Model-Aided Macroprudential Analysis

Jaromír Beneš
Michael Kümhof
Douglas Laxton

October 2013
BIS Mexico City

▪ Plan of My Talk ▪

- Three neglected yet essential themes in macroprudential modeling
- Introduction to a prototypical model of macroeconomic stress with credit risk
- Simulation experiments

▪ The Usual Dislaimer ▪

The views expressed are the authors' own, and do not necessarily represent the views of the International Monetary Fund, its Management, its Executive Board, or any of its Executive Directors

· Introduction ·

- Central banks enhance macrofinancial stability analysis and consider possible pro-active macroprudential policies.

- These new areas of expertise will require an analytical framework combining various types of tools (simualtion models, estimated equations, spreadsheet models) with judgment.

- To keep the pieces consistent and the focus on broad picture (as opposed to being overwhelmed by detail), a top-down model is convenient to describe major macrofinancial risks and policy trade-offs.

- We discuss three themes that appear often negelected, and draw implications for mmacroprudential modeling.

▪ Three Neglected Yet Essential Themes ▪

Banks are not intermediaries

Endogenous aggregate risk

Global nonlinearities and robust control

▪ Banks Are Not Intermediaries ▪

▪ Banks Are Not Intermediaries ▪

- Non-bank intermediaries (shadow banks): take someone's savings (real resources) and lend them out to someone else who has a use for them

- Banks just do not do that: Banks provide credit by creating bank liabilities (deposits) out of thin air

Banks facilitate intermediation
after deposits are created

- This distinction has far-reaching implications for macro-financial stability and macroprudential analysis

▪ How Banks and Non-Banks Make Loans ▪

	Non-bank intermediaries		
Borrower $\leftarrow$	ΔLoans	ΔDeposits	$\leftarrow$ Saver

Banks	
ΔLoans	ΔDeposits

$\searrow$ Borrower $\swarrow$

▪ Bank Balance Sheet Is Like Rubber Band ▪

- In non-bank intermediaries: deposits come before loans
  In banks: loans come before deposits

- New loans involve no intermediation whatsoever: they create brand new purchasing power

  No funds are being withdrawn from previous uses as savings

- Bank liabilities can be only created/destroyed by creating new loans/repaying existing loans

  Appart from cash withdrawals/deposits – which are minuscule

- Banks can inflate or deflate balance sheets very easily: traditional models of intermediation cannot capture that

  Borio and Disyatat's (2011) rubber bands

▪ What Limits Bank Balance Sheets ▪

- Not availability of savings
- Not availability of central bank reserves

Banks always acquire central bank liquidity
in a completely separate transaction afterwards

- Risk bearing capacity of bank capital ✓

Capital regulation, market discipline

▪ Take-Aways for Macroprudential Modeling ▪

- Make a distinction between saving and financing
- Bank liabilities are the latter; this needs to be reflected in the specification of demand for bank liabilities
- The essence of macroprudential analysis does not require two types of agents (borrowers and savers)
- Banks can easily start a lending boom by inflating their balance sheets and providing financing

  Banks do not have to attract deposits or savings

- Endogenous risk cycles

▪ Endogenous Nondiversifiable Risk ▪

▪ Endogenous Nondiversifiable Risk ▪

- Bank balance sheets bear risk
- Some of the risk cannot be diversified or hedged against

  Nondiversified risk is one of the core concepts
  in macroprudential analysis

- The risk is endogenously linked to the macroeconomy

  Credit, market, roll-over risks, ...

- Bank decision-making is choice under uncertainty
- Cycles in risk have first-order impact on bank behavior, and hence first-order impact on the macroeconomy

▪ Take-Aways for Macroprudential Modeling ▪

- Build a complete (albeit simple) feedback mechanism
- Expose banks to nondiversifiable risk
- Have bank capital absorb ensuing losses
- Endogenize the risk: connect it with the rest of the model

Analogy: Would a monetary policy model with
exogenous inflation expectations make any sense?

- Capital regulation and market discipline under uncertainty means constraints are rarely ever-binding inequalities

Prime example: Capital requirements
and regulatory capital buffers

▪ Global Nonlinearities ▪

- Macroprudential policy aims to make the economy more resilient to large balance-sheet stress events, ...

  ...not to fine-tune regular business cycles

- Nonlinearities are the essence of the game
- Local approximation approaches distort the picture
- Macroprudential policy is not an optimal control problem, let alone linear-quadratic
- Macroprudential policy is best viewed as robust control
- Amount of uncertainty is enormous: traditional empirical methods likely to give false sense of knowledge

▪ Take-Aways For Macroprudential Modeling ▪

- Center macroprudential models around key nonlinearties
- Solve the nonlinearities using global solution approaches
- Design macroprudential policy as a robust control problem

▪ Leijonhufvud's Corridor Stability ▪

▪ What's Different About Macroprudential Analysis ▪

Monetary	Macroprudential
Regular business cycles	Financial cycles: longer, more asymmetric
The most likely projection	Not-so-likely yet plausible stress scenarios
Relatively stable trade-offs	Global nonlinearities, rapidly changing trade-offs
Linear-quadratic control	Robust control
Mostly flows	Stock-flow, balance sheets

Prototypical Macroeconomic Stress Model with Credit Risk

Jaromír Beneš
Michael Kümhof
Douglas Laxton

October 2013
BIS Mexico City

▪ The Usual Dislaimer ▪

The views expressed are the authors' own, and do not necessarily represent the views of the International Monetary Fund, its Management, its Executive Board, or any of its Executive Directors

▪ Essential Features ▪

- Endogenous feedback between real and financial sectors based on endogenous aggregate (=nondiversifiable by assumption) credit risk
- Focus on the solvency risk on the loan book (credit risk), not trading book (market risk), or liquidity risk
- Nonlinearities: the model is capable of telling narratives about tail-risk events and episodes of extreme financial distress
- Design of the financial sector nonrestrictive: can be used within a broad variety of model specifications

- We combine standard macro modeling methodology with four pieces from finance and banking

  1. Asymptotic single risk factor model
     Gordy (2000, 2003)
  2. Loan portfolio value theory
     Vasicek (2002)
  3. Capital regulation as incentive based mechanism
     Milne (2002)
  4. Costly external capital flows
     Estrella (2004)

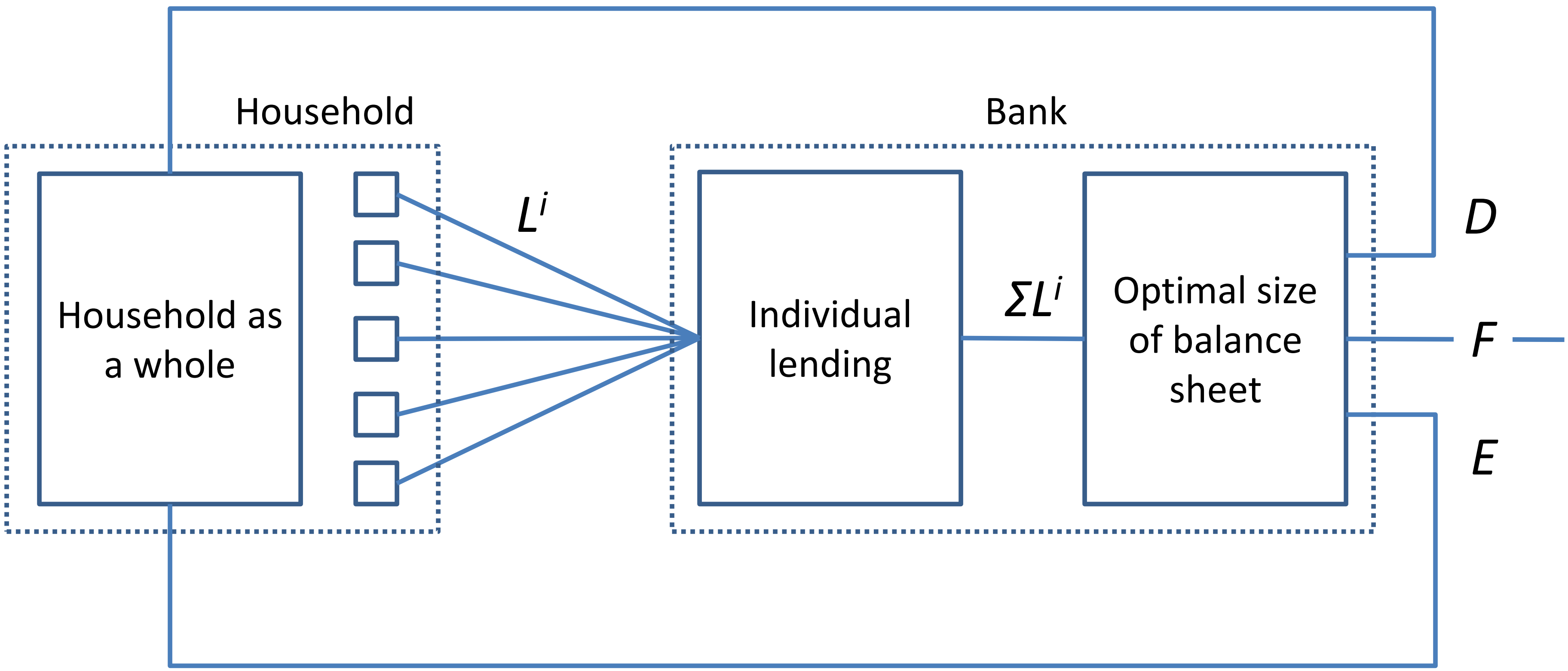
▪ What The Model Does Not Address ▪

- Non-bank intermediaries (shadow banks), collateral chains
- Liquidity ror oll-over risk
- Interbank lending and interbank counterparty exposures
- Interconnectedness dimension of systemic risk

▪ Real Economy ▪

- Fairly standard, not discussed in this presentation
- Small open economy
- Households and producers are one entity from the point of view of balance sheets or net worth
- One production function: capital, labour and intermediate imports
- Export sector subject to exogenous terms of trade
- Rigidities. . .
- Certain extent of financial dollarization,
indirect currrency risk

▪ Banking Sector ▪



▪ What Banks Do ▪

1. Individual lending:
   Noncontingent loan contracts with individual borrowers
2. Optimal size of the balance sheet:
   The size of a risky loan portfolio that can be supported by given equity (bank capital)

▪ Bank Balance Sheets ▪

L_t	Loans to residents	Resident deposits	D_t
		Nonresident deposits	F_t
		Bank capital	E_t

For notational convenience in the presentation, we assume both resident and nonresident deposits are denominated in localy currency, and perfect substitutes, $d_t = D_t + F_t$

▪ Loan Portfolio ▪

- Loan portfolio: a large number of one-period loans granted to individual borrowers

$$L_t = \sum L_t^i$$

- Each loan i either performs at time $t+1$ ($H_{t+1}^i = 0$) or becomes nonperforming ($H_{t+1}^i = 0$).

▪ Individual Lending ▪

- Asymptotic single risk factor model
- Each individual loan is noncontingent and its performance is determined by underlying asset (production capital)
- Stochastic default threshold

$$R^i_{K,t+1} P_{K,t} K^i_t \begin{cases} \geq \dfrac{1}{\kappa \exp u^i_t} R^i_{L,t} L^i_t \;\Rightarrow\; H^i_t = 0 \text{ (loan performs)} \\ < \dfrac{1}{\kappa \exp u^i_t} R^i_{L,t} L^i_t \;\Rightarrow\; H^i_t = 1 \text{ (default)} \end{cases}$$

- Each loan is risky ex-ante, and the bank lending supply curve is given by

$$R^i_{L,t}\Big(1-\underbrace{\lambda \mathrm{E}_t[H^i_{t+1}]}_{\text{LGD}\times\text{PD}}\Big)=\hat{R}_t \tag{1}$$

$\hat{R}_t$ required rate of return on loans (determined later), λ loss given default

Connect Credit Risk with Macroeconomy

- Ex-ante PD is given by the probability of default

$$\mathrm{E}_t[H^i_{t+1}] = \Pr\left(R^i_{K,t+1} < \frac{R^i_{L,t}L^i_t}{\kappa \exp u^i_t P_{K,t}K^i_t}\right) = \Pr\left(r^i_{t+1} < \bar{r}^i_t\right)$$

where $r^i_{t+1} = \log R_{K,t+1} + u^i_t$, and $\bar{r}^i_t = \log \frac{R^i_{L,t}L^i_t}{\kappa P_{K,t}K^i_t}$

- Individual returns on capital, $i \neq j$

$$r^i_{t+1} \sim \mathrm{N}(\mu_t, \sigma), \quad r^j_{t+1} \sim \mathrm{N}(\mu_t, \sigma), \quad \mathrm{corr}(r^i_{t+1}, r^j_{t+1}) = \rho$$

- Conditional mean is determined endogenously by the model

$$\mu_t = \mathrm{E}_t[r^i_{t+1}] = \mathrm{E}_t[r^j_{t+1}] = \mathrm{E}_t[r_{t+1}] = \mathrm{E}_t[\log R_{K,t+1}]$$

- Conditional variance, σ^2, and cross-correlation, ρ, are treated parameterically

- The assumptions are equivalent to saying uncertainty in each r^i_{t+1} consists of an aggregate and an idiosyncratic component

$$r^i_{t+1} \quad = \quad \overbrace{r_{t+1} \sim \mathrm{N}(\mu_t, \sigma\sqrt{\rho})}^{\text{Aggregate}} \quad + \quad \overbrace{u^i_{t+1} \sim \mathrm{N}(0, \sigma\sqrt{1-\rho})}^{\text{Idiosyncratic}}$$

- Ex-ante PD is the same for all loans in ex-ante symmetric equilibrium (homogenous portfolio), and we denote it by $p_t = \mathrm{E}_t[H^i_{t+1}] = \mathrm{E}_t[H^j_{t+1}]$ for future reference.

▪ Loan Portfolio ▪

- Because of the aggregate component (cross-correlations of individual returns), banks cannot fully diversify all risk
- Vasicek (2002) derives two important characteristics of a risky loan portfolio

  1. Ex-ante distribution of expected portfolio default ratio
  2. Actual ex-post portfolio default ratio, H_{t+1}, for a given observed aggregate return on underlying assets, $R_{K,t+1}$

▪ Ex-Post Actual Portfolio Loss ▪

- Portfolio default ratio (total proprotion of nonperforming loans in a portfolio)

$$H_{t+1} = \frac{\sum H_{t+1} L_t^i}{\sum L_t^i} \in [0, 1]$$

- By the law of large numbers

$$H_{t+1} = \Pr\left(H_{t+1}^i \,|\, r_{t+1}\right) = \Phi\left(-\frac{r_{t+1} - \bar{r}_t}{\sigma\sqrt{1-\rho}}\right)$$

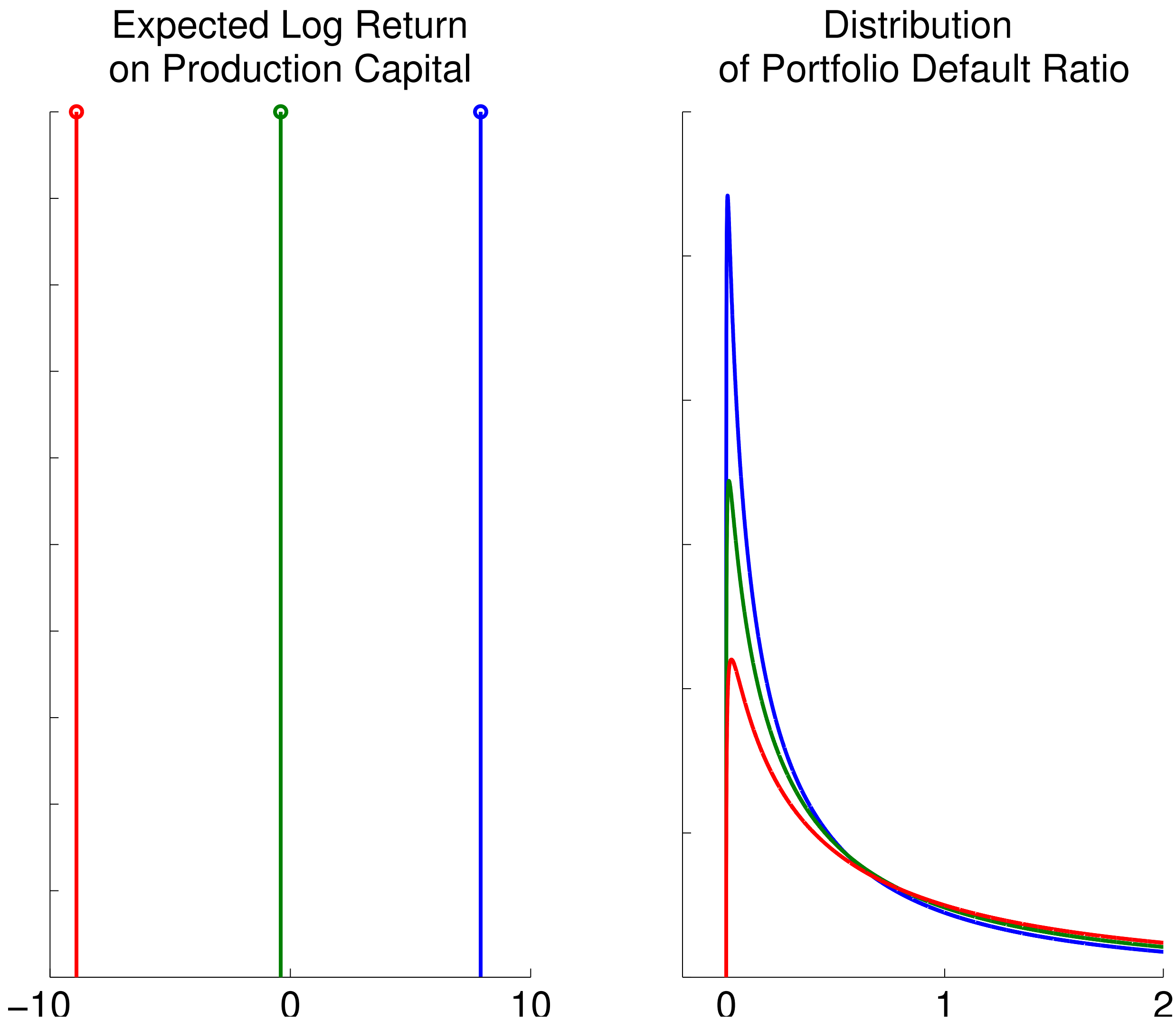
▪ Ex-Ante Distribution of Portfolio Default Ratio ▪

- Distribution function for portfolio default ratio

$$\Gamma_t = \Pr\left(H_{t+1} < X\right) = \Phi\left(\frac{\Phi^{-1}(X)\sqrt{1-\rho} - \Phi^{-1}(\pi_t)}{\sqrt{\rho}}\right)$$

- In homogenous portfolio, the distribution is a function of
  - ex-ante probability of default at each exposure, p_t
  - cross-correlation of individual exposures, ρ

▪ Ex-Ante Portfolio Default Ratio ▪



Optimal Size of Bank Balance Sheet

- Banks choose the size of their balance sheets subject to
  - ex-post capital adequacy requirements
  - costs of external capital flows

- If the ex-post value of bank capital, EE_{t+1}, falls below a given proportion, g, of the ex-post value of assets, AA_{t+1}, the bank is subjected to a regulatory penalty proportional to its assets

$$\text{Ex-post assets } AA_{t+1} = R_{L,t} L_t (1 - \lambda H_{t+1})$$
$$\text{Ex-post capital } BB_{t+1} = AA_{t+1} - R_t (D_t + F_t)$$

$$\text{if } EE_{t+1} < gAA_{t+1} \Rightarrow \text{penalty } \upsilon L_t$$

- Ex-ante expected cost of the regulatory penalty considered by the bank

$$uL_t \cdot \Gamma_t(\bar{H}_t)$$

where $\Gamma_t(\bar{H}_t)$ is probability of shortfall in regulatory capital, $\bar{H}_t$ is the cut-off portfolio default ratio

$$\bar{H}_t = \frac{1}{\lambda}\left[1 - \frac{R_t}{(1-g)R_{L,t}}\left(1 - \frac{E_t}{L_t}\right)\right]$$

- Key results

$$\hat{R}_t \approx R_t + u\left[1 - \Gamma_t\left(\bar{H}_t\right) + \frac{\Gamma_t'\left(\bar{H}_t\right)R_t}{\lambda(1-g)R_{L,t}}\frac{E_t}{L_t}\right] \tag{2}$$

- Banks choose to hold regulatory capital buffers above g

▪ Cost of External Capital Flows ▪

- To generate nontrivial implications of capital adequacy requirements, we need to make it not so easy for banks to manage their capital period by period
- . . . otherwise the banks would be always able to raise fresh capital if need be immediately and costlessly from equity markets
- Empirical evidence and theoretical justification for costs and delays associated with external flows of bank capital
- The costs and delays make banks more reliant on retained earnings, especially in the short run

- Simple quadratic adjustment costs

$$\propto \left(\log E_t - \log R_{E,t} E_{t-1}\right)^2$$

where $R_{E,t}$ is last period's return on bank capital

▪ Spreads, Leverage, and Nonlinearities ▪

- Combine the individual lending supply curve (1) and the condition for optimal choice of the size of the balance sheet (2)

$$R_L(1-\lambda \mathrm{E}_t[H_{t+1}]) \approx R_t + u\left[1-\Gamma_t\left(\bar{H}_t\right)+\frac{\Gamma_t'\left(\bar{H}_t\right)R_t}{\lambda(1-g)R_{L,t}}\frac{E_t}{L_t}\right]$$

- The overall lending spread can be thought of as consisting of two components

$$R_{L,t} \approx R_t + \text{Type 1 Spread} + \text{Type 2 Spread}$$

(they are not though independent of each other)

- Type 1 spread is associated with the risk of individual loans
  - depends on borrowers' loan-to-value ratio, $\frac{L_t}{P_{K,t}K_t}$
  - helps create "capital to cover expected losses"
- Type 2 spread is associated with the risk of the portfolio as a whole
  - depends on banks' ex-ante plain capital ratio, $\frac{E_t}{L_t}$
  - helps create "credit risk capital", Wilson (1998)
- Main sources of nonlinearities in the model

▪ What Borrowers Do ▪

- Representative household consists of a large number of individual members
- Individuals are identical ex-ante, heterogenous ex-post (with complete risk sharing within the household)
- Individuals choose bank loans and physical capital subject to a lending supply curve (1)

$$\Lambda_t = \beta \mathrm{E}_t[\Lambda_{t+1}] R_{L,t} (1 + V_t)$$

$$\Lambda_t = \beta \mathrm{E}_t \left[\Lambda_{t+1} \left(R_{K,t+1} + R_{L,t} \frac{L_t}{P_{K,t} K_t} V_t \right) \right]$$

- Household as a whole makes all other choices (consumption, labor, ...)

▪ Demand for Bank Liabilities ▪

- Certain proportion of household outlays and trade in physical capital claims must be financed by bank deposits

$$DD_t = \phi_C P_t C_t + \phi_I P_t I_t + \phi_K P_{K,t} K_t$$

where DD_t is beginning-of-period deposits available

$$DD_t = R_{t-1} D_{t-1} - R_{L,t-1} L_{t-1} + L_t$$

Simulation Experiments

Jaromír Beneš

Michael Kümhof

Douglas Laxton

October 2013

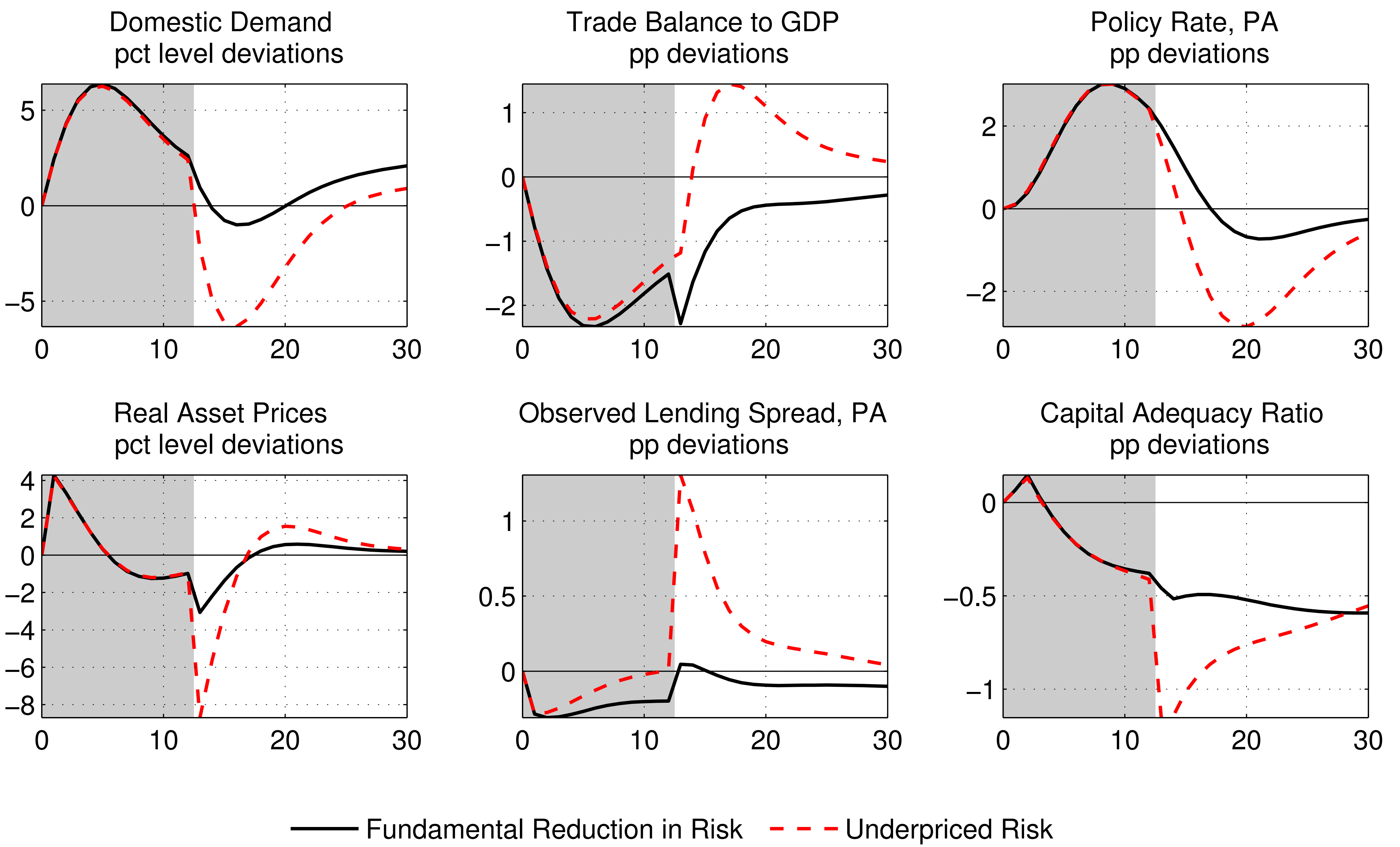
BIS Mexico City

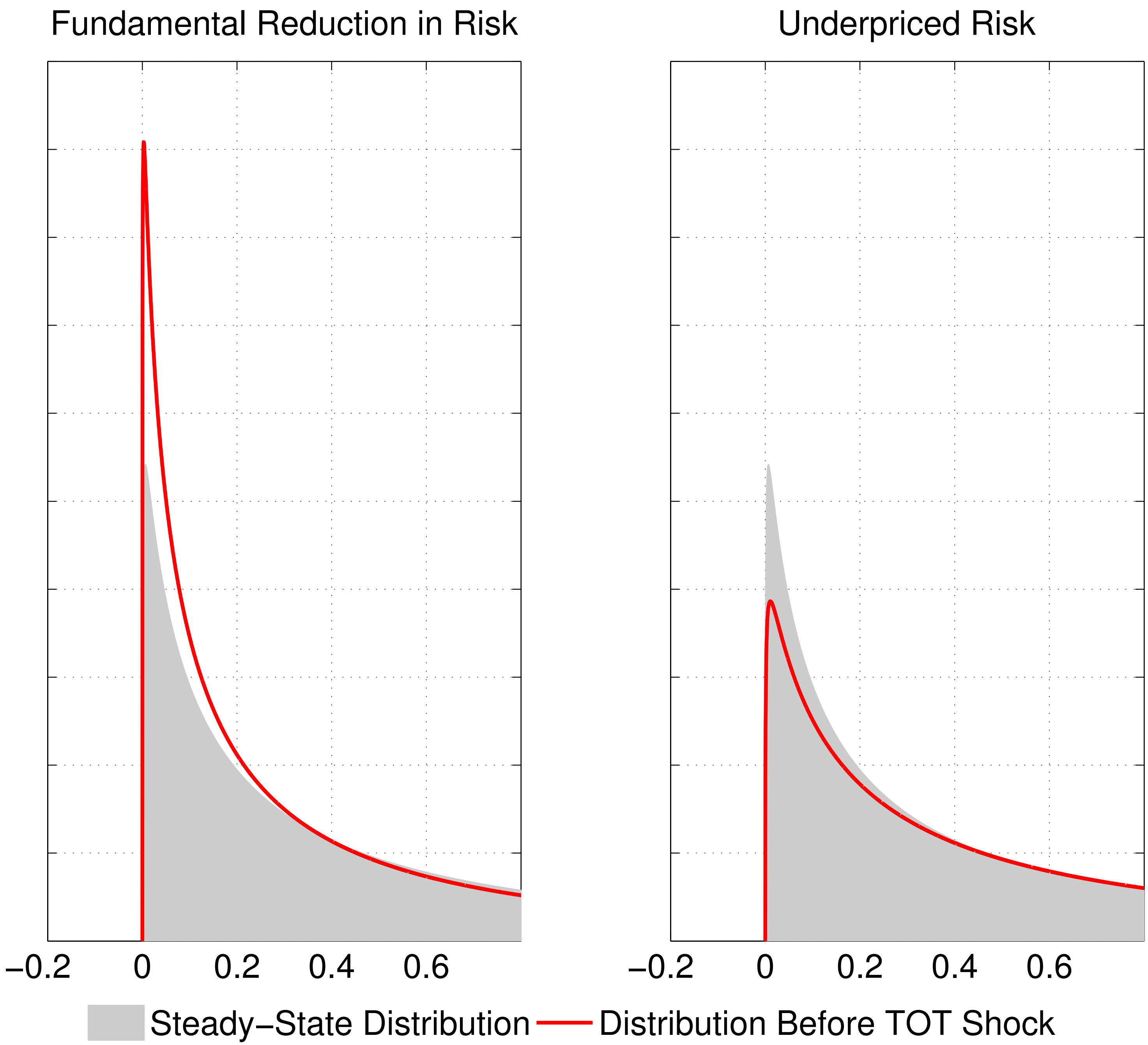
▪ The Usual Dislaimer ▪

The views expressed are the authors' own, and do not necessarily represent the views of the International Monetary Fund, its Management, its Executive Board, or any of its Executive Directors

▪ “Good” and “Bad” Credit Expansions ▪

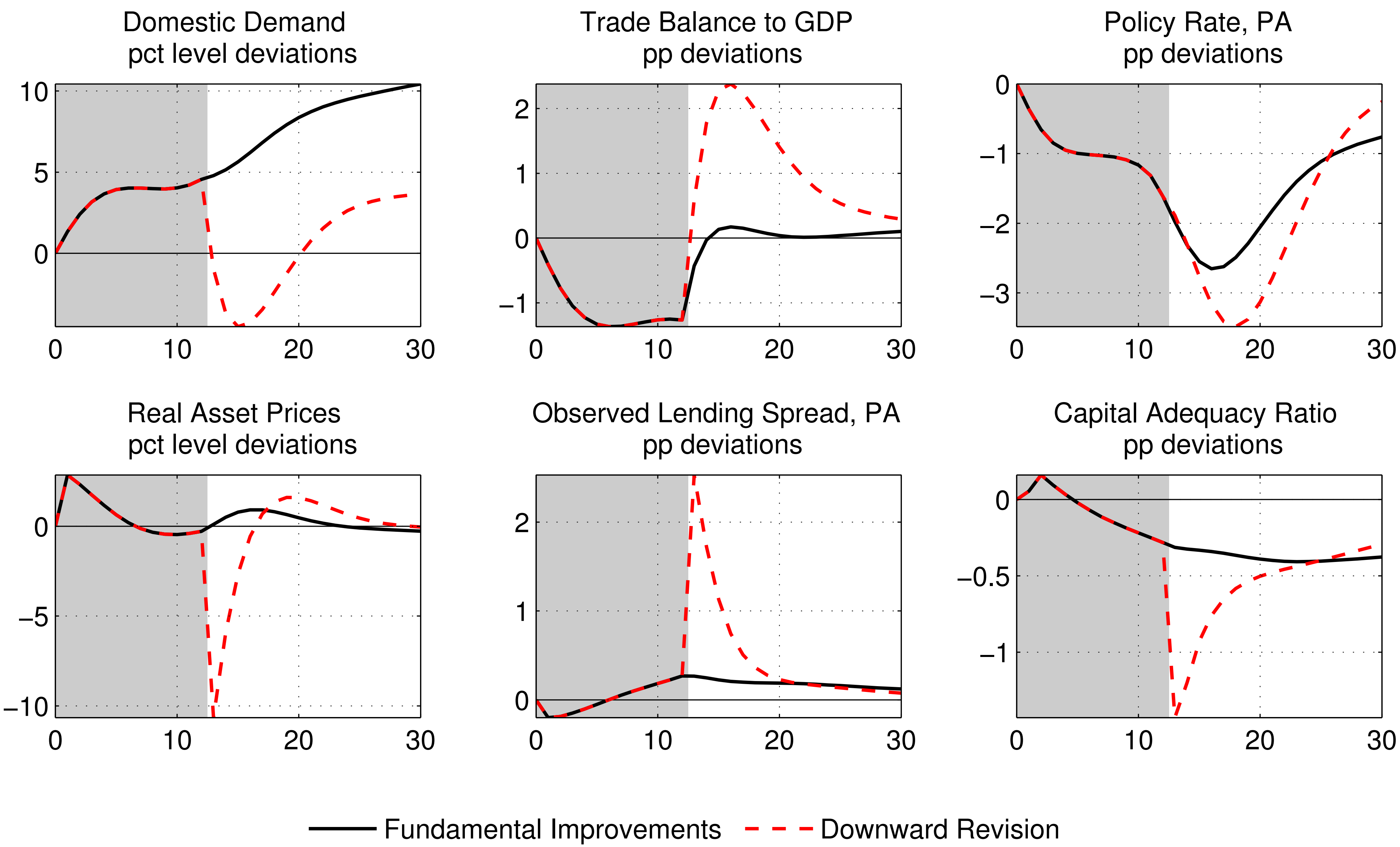
- Good credit expansion
  - Greadual reductions in overall credit risk
  - Banks respond by moving the lending supply curves north-west
- Bad credit expansion
  - Bank loans granted as if there were reductions in overall credit risk (as in the “good credit” case), but there are none
  - Not necessarily banks′ failure or irrationality: it can be intentional behaviour (i.e. subprime)
- After three years of credit expansion, an adverse non-financial shock hits the economy (terms of trade shock here)


Domestic Demand
pct level deviations
Trade Balance to GDP
pp deviations
Policy Rate, PA
pp deviations
Real Asset Prices
pct level deviations
Observed Lending Spread, PA
pp deviations
Capital Adequacy Ratio
pp deviations
Fundamental Reduction in Risk
Underpriced Risk


Fundamental Reduction in Risk
Underpriced Risk
–0.2
0
0.2
0.4
0.6
Steady–State Distribution
Distribution Before TOT Shock

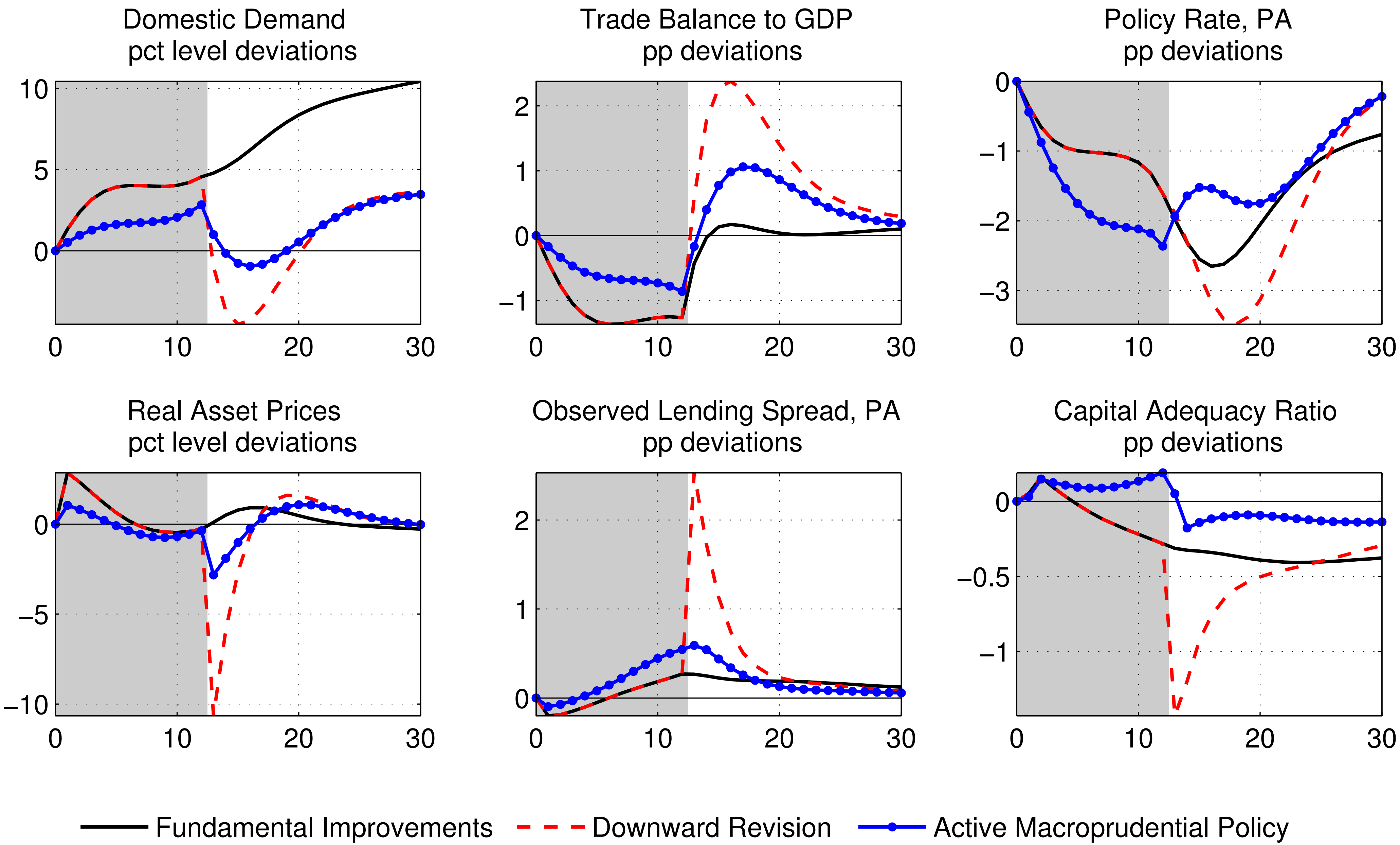
▪ Expectations and Bubbles ▪

- Future anticipated improvements in fundamentals
  - Productivity in exporting industries anticipated to gradually start to improve in three years from now
- Downward revision
  - The extent of the improvemens is revised downward before they take place (at the end of the third year) by a half

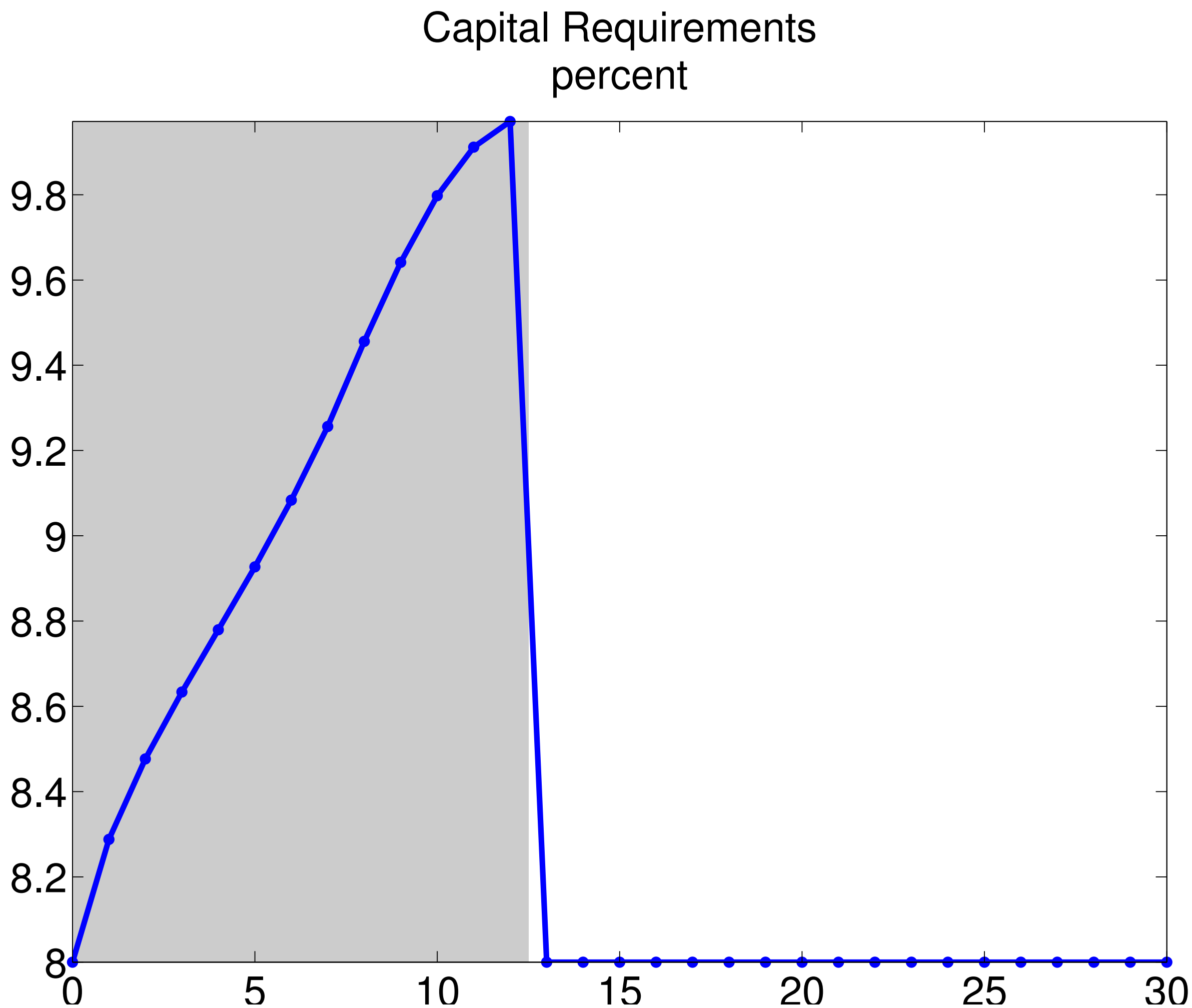

Domestic Demand
pct level deviations
Trade Balance to GDP
pp deviations
Policy Rate, PA
pp deviations
Real Asset Prices
pct level deviations
Observed Lending Spread, PA
pp deviations
Capital Adequacy Ratio
pp deviations
Fundamental Improvements
Downward Revision

▪ Proactive Macroprudential Policy ▪

- Resimulate the downward revision scenario again with proactive macroprudential policy
  - Create buffers in the upswing phase
  - Release the buffers quickly when risks materialize



Domestic Demand
pct level deviations
Trade Balance to GDP
pp deviations
Policy Rate, PA
pp deviations
Real Asset Prices
pct level deviations
Observed Lending Spread, PA
pp deviations
Capital Adequacy Ratio
pp deviations
Fundamental Improvements
Downward Revision
Active Macroprudential Policy


Capital Requirements
percent
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
0
5
10
15
20
25
30