1}{\mu}}$$

$$c^T = y^T - \delta b + q(b', \mathbf{S})\left[b' - (1-\delta)b\right]$$

$$\bar{w} \leq \mathcal{W}_t\left(c^T, F(h), h\right)$$

$$h \leq \bar{h}$$

Why crisis region expands with $\bar{w}$?

Value of repayment during rollover crisis, V^C, is reduced considerably more than V^F and V^D

$$V^R(\mathbf{S}) = \max_{c^T\ h,b'} \left\{ u(c) + \beta \mathbb{E}\left[V\left(b', \mathbf{s}'\right)\right]\right\}$$

subject to

$$c = \left(\omega \left(c^T\right)^{-\mu} + (1-\omega)\left(F(h)\right)^{-\mu}\right)^{-\frac{1}{\mu}}$$

$$c^T = y^T - \delta b$$

$$\bar{w} \leq \mathcal{W}_t\left(c^T, F(h), h\right)$$

$$h \leq \bar{h}$$

Why crisis region expands with $\bar{w}$?

Value of repayment during rollover crisis, V^C, is reduced considerably more than V^F and V^D

$$V^R(\mathbf{S}) = \max_{c^T\ h,b'} \left\{ u(c) + \beta \mathbb{E}\left[V\left(b', \mathbf{s}'\right)\right]\right\}$$

subject to

$$c = \left(\omega \left(c^T \right)^{-\mu} + (1-\omega) \left(F(h) \right)^{-\mu} \right)^{-\frac{1}{\mu}}$$

$$c^T = y^T - \delta b$$

$$\bar{w} \leq \mathcal{W}_t \left(c^T, F(h), h \right)$$

$$h \leq \bar{h}$$

Even if unemployment not "observed", rigidity can trigger crisis

"The assessment of the Governing Council is that we are in a situation now where you have large parts of the euro area in what we call a "bad equilibrium", namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios. So, there is a case for intervening, in a sense, to "break" these expectations"

Mario Draghi, 2012 Speech