Modeling & Managing Sovereign & Systemic Risk

Fiscal Solvency & Macroeconomic Uncertainty in Emerging Markets: *The Tale of the Tormented Insurer*

Enrique G. Mendoza
IMF, Univ. of Maryland
& NBER

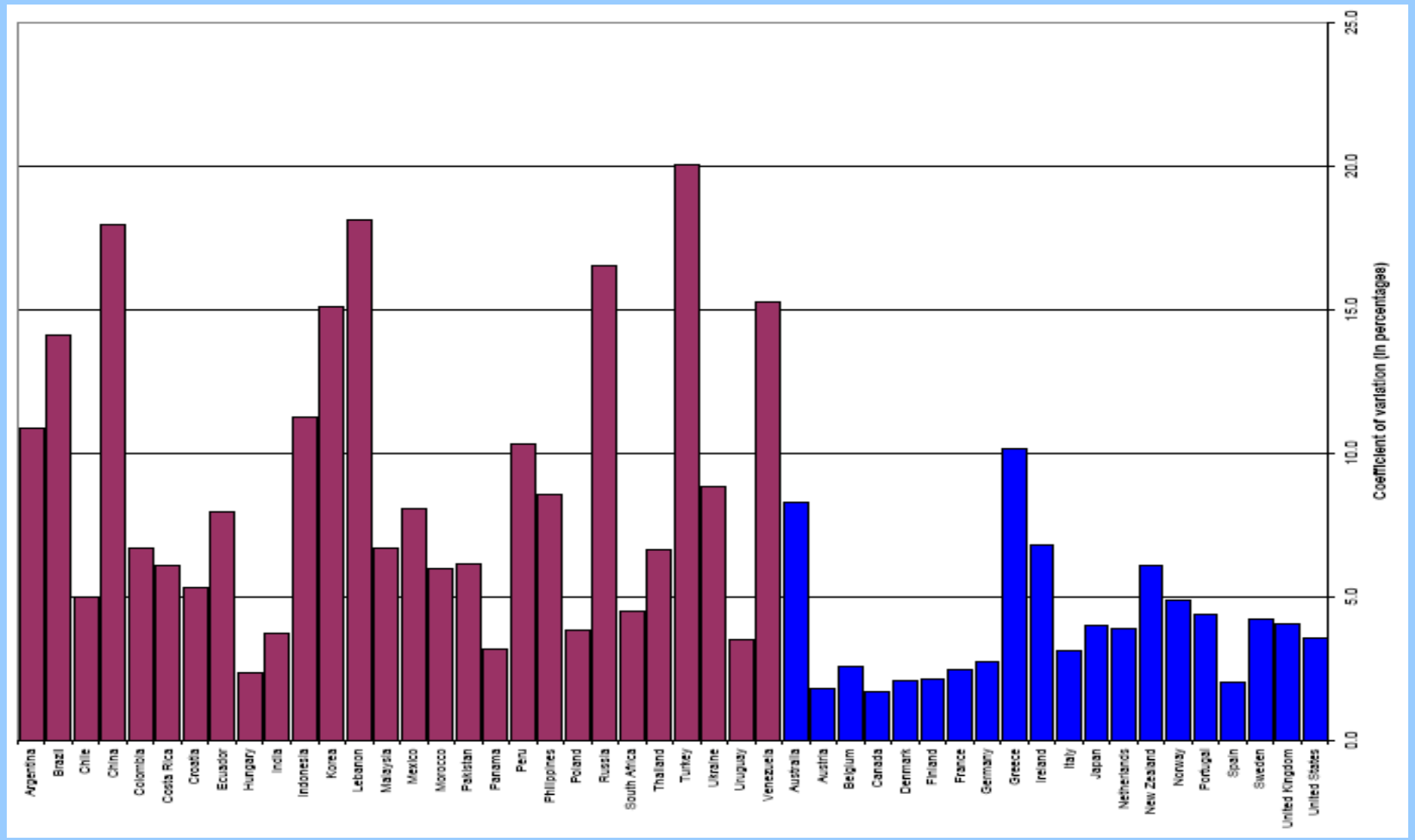
P. Marcelo Oviedo
Iowa State University

The fiscal problem of emerging economies

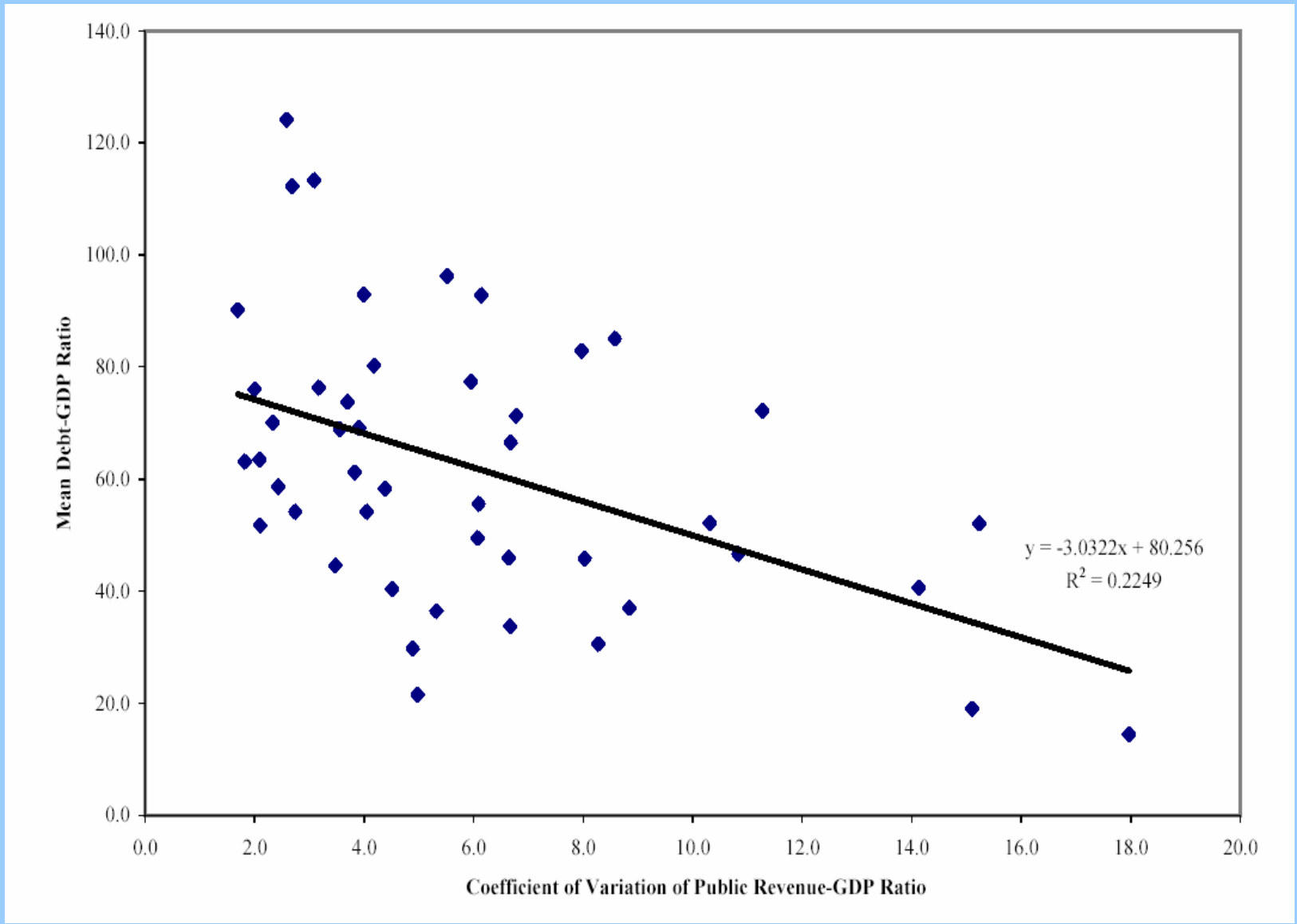
1. High, growing public debt (mostly nsc instruments)
   - Driven by financial instability, not standard primary deficits
2. Low and volatile public revenue ratios
   - Dependent on non-tax components (commodity exports)
   - Average debt ratios fall as revenue variability rises
3. Fiscal policies display abnormal cyclical behavior
   - GDP correlations of primary balance (gov. expenditures) close to zero or slightly negative (positive)
   - Downward rigidities in cutting outlays, cuts in “bad times”
   - Excess variability of public relative to private expenditures

Coefficients of variation of public revenue-GDP ratios

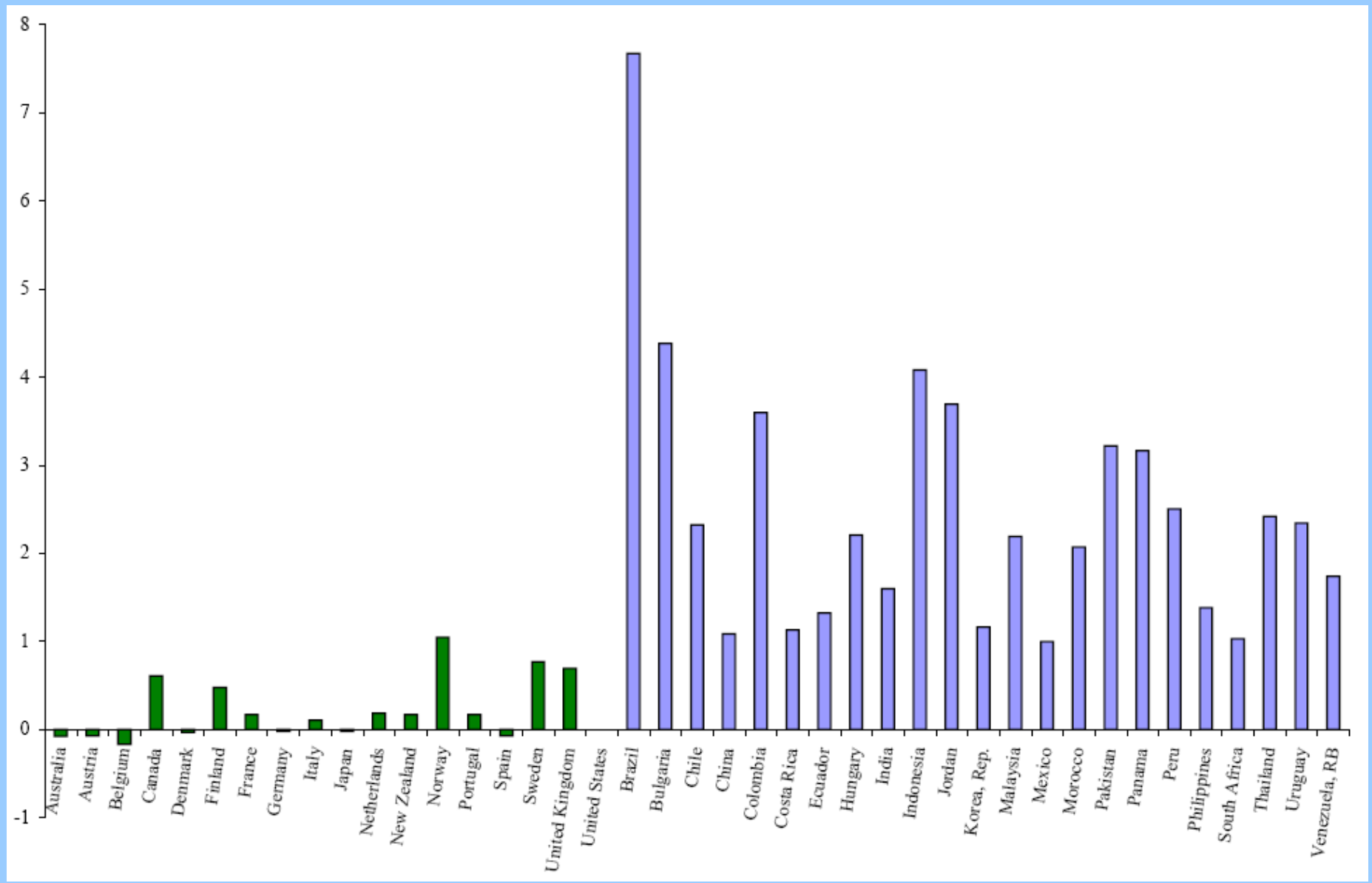
(1990-2002)



Mean debt ratios fall as revenue volatility rises



Excess variability of government purchases relative to private expenditures



The EMs fiscal dilemma: A problem of social insurance

- Institutions & policies split domestic income between private and public sectors
- 1st best: Pool incomes, equate mg. ut. of expenditures
  - Needs state-contingent, non-distorting taxes, transfers or debt
- 2nd best: Choose optimal debt & expenditures policies given limited debt instruments, low/volatile revenues, fiscal rigidities
  - Sustainable debt has a self insurance feature
- Debt sustainability analysis requires:
  - EM features: suboptimal taxes, credit frictions, macro volatility, policy rigidities
  - Forward looking, structural treatment (Lucas critique argument)

Solving the 2nd best problem: The tormented insurer framework

- Gov. aims to smooth its outlays relative to the volatility of revenues but using only non-state-contingent debt
- Sustainable debt features a *Natural Debt Limit*
  - *NDL* = annuity value of primary balance at *fiscal crisis*
  - *Fiscal crisis:* long sequence of low revenues, outlays cut to lowest "tolerable" levels
  - NDL is also a credible commitment to be able to repay, but is NOT generally the same as sustainable debt, which is set by budget constraint
- Structural DSGE tool for public/external debt analysis:
  - Calibrated to country-specific features
  - Models explicitly gov. behavior and GE of the economy

Basic model: random revenue, ad-hoc outlays

- Gov. budget constraint: $\gamma b_{t+1}^{g} = b_t^{g} R_t - (t_t - g_t)$
- Markov process of revenues: $t \in [t^{min}, t^{max}]$, π
- Fiscal crisis: $t_t = t^{\min}$ "almost surely", $g_t = g^{\min}$
- Gov. keeps $g_t = g$ as long as it can access debt market
- NDL: $b_{t+1}^{g} \leq \phi = \dfrac{t^{\min} - g^{\min}}{R - \gamma}$
  - "classic" sustainability ratio exceeds NDL since it uses $\mathrm{E}[t\text{-}g]$
- Sustainable debt: $b_{t+1}^{g} = \gamma^{-1} \min\left[\phi,\ g - t_t + b_t^{g} R\right]$

Lessons from the basic model

- Higher revenue volatility tightens NDL ($\downarrow t^{min}$ as $\uparrow sd(t)$)
- Commitments to repay & cut outlays at fiscal crisis support each other
  - Given *t* process, countries with lower $g^{\min}$ can borrow more, and are less likely to face fiscal crisis
- Insurance argument in favor of indirect taxation
- Degenerate long-run debt distribution: debt converges to NDL or vanishes depending on initial conditions
  - "Time to fiscal crisis:" $\left(\frac{R}{\gamma}\right)^{T} = \frac{g - g^{\min}}{g - t^{\min}}$

Application of the basic model (cont'd)

	Brazil	Colombia	Costa Rica	Mexico
Public debt	*1990-2002*	*1990-2002*	*1990-2002*	*1990-2002*
average	40.68	33.71	49.46	45.92
maximum	56.00	50.20	53.08	54.90
year of maximum	2002	2002	1996	1998
Implied fiscal adjustment to support maximum debt as NDL				
in no. of std. deviations	2.55	2.30	1.16	2.02
in % of GDP	6.73	3.99	2.15	1.54
Benchmark Natural Debt Limits				
(1961-2000 per-capita growth rates, 5% real interest rate)				
Growth rate	2.55	1.86	1.83	2.20
Natural debt limit	56.09	50.49	53.31	54.92
Growth Slowdown Scenario				
(1981-2000 per-capita growth rates)				
Growth rate	0.48	1.05	1.25	0.83
Natural debt limit	30.34	40.10	45.10	36.96
High Real Interest Rate Scenario				
(8% real interest rate)				
Growth rate	2.55	1.86	1.83	2.20
Natural debt limit	25.19	25.81	27.39	26.53

The DSGE model

- Public debt and expenditure policies are endogenous
  - Government's behavior as insurer is endogenous
  - Gov. maximizes CRRA payoff (provides incentive to smooth and yields NDL as feature of optimal plans)
  - Non-state-contingent debt
- Private sector chooses NFA, public debt & consumption
- Strategic interaction between public & private sectors
  - Markov perfect equilibrium
  - Two forms of market incompleteness: vis-à-vis rest of the world and between domestic private and public sectors
  - Public and private precautionary savings motives
- Stochastic output & taxes induce revenue volatility

Markov-perfect equilibrium

- Government:

$$V(b^g, b^I, e) = \max_{b^{g'}, g} \left\{ \frac{g^{1-\sigma}}{1-\sigma} + \beta\gamma^{1-\sigma} E\Big[V(b^{g'}, \tilde{b}^{I'}, e') \Big] \right\}$$

$$s.t. \qquad g + z + \Re b^g = \tau y + b^{g'},$$

$$\tilde{b}^{I'}(b^g, b^I, e), \quad \Pi\big[e' \mid e\big], \quad e \equiv (y, \tau), \quad b^{g'} \leq \phi^g$$

- Private sector:

$$W(b^g, b^I, e) = \max_{b^{I'}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta\gamma^{1-\sigma} E\Big[W(\tilde{b}^{g'}, b^{I'}, e') \Big] \right\}$$

$$s.t. \quad c + x = (1-\tau)y + z - \tilde{b}^{g'} - b^{I'} + (b^g + b^I)\Re,$$

$$\tilde{b}^{g'}(b^g, b^I, e), \quad \Pi\big[e' \mid e\big], \qquad b^{I'} \geq \phi^I$$

- Market-clearing and Markov eq. conditions:

$$\tilde{b}^{g'}(\cdot) = b^{g'}(\cdot), \qquad \tilde{b}^{I'}(\cdot) = b^{I'}(\cdot), \quad c + g + x = y - b^{I'} + b^I\Re$$

Application to Mexico

- Mexico's GDP and "implied tax" processes:

Statistic	Mexican data (a) GDP	Mexican data (a) Implied tax rate	Markov chain (b) GDP	Markov chain (b) Implied tax rate
Standard deviation	0.02948	0.06027	0.02781	0.05689
Minimum	-0.07073	-0.12294	-0.04670	-0.09991
Maximum	0.05018	0.01080	0.04670	0.09991
Cross correlation	-0.24172	-0.24172	-0.19786	-0.19786
Autocorrelation	0.351	0.535	0.278	0.576

- Main results:
  1. 53% mean debt ratio, but fluctuations are highly persistent
  2. Acylical gov. purchases and primary balance
  3. Average debt ratios fall as volatility increases
  4. 1.6 to 3.5% welfare costs due domestic incompleteness

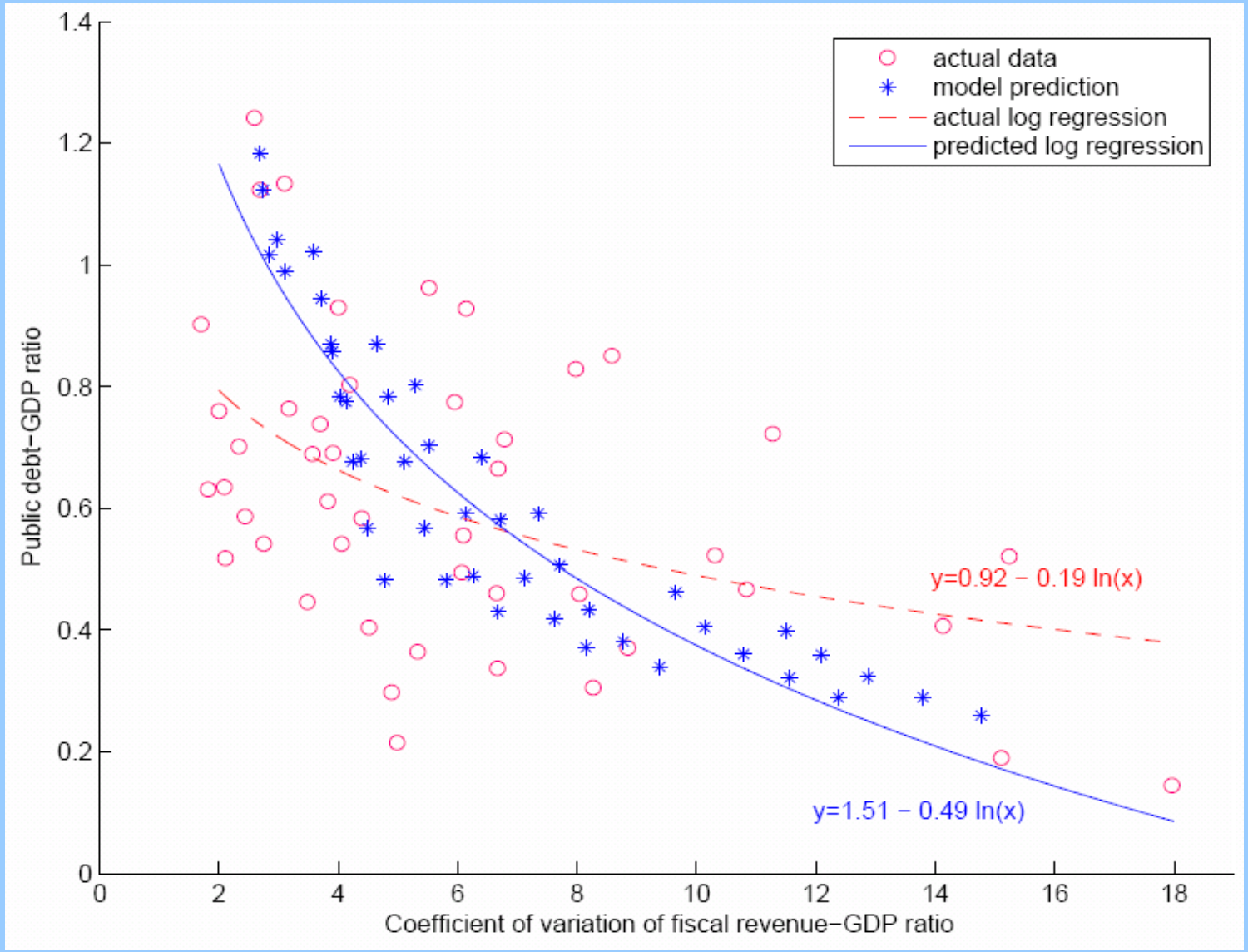
Calibration to Mexican data

Notation	Parameter / Variable	Value
β	Discount factor	0.925
γ	Gross growth rate	1.036
ϕ^g	Natural debt limit on public debt	1.318
ϕ^I	Ad-hoc debt limit on international debt	-0.500
σ	Coefficient of relative risk aversion	2.000
τ	Mean income-tax rate	0.256
R	Gross world interest rate	1.0986
x	Private investment expenditures	0.226
z	Government transfers	0.111
	Minimum value government debt	0.000
	Maximum value of international assets	0.100

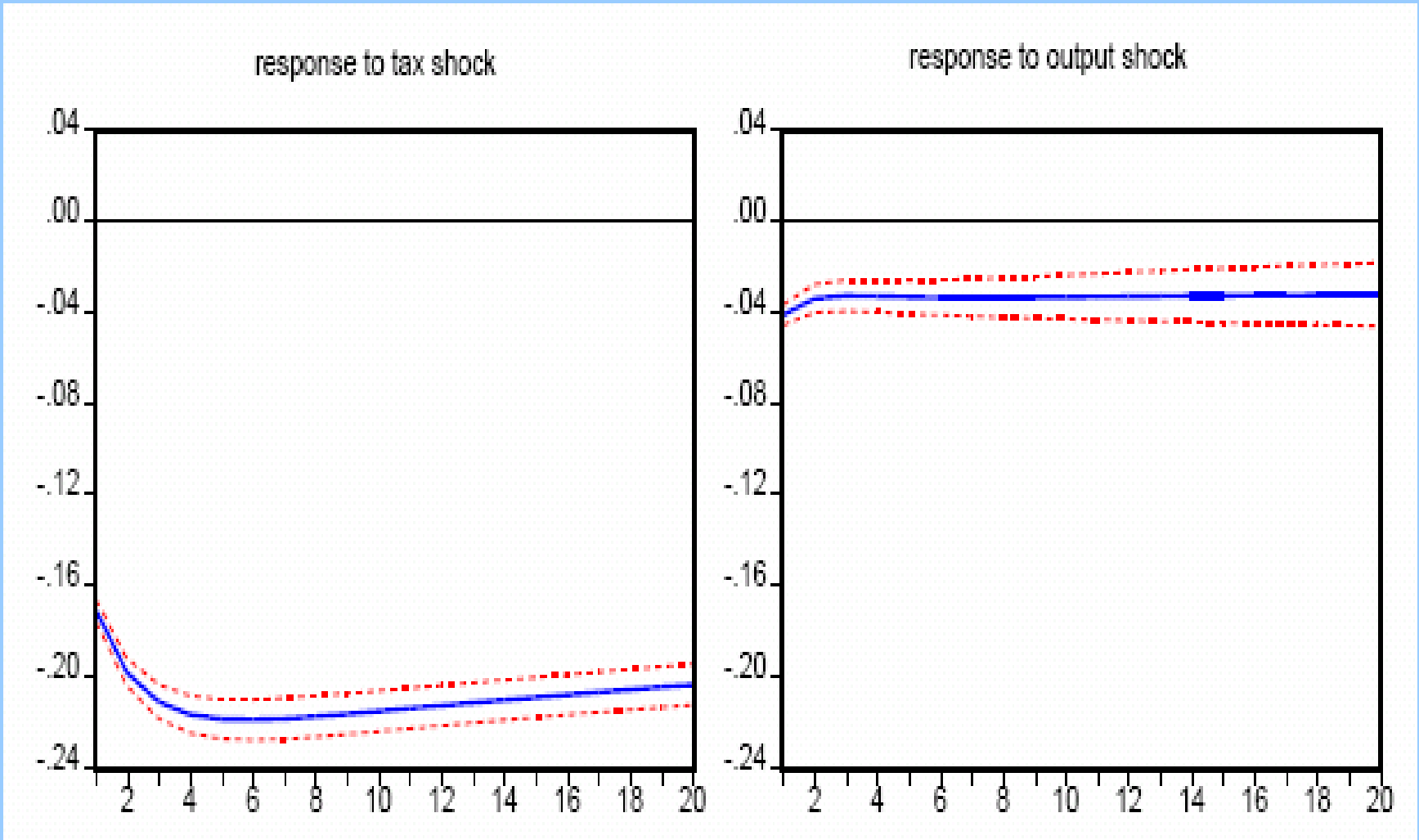
Moments of the stochastic long-run equilibrium

Variable (x)	E$[x]$	$\sigma(x)$	cv(x)	$\rho(x)$	$\rho(x, y_i)$, where $y_i =$ GDP	after tax inc.	fiscal revenue
GDP	1.00	2.80	2.80	0.28	1.00	0.86	0.28
GNP	0.97	3.03	3.13	0.42	0.95	0.82	0.26
After-tax income	0.74	2.78	3.73	0.38	0.86	1.00	-0.25
Consumption	0.64	3.20	4.97	0.97	0.20	0.24	-0.07
Gov. expenditures	0.10	2.83	29.07	1.00	0.02	-0.04	0.12
Tax rate	0.26	1.47	5.73	0.58	-0.20	-0.68	0.88
Fiscal revenue	0.26	1.50	5.86	0.53	0.28	-0.25	1.00
Primary fiscal balance	0.05	3.05	64.47	0.90	0.12	-0.09	0.38
Current account	0.00	2.27	-	0.24	0.96	0.80	0.31
Trade balance	0.03	2.55	79.43	0.34	0.82	0.68	0.28
Public debt	0.53	30.51	57.37	1.00	0.00	0.02	-0.05
International assets	-0.36	10.72	-29.72	0.98	0.08	0.08	0.00

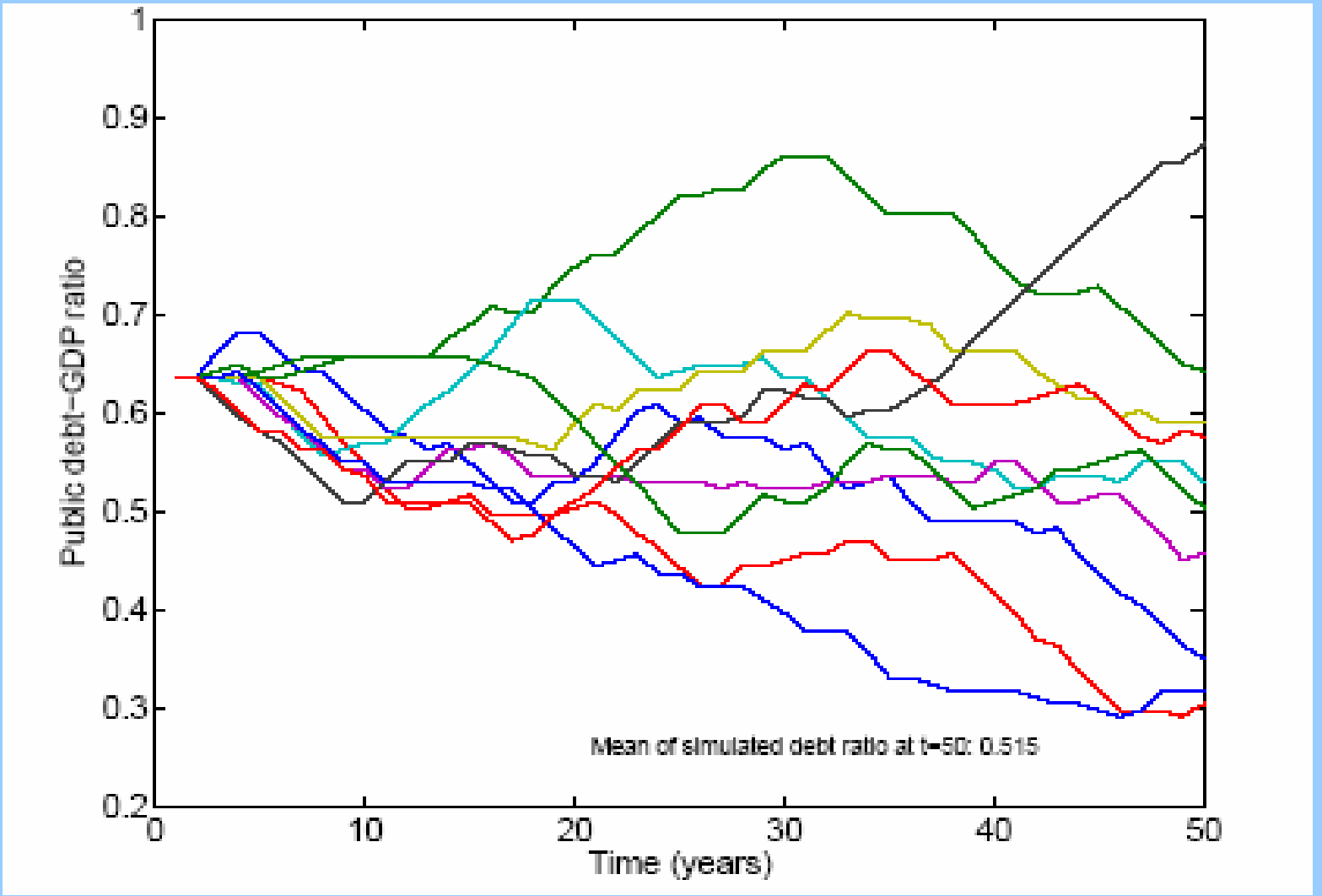
Revenue variability and average public debt ratios



Impulse response functions of c/g ratio



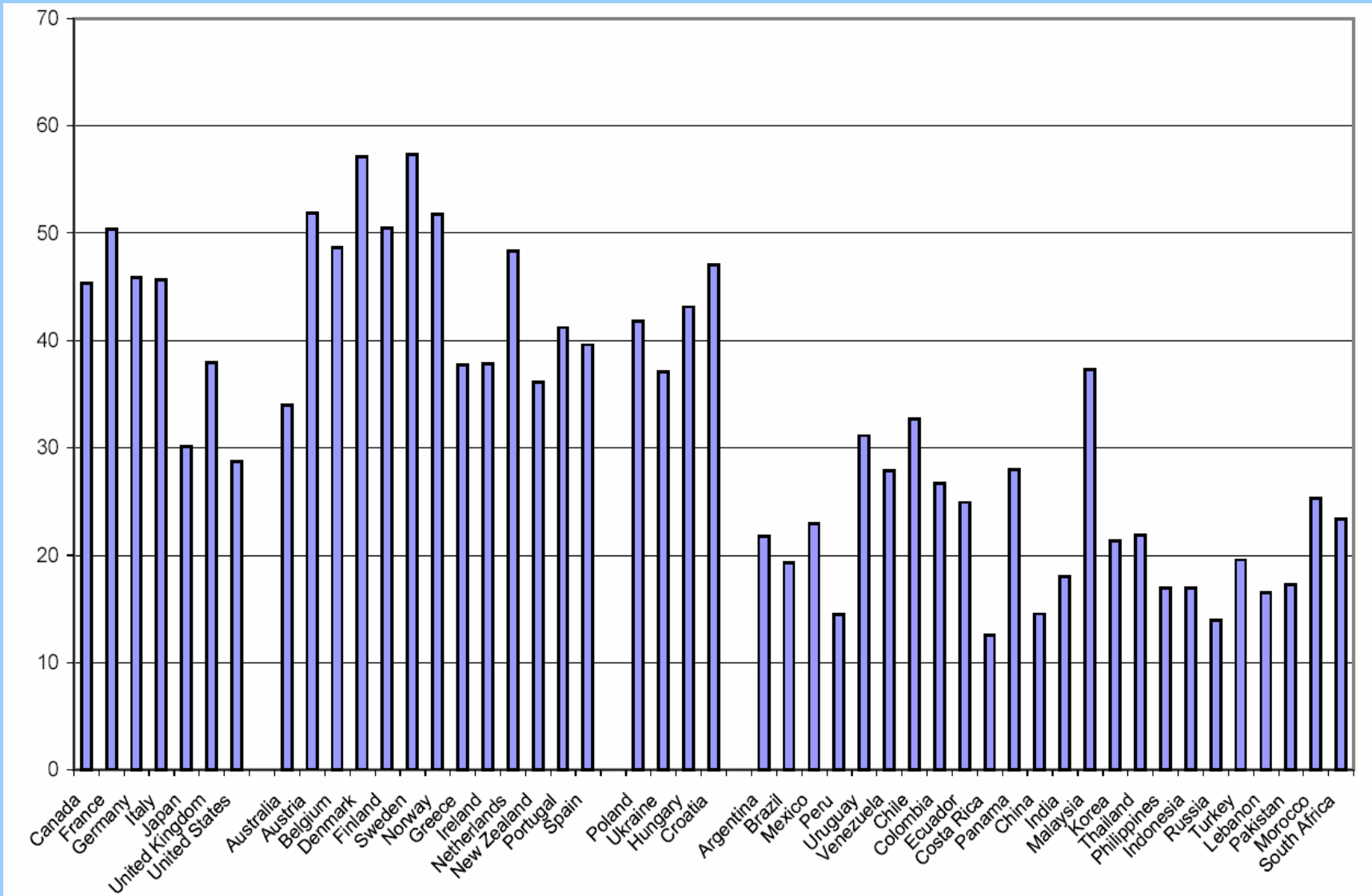
Stochastic simulations of debt-GDP ratio
(starting from initial condition of 63.4%)



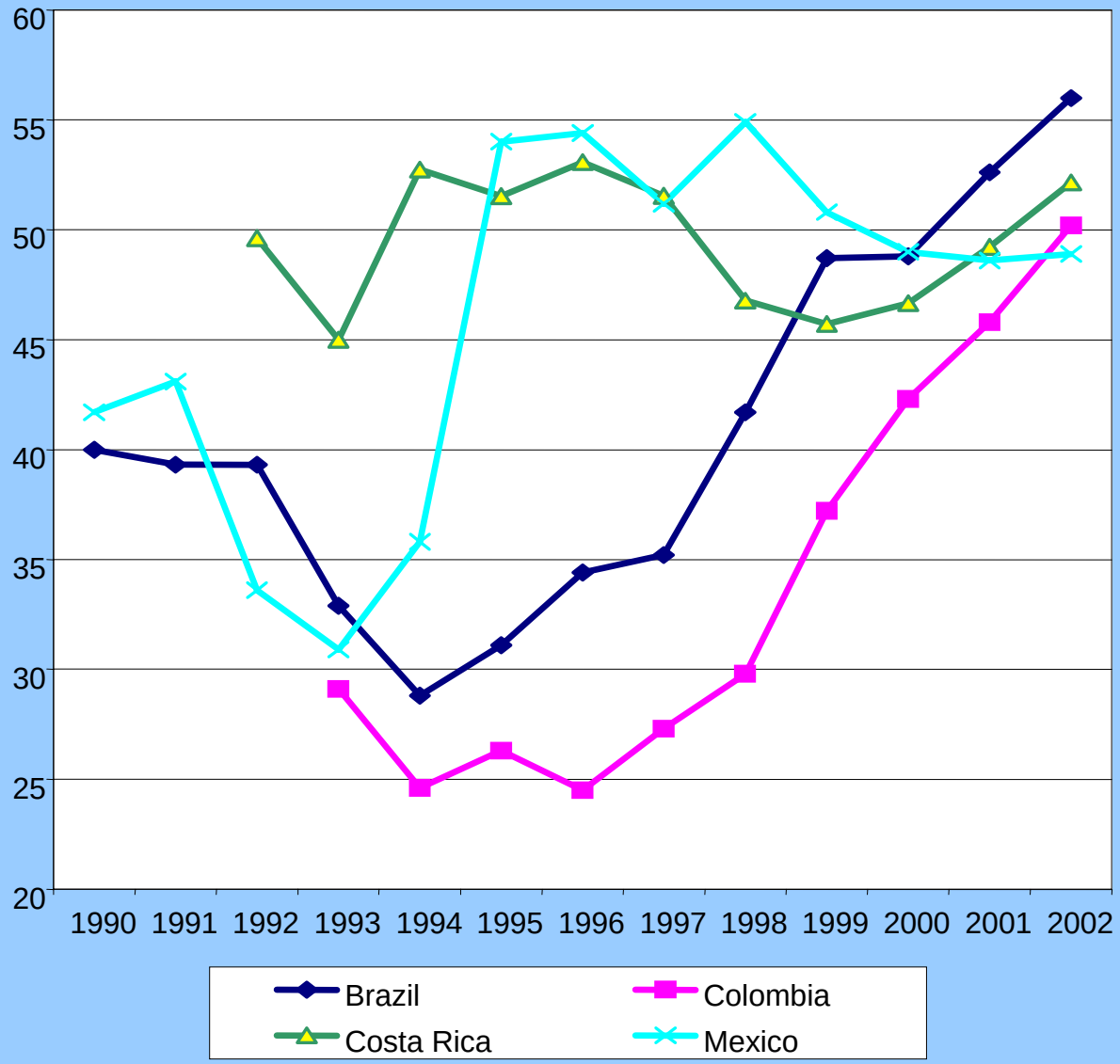
Conclusions

- Method to assess fiscal solvency in emerging economies with “tormented insurer” features
- Policy implication: VATs may be useful for producing higher, stable revenues & enhance flexibility of outlays
- Basic model:
  - Debt exceeds NDL in two out of four countries
  - In GS, HRIR scenarios debt is too high in all four countries
  - Short time to fiscal crisis for repeated negative shocks
- DSGE model (applied to Mexico):
  - Current debt ratio of 45% and an average debt ratio of 53% are consistent with fiscal solvency
  - Accounts for acyclical expenditures and primary balance
  - Accounts for link between lower debt and higher volatility
  - Large welfare costs of domestic market incompleteness

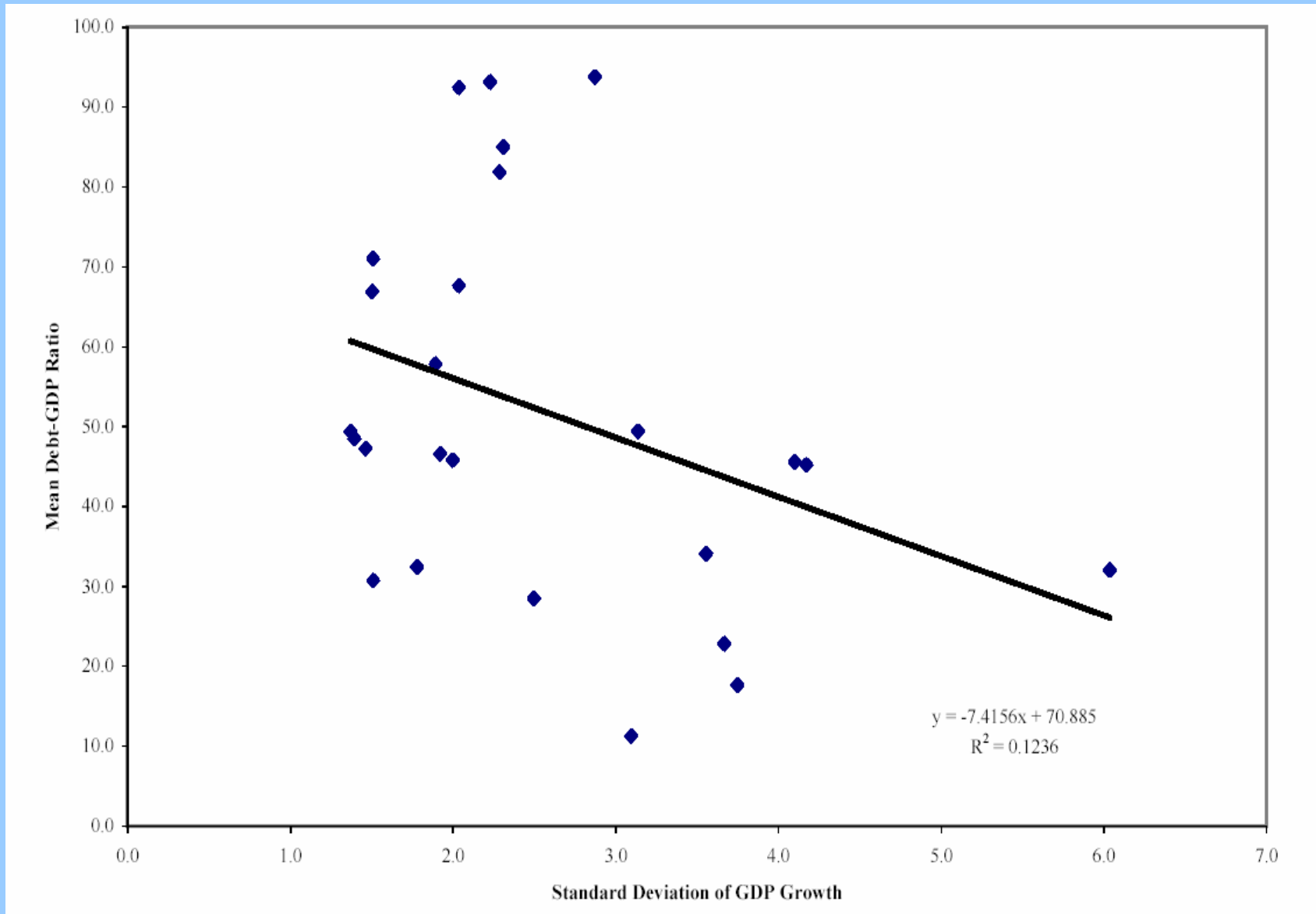
Revenue ratios are smaller



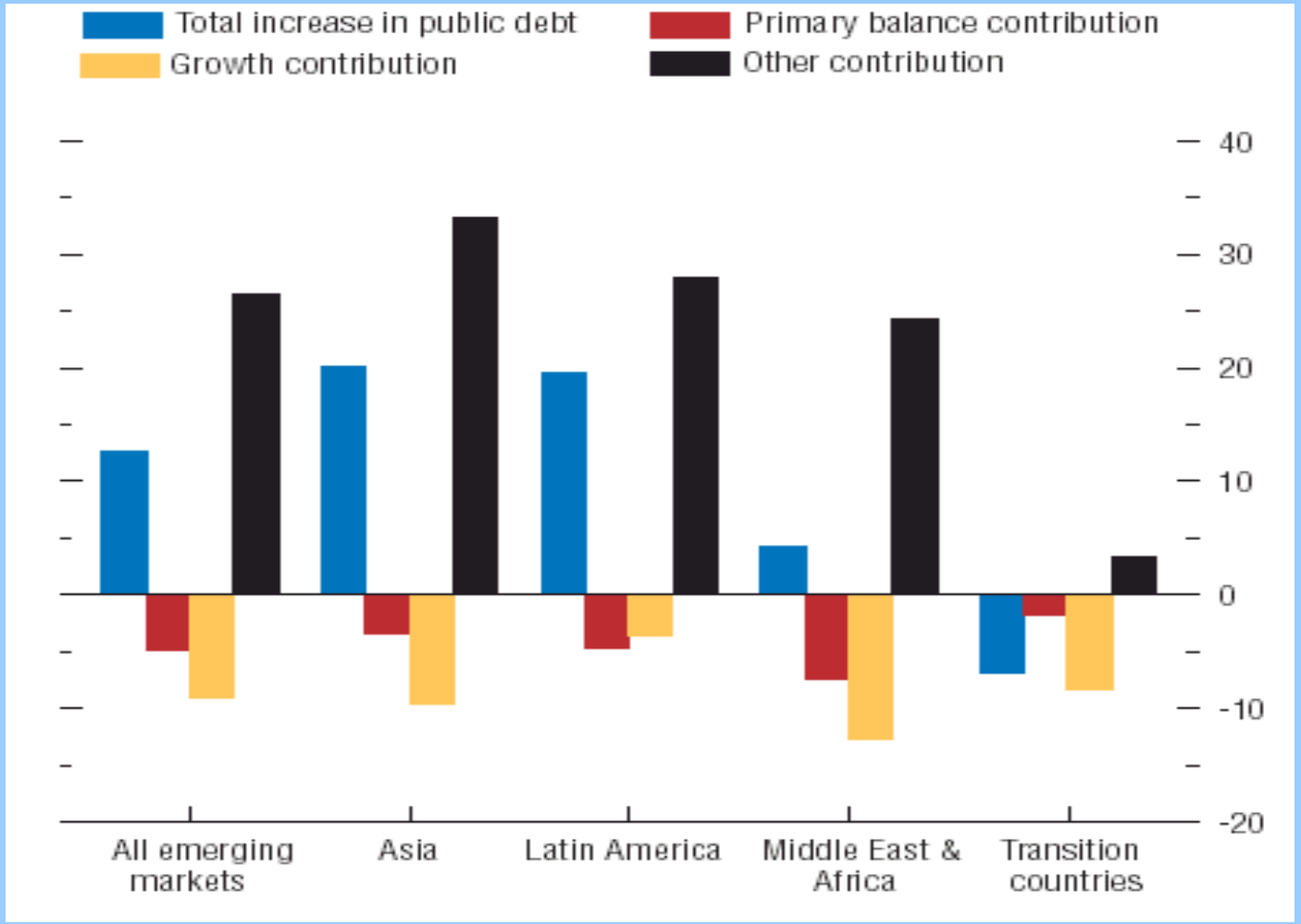
Public debt ratios are growing rapidly



..or as output volatility increases



Financial instability drives growing debt ratios



Source: **IMF (2003), p. 54**.

Note: “Other” includes contingent liabilities and costs due to changes in interest rates and exchange rates.

Application of the basic model

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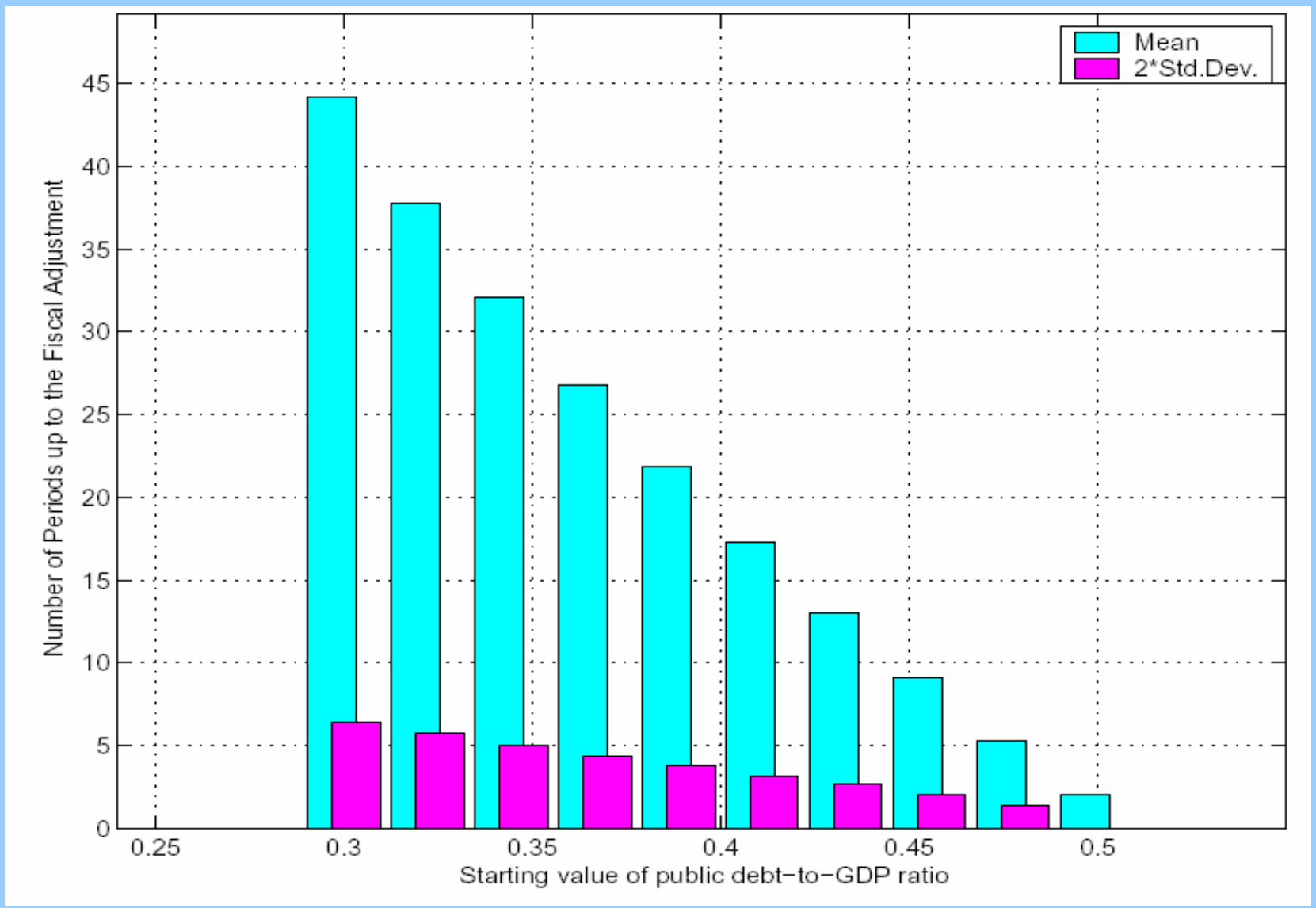
Public debt-GDP ratio	*1990-2002*	*1990-2002*	*1990-2002*	*1990-2002*
average	40.68	33.71	49.46	45.92
maximum	56.00	50.20	53.08	54.90
year of maximum	2002	2002	1996	1998
Public revenue-GDP ratio	*1990-2002*	*1990-1999*	*1990-2000*	*1990-2002*
average	19.28	12.64	20.28	22.96
coeff. of variation	14.13	8.86	5.41	8.04
two-standard dev. Floor	13.83	10.40	18.09	19.27
Non-interest outlays-GDP ratio	*1991-1998*	*1990-1999*	*1990-2000*	*1990-2002*
average	19.19	12.80	18.54	19.27
coeff. of variation	13.76	13.55	9.98	3.96

Average & extreme "time to fiscal crisis:" Mexico



Default risk in the basic model

- Eaton-Gersovitz class of models of default risk yield very small debt ratios and risk premia (Arellano (2004))
- Reduced form of arbitrage condition with default risk:

$$R(b_t) = \frac{R^w}{\lambda(b_t)} = \frac{R^w}{\exp(-ab_t)}, \qquad a > 0$$

  - $\lambda(b)$ = prob. of repayment, $1-\lambda(b)$ = prob. of default
  - prob. of default and $R(b)$ are increasing and convex on b_t
  - prob. of default is zero at zero debt
  - Mexico 1998: b = 54.9%, R^w = 3.2% (real 90-day T-bill rate), $R(b)$ = 10.48% (R^w + *EMBI spread*), which imply a = 0.124.
- Redo NDL analysis and debt dynamics using $R(b)$

Table 2. Natural Debt Limits with Default Risk

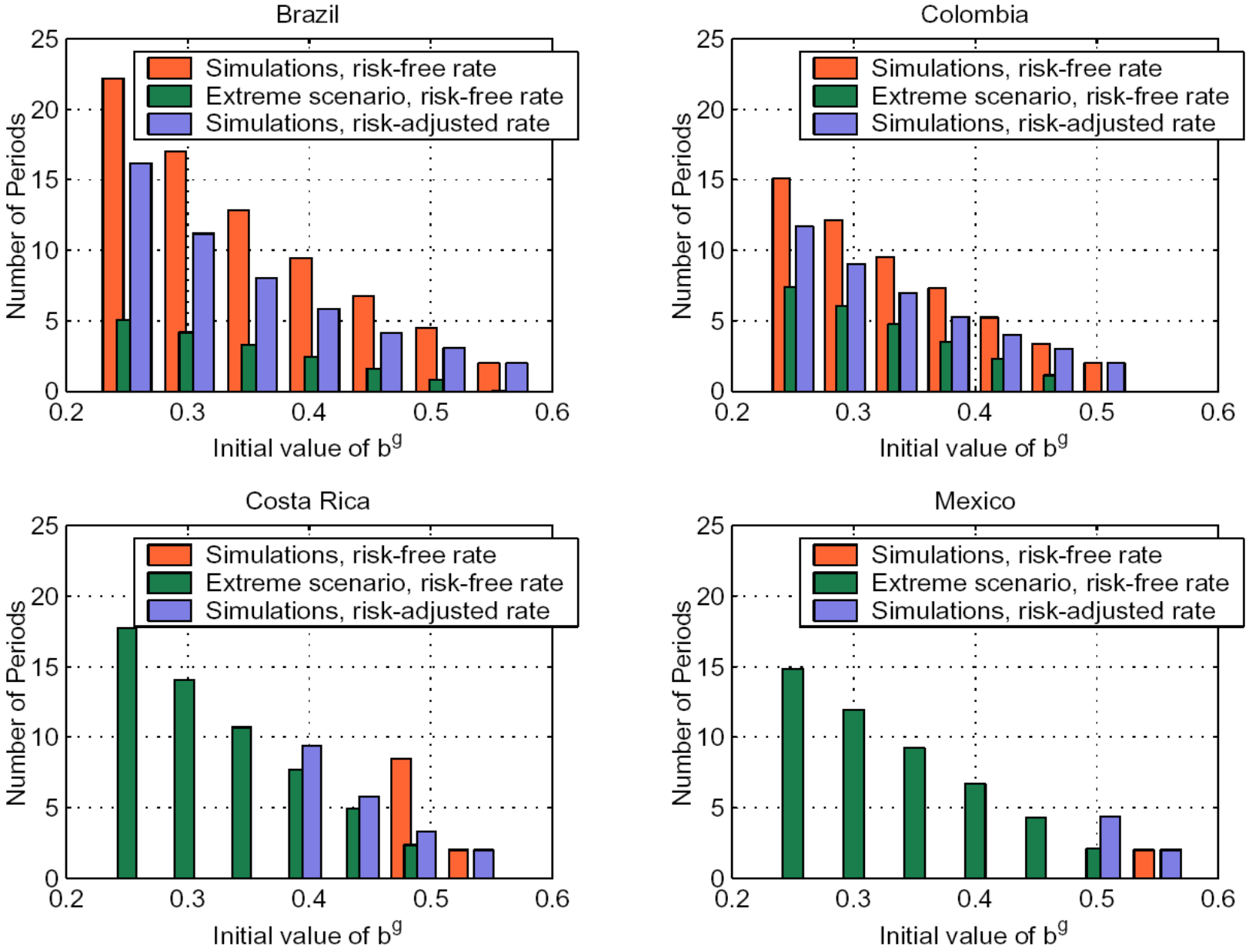
	Brazil	Colombia	Costa Rica	Mexico
Benchmark NDLs with default risk 1/				
Natural debt limit	33.28	33.18	34.14	33.88
Probability of default	4.04	4.03	4.14	4.11
Default risk premium	4.31	4.30	4.42	4.39
NDLs in the growth slowdown scenario with default risk				
Natural debt limit	26.12	30.38	32.12	29.12
Probability of default	3.18	3.69	3.90	3.54
Default risk premium	3.37	3.93	4.16	3.76
NDLs in the growth slowdown scenario without default risk and risk free rate of 2.36 percent				
Natural debt limit	72.95	121.60	152.30	100.80
Required fiscal adjustment to support observed maximum debt ratios as NDLS 2/				
Natural debt limit	56.00	50.20	53.08	54.90
Probability of default	6.70	6.03	6.36	6.57
Default risk premium	7.35	6.57	6.95	7.20
Implied minimum non-interest outlays	9.82	6.85	14.12	15.23
relative to average outlays	-9.37	-5.95	-4.42	-4.04
in number of st. devs.	3.55	3.43	2.39	5.30

Notes: Calculations done as described in the text, using a risk free rate of 2.36 percent, which is the 1990-2002 average of the inflation-adjusted 90-day U.S. T-bill rate.

1/ Based on the benchmark values of growth rates and minimum revenue and outlays shown in Table 1

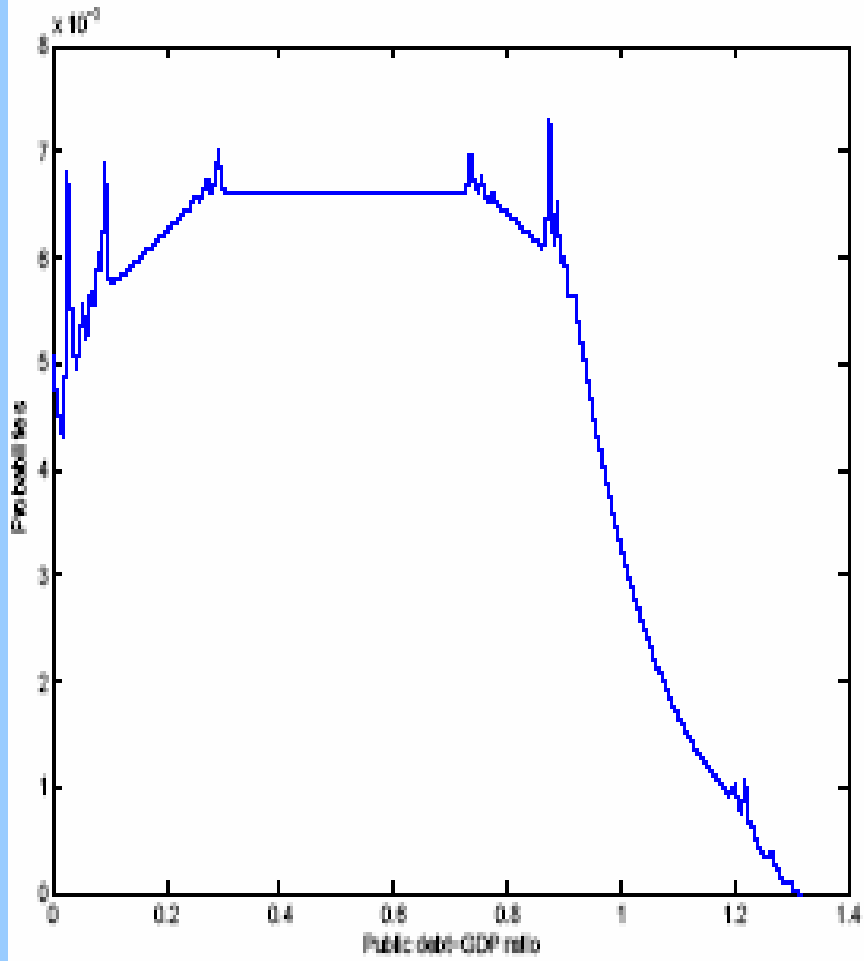
2/ Values of minimum outlays required to support maximum debt ratios shown in Table 1 as NDLs in the setting with default risk, using growth rates from the benchmark scenario.

Figure 4. Time to Hit a Fiscal Crisis with and without Default Risk



Long-run distributions of public debt and NFA

Public debt/GDP ratio



NFA/GDP ratio