Modeling General-Equilibrium Macroeconomic Stress Scenarios in MATLAB

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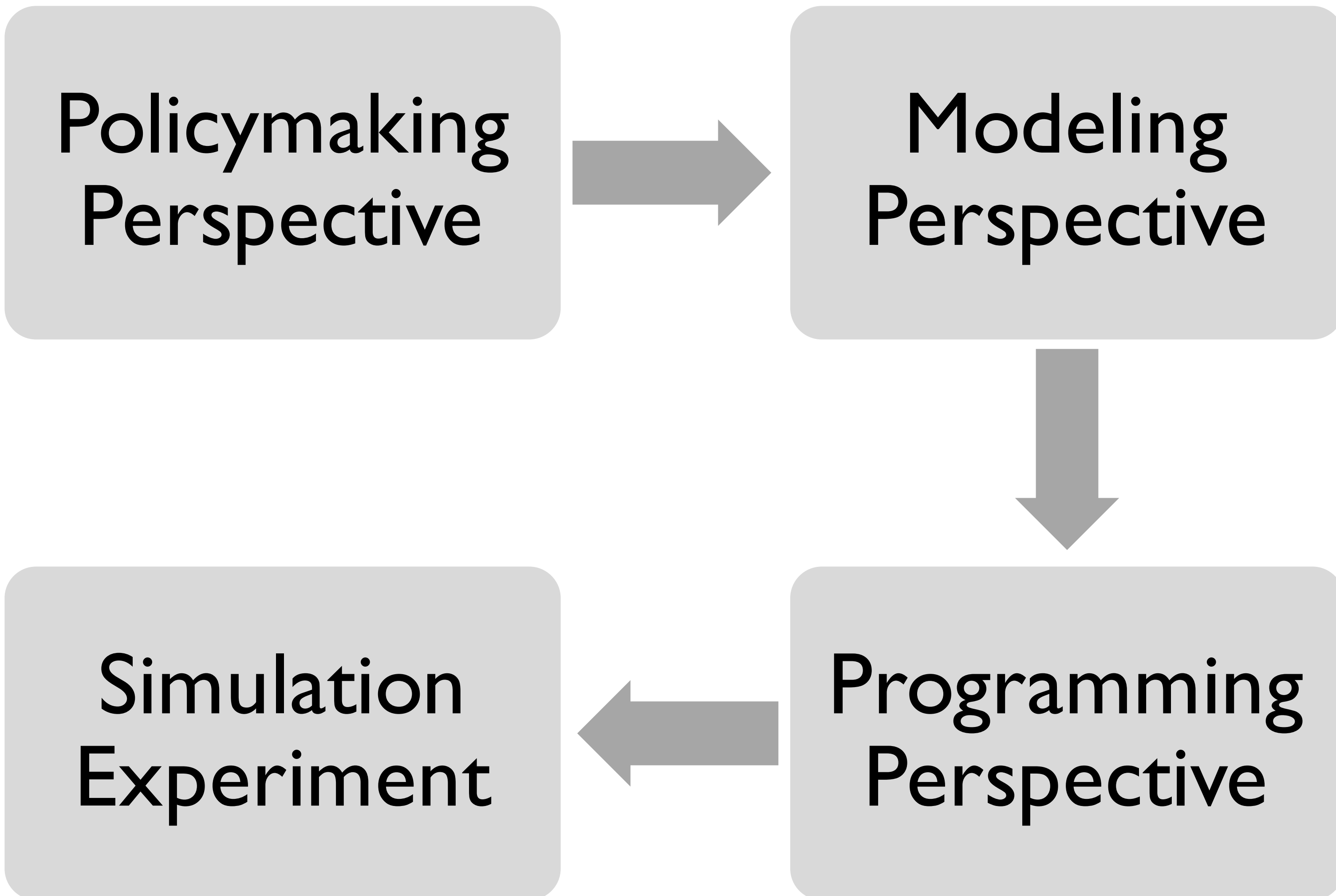
Macroprudential Policy…Is What?

- Narrow versus broader scope
- Broad policy objectives
  - Minimize incidence of balance sheet crises
  - Limit disruptions to key financial services
- Key elements in macroprudential analysis
  - Tail-risk distress scenarios
  - Feedback between balance sheets and real economy
  - Possibility of severe nonlinearities
- Models to support macroprudential policy

Plan of Presentation



POLICYMAKING PERSPECTIVE

Macroprudential Policy Exercise

Assess risks

Design macro(-economic/-financial) stress scenario(s)

- Slow-burn (low-frequency) shocks and risks
- Unlikely yet plausible scenarios with large impact

Evaluate impact of scenario(s)

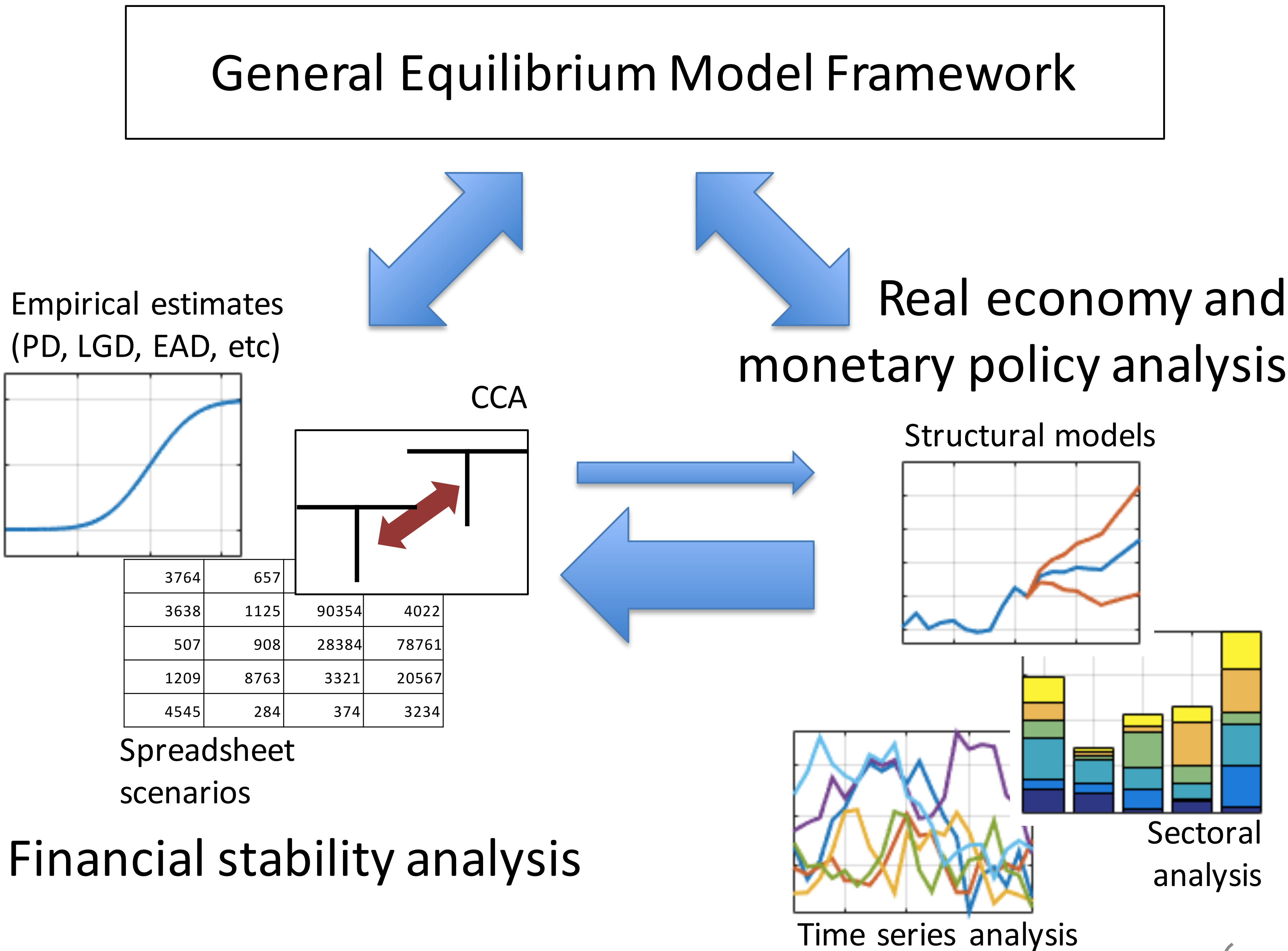
- Resilience of sectoral balance sheets
- Feedback between financial and real

Communicate with policy makers

- Consider possible policy responses

Communicate to public

- Regular Financial Stability Reports


General Equilibrium Model Framework
Empirical estimates
(PD, LGD, EAD, etc)
CCA
Real economy and
monetary policy analysis
Structural models
3764 657
3638 1125 90354 4022
507 908 28384 78761
1209 8763 3321 20567
4545 284 374 3234
Spreadsheet
scenarios
Financial stability analysis
Sectoral
analysis
Time series analysis

Role of General Equilibrium Models

- Integrate all pieces of information
- Balance sheet consistency across sectors and time
- Facilitate internal communication (explicit assumptions, most critical assumptions)
- Make process accountable
- Make external communication transparent, credible
- Model-based scenario analysis, not accurate probabilistic predictions

Limitations…

- Fundamental uncertainty
- Nonlinear feedback
- Corridor stability
- Estimation and backtesting difficult in crisis modeling
  - Distress episodes are few and far apart
  - Each has a different cause
  - Need to evaluate international evidence

➔ Common variety of macro models not well-suited

MODELING PERSPECTIVE

Macro Model with Credit Risk

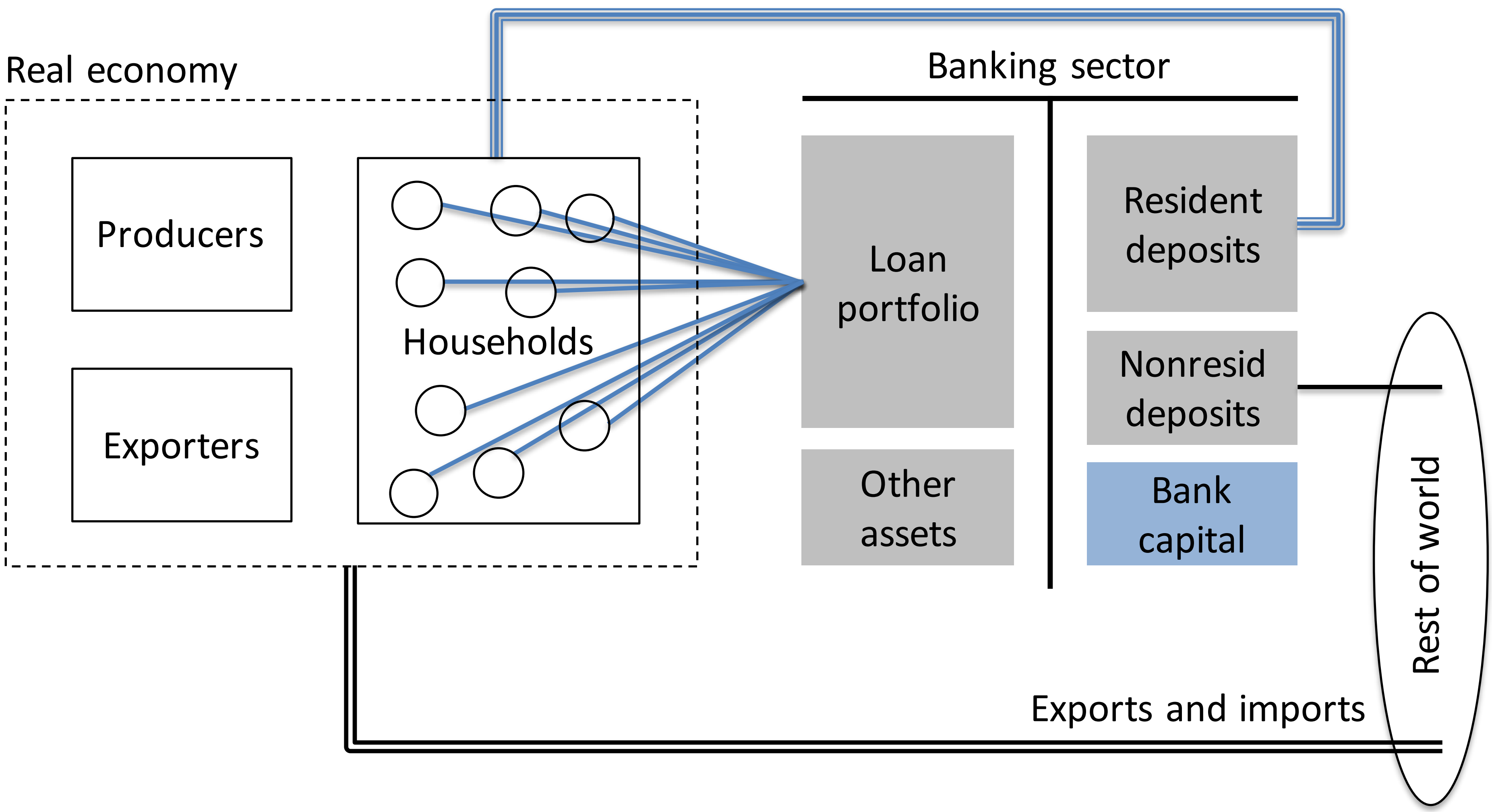
Real economy

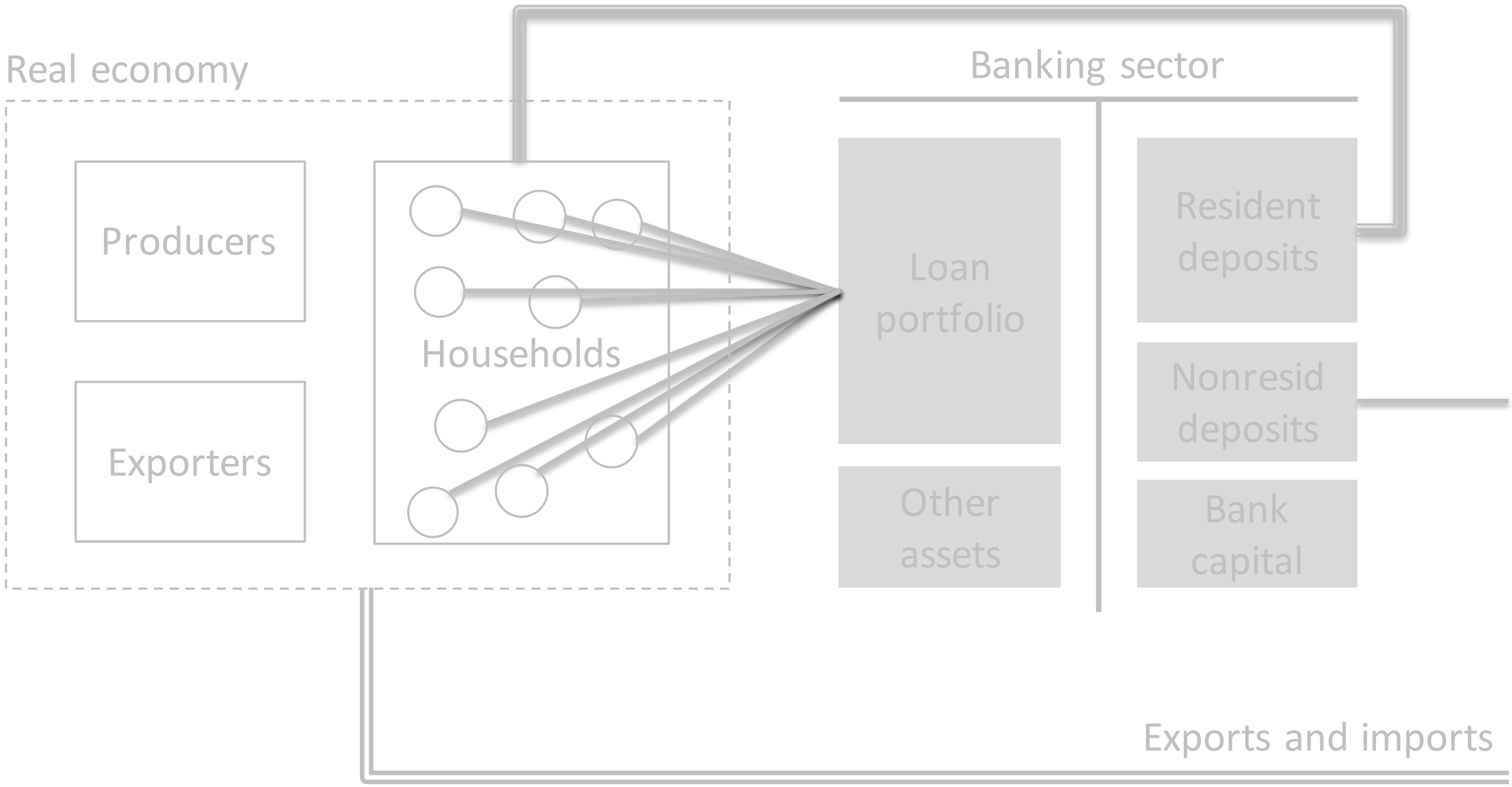
- Relatively standard (DSGE) structure
- Monetary economy
- Optimizing agents with finite (short) planning horizons
- Mixed expectations

Financial sector

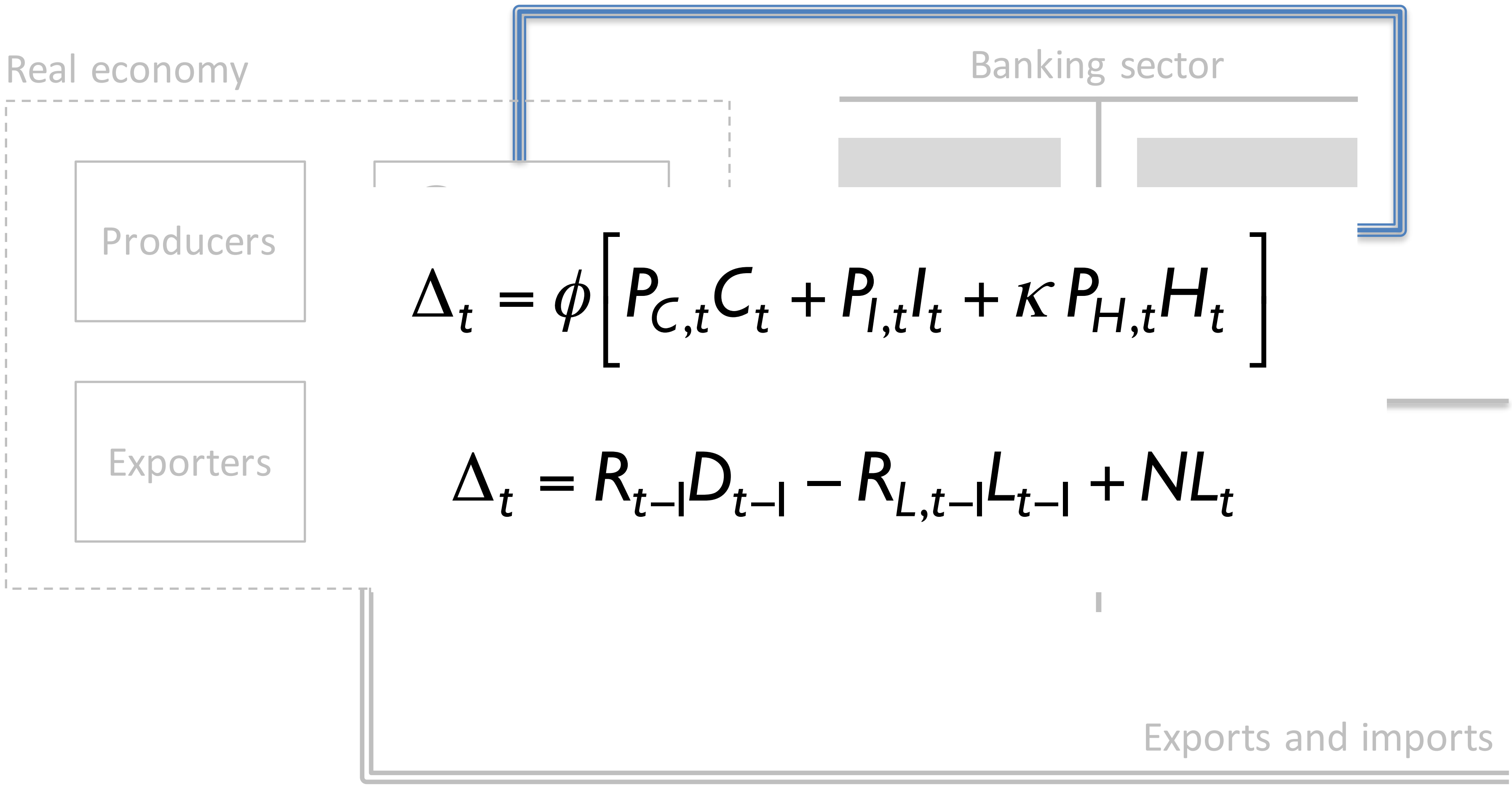
- Credit risk on loan books
- Asymptotic single factor risk model
- Advanced IRB to model regulatory capital constraints

Structure of Model



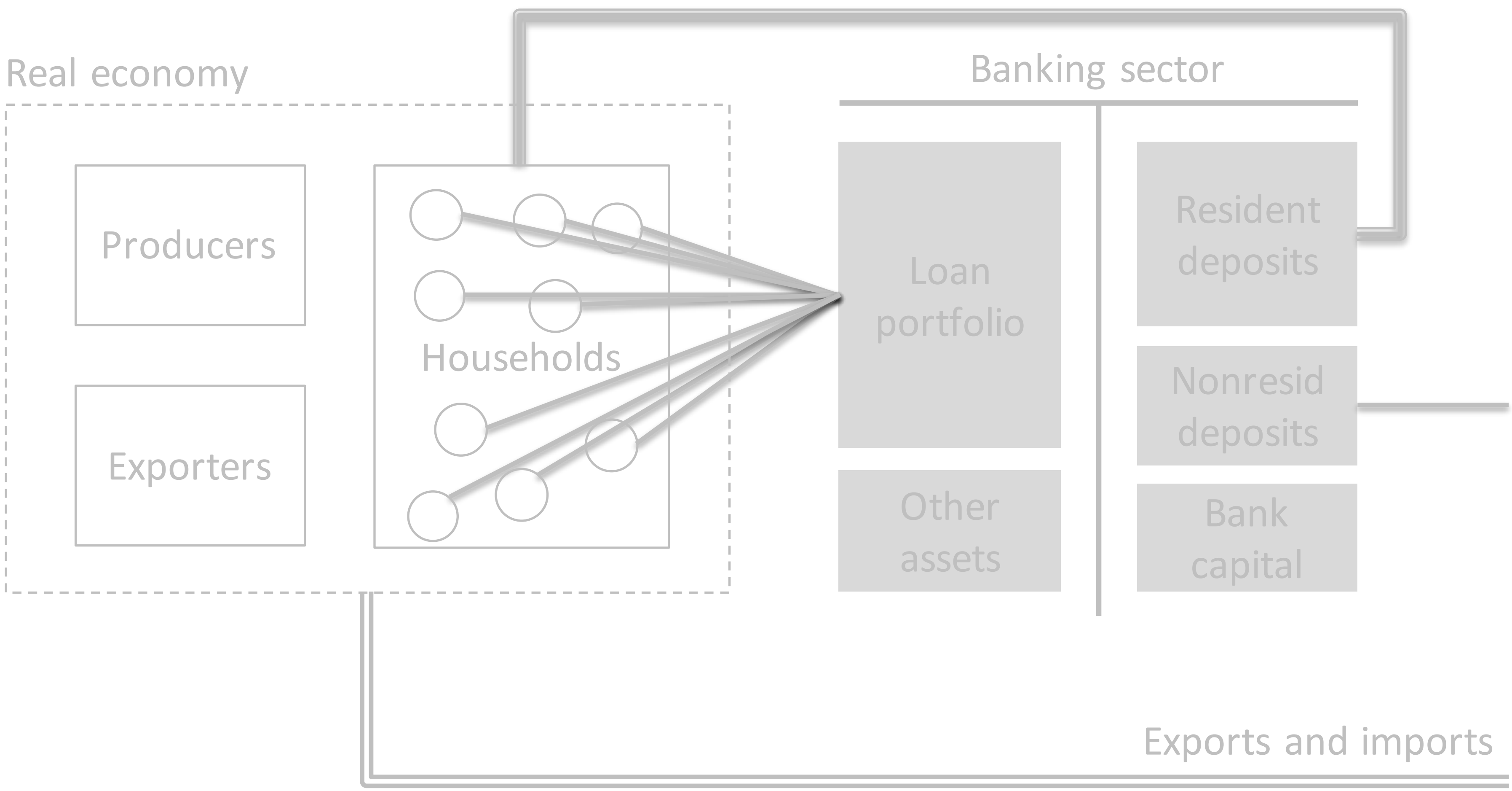

Real economy
Producers
Exporters
Households
Banking sector
Loan portfolio
Other assets
Resident deposits
Nonresid deposits
Bank capital
Exports and imports

Demand for Deposits



$$\Delta_t = \phi \left[P_{C,t} C_t + P_{I,t} I_t + \kappa P_{H,t} H_t \right]$$

$$\Delta_t = R_{t-1} D_{t-1} - R_{L,t-1} L_{t-1} + NL_t$$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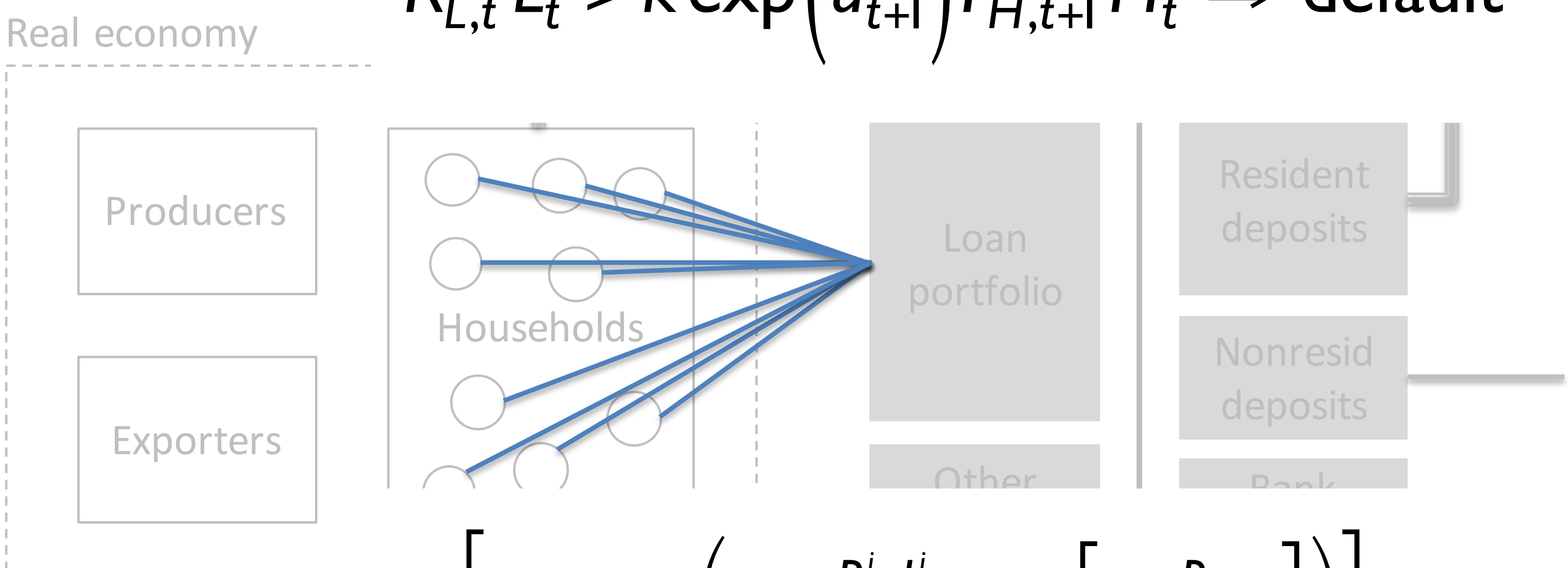
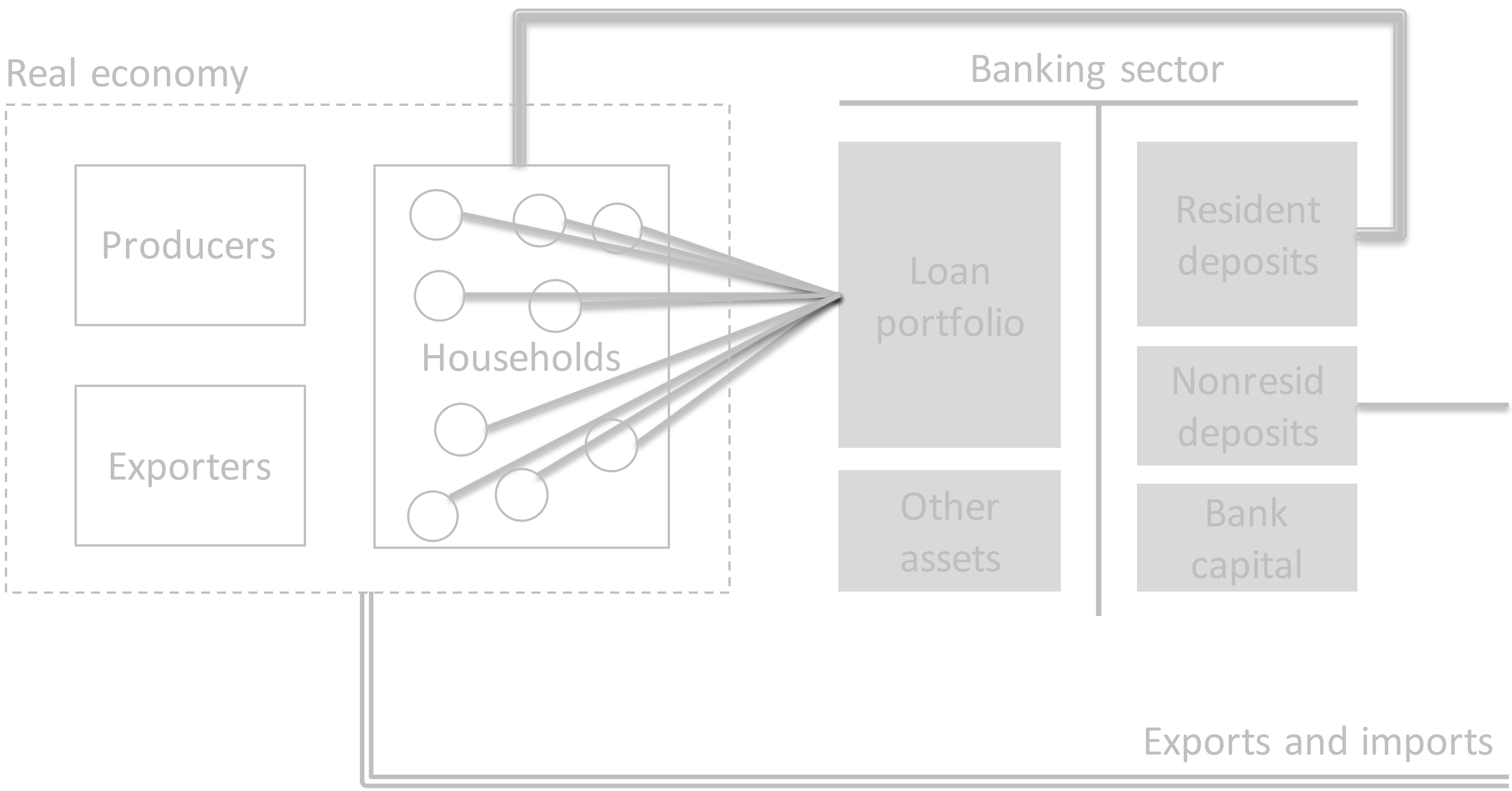
Individual Bank Loans

$$R^i_{L,t}\, L^i_t > k \exp\left(u^i_{t+1}\right) P_{H,t+1}\, H^i_t \Rightarrow \text{default}$$



$$R^i_{L,t}\left[1-\lambda\,\Phi\left(\frac{\log\frac{R^i_{L,t}L^i_t}{k\,P_{H,t}H^i_t}-\mathrm{E}_t\left[\log\frac{P_{H,t+1}}{P_{H,t}}\right]}{\sigma}\right)\right]=R^*_t$$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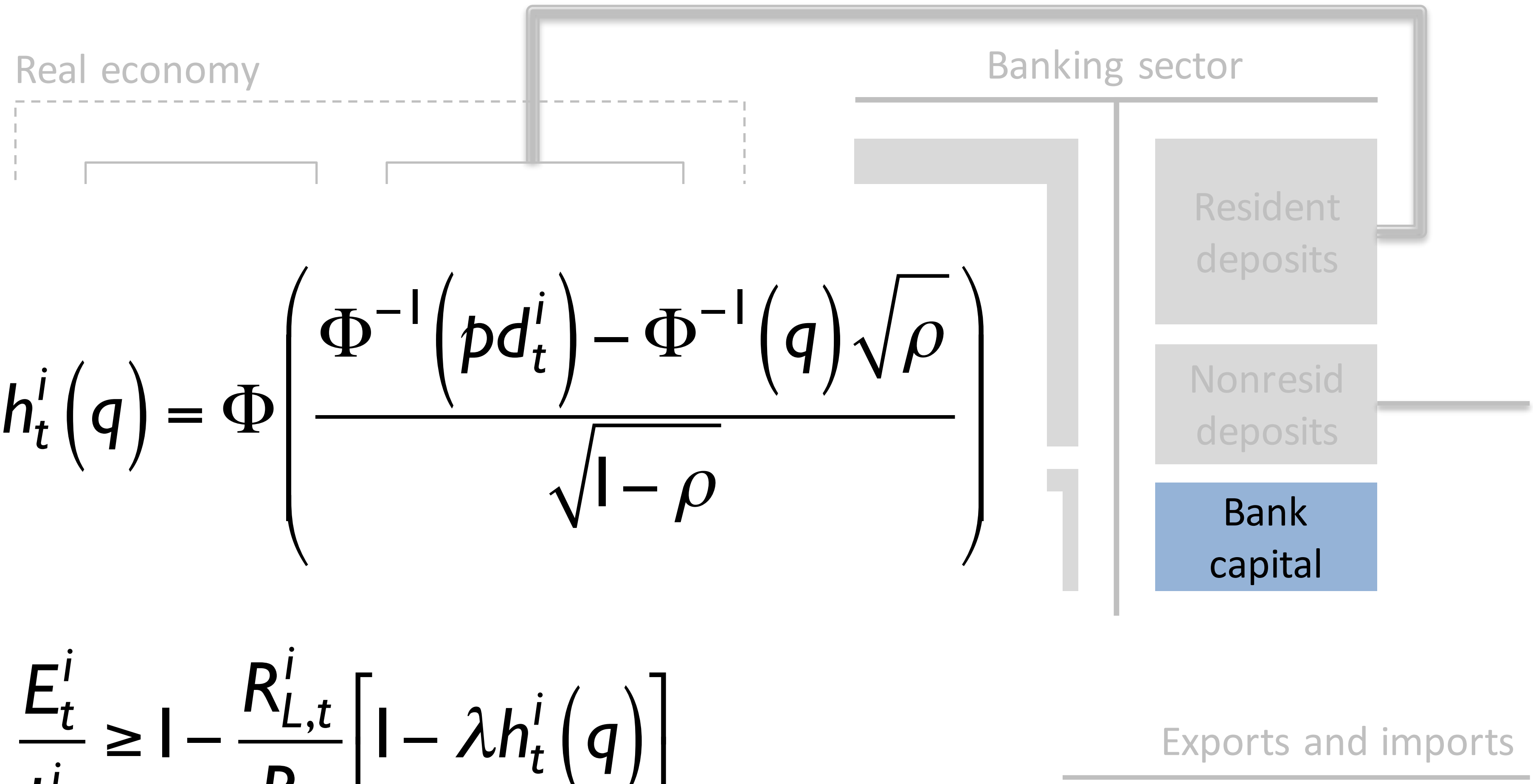
Bank Capital Regulation



$$h_t^i(q) = \Phi\left(\frac{\Phi^{-1}\left(pd_t^i\right) - \Phi^{-1}(q)\sqrt{\rho}}{\sqrt{1-\rho}}\right)$$

$$\frac{E_t^i}{L_t^i} \geq 1 - \frac{R_{L,t}^i}{R_t}\left[1 - \lambda h_t^i(q)\right]$$

PROGRAMMING PERSPECTIVE

IRIS Toolbox

60+ classes, 30+ packages, 2,300+ functions

www.iris-toolbox.com

Structural modeling (DSGE)

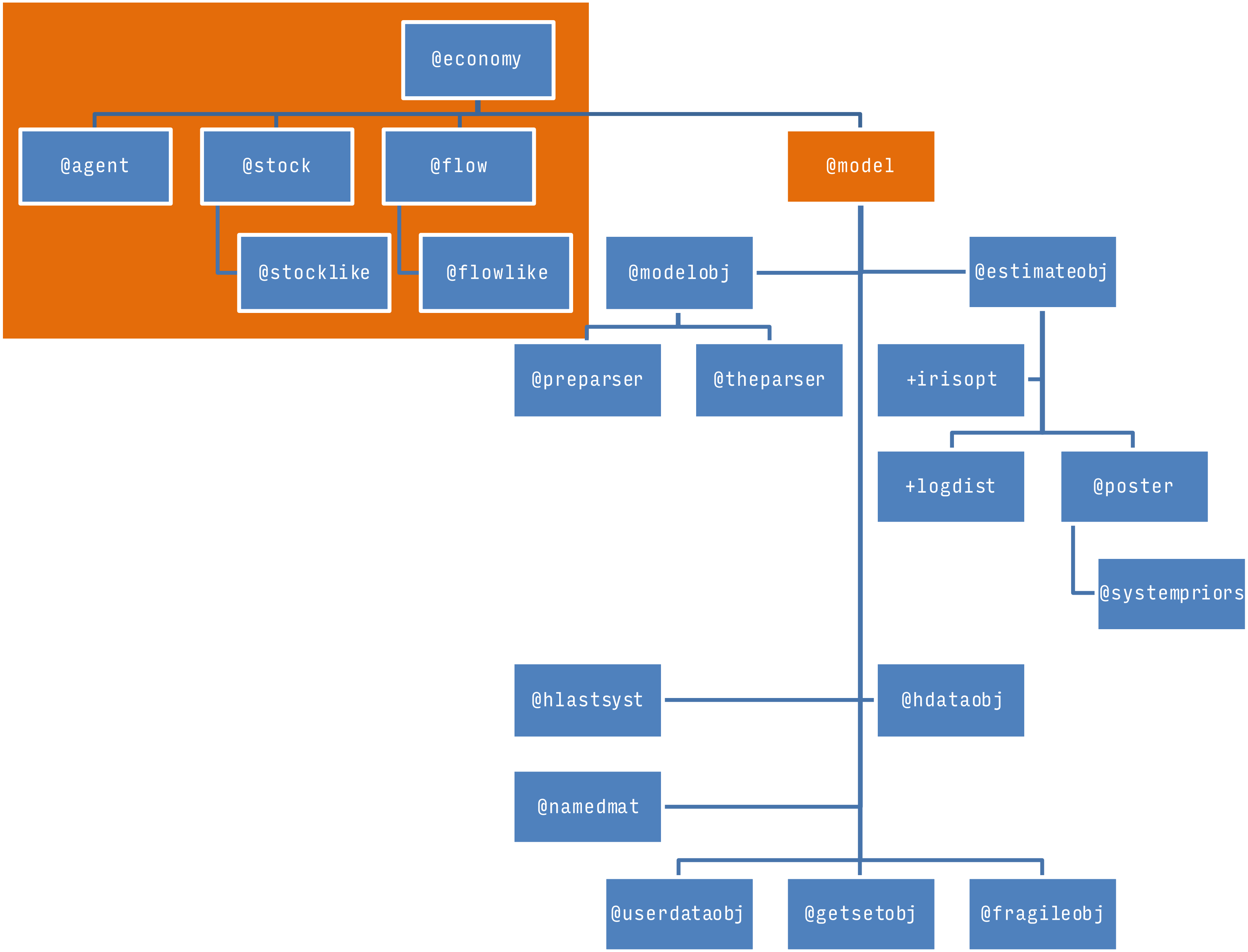
MV time series analysis

Time series and database management

Reporting

Documentation

Model Related Classes and Packages



Building Model Equations

- Two types of equations
  - Behavioral rules
  - Stock-flow and other identities
- Behavioral rules
  - Optimizing principles
  - Rules of thumb
  - Empirical equations
- Stock-flow identities
  - Logical structure of the model

Transactions Flow Matrix

Market clearing

		Households	Producers	Exporters	Banks	Central Bank	Rest of world	Σ
Transaction flows – Current account	Consumption	$-PC\times C$	$PC\times C$					0
	Wage bill	$W\times N$	$-W\times NY$	$-W\times NX$				0
	Imports		$-PM\times MY$	$-PM\times MX$			$PM\times M$	0
	Exports			$PX\times X$			$-PX\times X$	0
	Distrib surplus producers	Π	$-\Pi$					0
	Distrib surplus banks				$-\Gamma$		Γ	0
	Distrib surplus CB	Ω				$-\Omega$		0
	Deposit interest	$RD(0)\times D(0)$			$-RD(0)\times D(0)$			0
	Loan interest	$-RL(0)\times L(0)$			$RL(0)\times L(0)$			0
	Loan loss	$L(0)[1+RL(0)]\times UL$			$-L(0)[1+RL(0)]\times UL$			0
	CB liquidity surplus interest				$R(0)\times B(0)$	$-R(0)\times B(0)$		0
	Net foreign liabs interest				$-RF(0)\times F(0)$		$RF(0)\times F(0)$	0
Transaction flows – Capital account	Net acquisition of housing	$-PH\times \Delta H$						0
	Chng in deposits	$-\Delta D$			ΔD			0
	Chng in loans	ΔL			$-\Delta L$			0
	Chng in CB liquidity surplus				$-\Delta B$	ΔB		0
	Chng in foreign liabs				ΔF		$-\Delta F$	0
	Σ	0	0	0	0	0	0	

Budget constraints

Net Worth Matrix

Delegated agents

		Households	Producers	Exporters	Banks	Central Bank	Rest of world
	Opening net worth	$VH0$	0	0	$VB(0)$	$VC(0)$	$VR(0)$
Change in net worth: Transaction chng	Net acquisition of housing	$PH\times\Delta H$					
	Chng in deposits	ΔD			$-\Delta D$		
	Chng in loans	$-\Delta L$			ΔL		
	Chng in CB liquidity surplus				ΔB	$-\Delta B$	
	Chng in foreign liabs				$-\Delta F$		ΔF
Change in net worth: Reval	Revaluation of housing	$\Delta PH\times H(0)$					
	Revaluation of net foreign liabs						$J\times F(0)$
	Closing net worth	VH	0	0	VB	VC	VR

Laws of motion for net worth (equity)

Stock-Flow Builder

```
%% Agents (Sectors)

households  = Agent( );
producers   = Agent( );
exporters   = Agent( );
centralBank = Agent( );
banks       = Agent( );
restOfWorld = Agent( );
```

```
%% Ownership and Delegation

households.Ownership    = [ centralBank ];
households.Delegates    = [ producers, exporters ];

restOfWorld.Ownership   = [ banks ];
```

```
%% Flows

consumption = FlowLike.Goods( );
labor       = FlowLike.Goods( );
imports     = FlowLike.Goods( );
exports     = FlowLike.Goods( );
```

```
%% Link Agents and Flows

households.Debits    = [ consumption ];
households.Credits   = [ labor ];

producers.Debits     = [ labor, imports ];
producers.Credits    = [ consumption ];

exporters.Debits     = [ labor, imports ];
exporters.Credits    = [ exports ];

restOfWorld.Debits   = [ exports ];
restOfWorld.Credits  = [ imports ];
```

Stock-Flow Builder

```
%% Stocks

housing      = StockLike.Physical( );
deposits     = StockLike.SafeDeposit( );
loans        = StockLike.RiskyLoan( );
netLiquidity = StockLike.SafeDeposit( );
netForeign   = StockLike.SafeDeposit( );
```

```
%% Link Agents and Stocks

households.Assets      = [ housing, deposits ];
households.Liabilities = [ loans ];
banks.Assets           = [ loans, netLiquidity ];
banks.Liabilities      = [ deposits, netForeign ];
restOfWorld.Assets     = [ netForeign ];
```

```
%% Economy

x = Economy( );

x.addAgent( household, 'Hh' );
x.addAgent( producer, 'Pr' );
x.addAgent( exporter, 'Ex' );
x.addAgent( centralBank, 'Cb' );
x.addAgent( banks, 'Bk' );
x.addAgent( restOfWorld, 'Rw' );

x.addFlow( consumption, 'C' );
x.addFlow( labor, 'N' );
x.addFlow( exports, 'X' );
x.addFlow( imports, 'M' );

x.addStock( housing, 'H' );
x.addStock( deposits, 'D' );
x.addStock( loans, 'L' );
x.addStock( netLiquidity, 'B' );
x.addStock( netForeign, 'F' );

x.build( );
```

Stock-Flow Builder

```
classdef Stock < handle

    properties
        HasPrice % true: Volume*Price, false: Value
        HasCashFlow % true: Next period CF prop to Value, false: No CF
        HasLoss % true: Loss on value and CF, false: No loss
        HasDeprec % true: Depreciation of volume, false: No depreciation
    end

    methods
        function This = Stock( HasPrice, HasCashFlow, HasLoss, HasDeprec )
            This.HasPrice = HasPrice;
            This.HasCashFlow = HasCashFlow;
            This.HasLoss = HasLoss;
            This.HasDeprec = HasDeprec;
        end
```

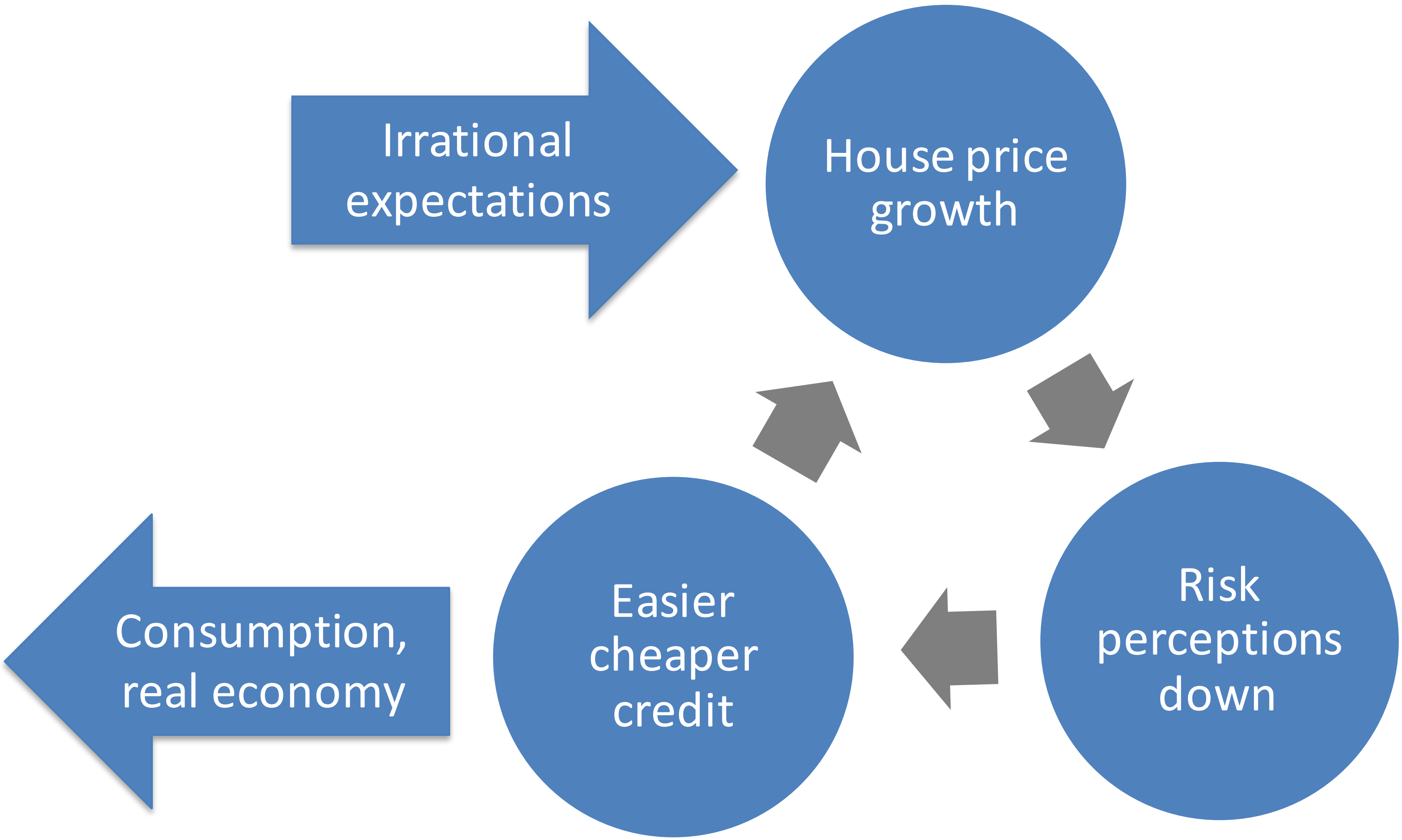
```
classdef StockLike < Stock

    enumeration
        %           ( HasPrice, HasCashFlow, HasLoss, HasDeprec )
        SafeDeposit ( false,    true,        false,   false )
        RiskyLoan   ( false,    true,        true,    false )
        Physical    ( true,     true,        false,   true )
        Share       ( true,     true,        false,   true )
    end

    methods
```

Behavioral Equations (Regexp Parser)

```
!substitutions

    UU := (bet*((1-chiv)/(Ve - chiv*V ))^sgmc);
    N0 := (n*&NY);
    RR := (1 / [ R/RL / (lmb*normpdf(log(Je)/varsgm)/varsgm) - 1 ]);

!transition_equations

% Households
%------------

    1 = ((C-chic*&C)/(1-chic))^sgmc * Lmb * PC *(1 + dc*Phi) ...
        !! 1 = C^sgmc * Lmb * PC *(1 + dc*Phi);

    R{-1}*D{-1} - (RL{-1}-1+the)*L{-1} + The - DA = dc*PC*C + dh*PH*KH;

    Phi = RL/(R+Psi) + Psi - 1;
    %$UU$*(R+Psi)/dPCe = Lmb*PC;

    Lmb*Phi = ...
        $UU$*a*(ups-1) * (V/L) * (L/DA)^ups ...
        * ((RL-1+the)*exp(EEPDU)/R)^(ups-1);

    $UU$*RL*(1+$RR$)/dPCe =# Lmb*PC*(1+Phi-Psi);
```

SIMULATION EXPERIMENT

House Price Bubble and Burst



House Price Bubble and Burst

- Irrational expectations
  - Sequence of shocks
- Burst of the bubble
  - Unexpected event
  - House prices go down to "fundamentals"
  - Painful deleveraging in both real and financial sector
- Re-simulate with loan-to-value caps
  - Inequality constraint in households decision
  - Complementary slackness translated into *min*(…)