Natural Resources and Sovereign Risk in Emerging Economies: A Curse *and* a Blessing

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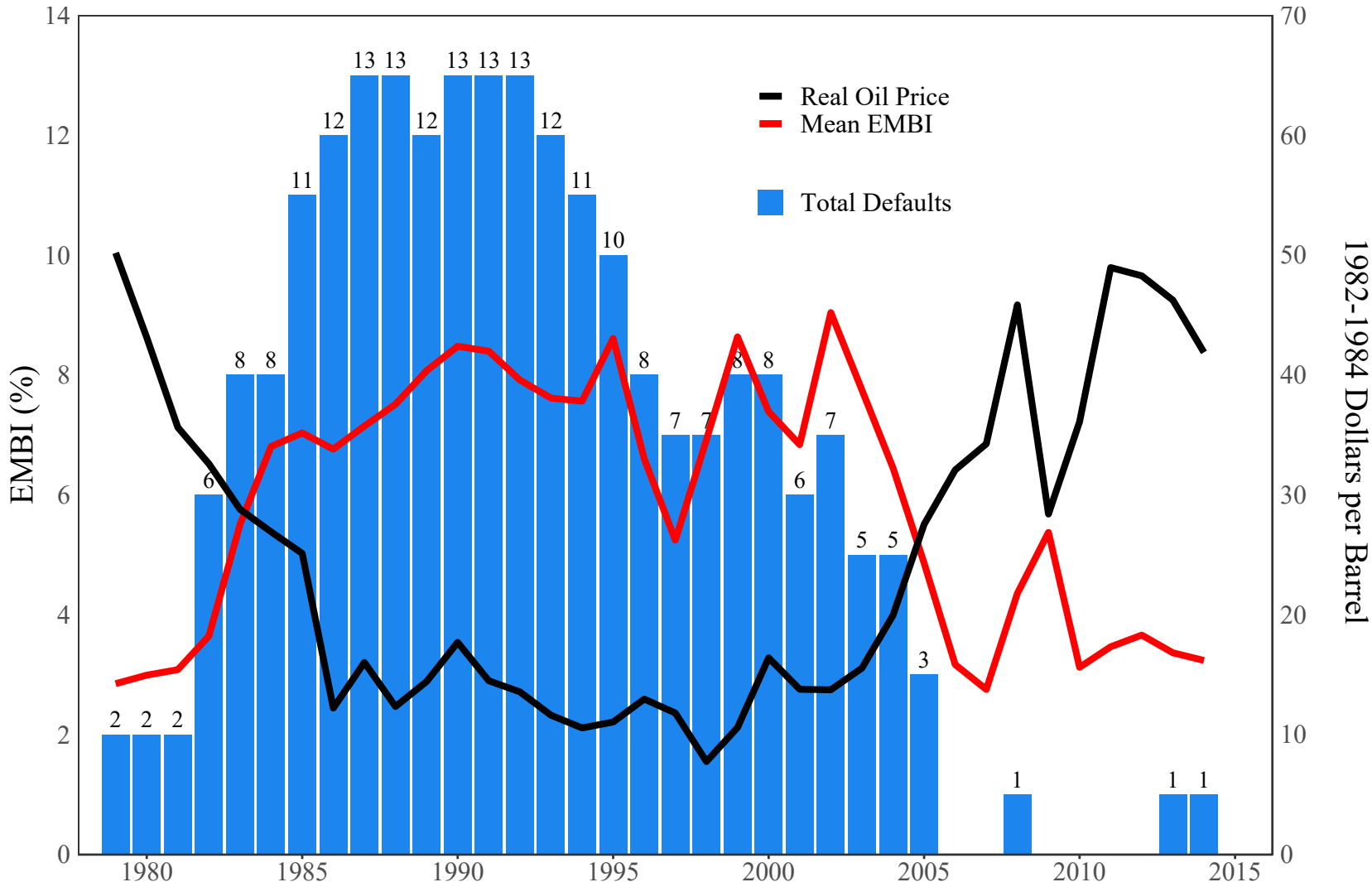
Motivation: Sovereign risk and oil prices



What we do in this paper

- Document new stylized facts on the relationship between sovereign debt/risk and oil extraction, reserves & prices for 30 largest oil producers in emerging economies
- Propose a sovereign default model with endogenous extraction to rationalize the empirical facts
- Derive analytic results for the interaction between oil-price shocks and oil reserves with debt and default risk
- Calibrate the model to a panel of oil producers (defaulters & nondefaulters) and examine its quantitative implications

Findings

- **Empirical**:
  - Ext. debt is high & default is common (16 countries at least once)
  - Correlations of country risk with oil variables
    1. *Real price*: $-$
    2. *Output* (conditional): $-$ on impact, uncorrelated in long-run
    3. *Reserves* (conditional): uncorrelated on impact, $+$ in long-run

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- **Theoretical**: Feedback mechanism links debt, risk & oil returns:
  - Endogenous default payoff via choice of extraction and reserves
  - Reserves managed strategically to make default less painful (sustainable debt falls)
  - Oil prices affect debt & spreads through this mechanism
  - Existing theoretical results extend to oil reserves & price shocks

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- **Quantitative**:
  - Reasonable fit to data moments
  - Shifting dynamic relationship of reserves and country risk
  - Endogenous extraction and default risk are quantitatively relevant

Empirical facts

Dataset

- 30 largest oil-producing emerging economies oil-producers
  - weighted by share of collective oil output
  - average external public debt ratio: 22.5% external public debt
  - 16 have defaulted at least once default episodes
- Country risk: Institutional Investor Index (1979-2016)
  - Scored by risk analysts at global banks, money management and securities firms
  - Index between 0 and 100 (least likelihood of default)
  - All risks related to investing in a country—political risk, exchange rate risk, economic risk, sovereign risk
- We use III because EMBI or CDS are not available for many countries and/or for a long enough time period

Key stylized facts

1. Country risk worsens as debt rises (mean corr. between debt ratio and III is -0.6)

2. Country risk worsens as real oil price falls over the business cycle (0.7 corr. with III) Table

3. Conditionally (DFE panel regression), country risk worsens when oil output falls on impact but in the long-run is unaffected DFE

4. Conditionally, country risk does not respond to oil reserves on impact but it rises in the long-run DFE

Model

A model of sovereign default & resource extraction

- Small open economy with two sectors/goods:
  - tradable non-storable consumption good y
  - stock of oil reserves s out of which x units can be extracted at a total cost $e(x,s) = \psi(\frac{x}{s})^{\gamma}x$
  - reserves law of motion $s' = s - x + \kappa$, where κ are oil discoveries

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- Sovereign:
  - operates oil industry
  - sells oil at given world price p (in units of traded goods)
  - issues debt ($b < 0$) without commitment to repay
  - maximizes private utility and transfers oil profits and resources generated by debt

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- p and y are exogenous stochastic processes

Sovereign's problem

Ex-ante payoff:

$$V(b,s,y,p) = \max\left\{v^{nd}(b,s,y,p), v^{d}(s,y,p)\right\}$$

Payoff under repayment:

$$v^{nd}(b,s,y,p) = \max_{\{c,x,b',s'\}} \left\{u(c) + \beta E\left[V\left(b',s',y',p'\right)\right]\right\}$$

subject to

$$c + A = y + px - e(x,s) + b - q\left(b',s',y,p\right)b',$$

$$s' = s - x + \kappa, \quad p' = z_p(p),$$

$$0 \leq x \leq s + \kappa.$$

Sovereign's problem contn'd

Payoff under default:

$$v^d(s,y,p) = \max_{\{c,x,s'\}} \left\{ u(c) + \beta\,(1-\lambda)\,Ev^d\left(s',y',p'\right) + \beta\lambda\,EV\left(0,s',y',p'\right) \right\}$$

subject to

$$c + A = y + h(p)\,x - e(x,s)\,,$$

$$s' = s - x + \kappa, \quad p' = z_p(p),$$

$$0 \leq x \leq s + \kappa,$$

Exogenous default cost:

$$h(p) = \hat{p} \quad if \quad p > \hat{p}$$

Default probability and debt pricing

- Default sets

$$D(b,s) = \left\{ \{y,p\} : v^{nd}(b,s,y,p) \leq v^{d}(s,y,p) \right\}$$

  - We proved $D(b,s)$ shrinks as b or s rise, and that $y_2 \in D(b,s)$ if $y_1 \in D(b,s)$ and $y_2 < y_1$ (same for p)

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- Conditional probability of default next period

$$P^{d}\left(b',s',y,p\right) = \sum_{y'} \sum_{p'} d(b',s',y',p')\pi(y',p'|y,p)$$

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$$P^{d}\left(b',s',y,p\right) = \sum_{y'} \sum_{p'} d(b',s',y',p')\pi(y',p'|y,p)$$

- No-arbitrage condition of risk-neutral foreign lenders

$$q\left(b',s',y,p\right) = q^{*}\left(1 - P^{d}\left(b',s',y,p\right)\right),$$

where $q^{*} \equiv 1/R^{*}$, and R^{*} is the world's risk-free real interest rate

Main analytic results (i.i.d. shocks, $\lambda = 0$, $\hat{p} = p$)

Existing results for (b, y) from Arellano (08) still hold:

- *Prop. 1*: Repayment payoff is non-decreasing in b, default sets shrink as b rises (i.e., grow as debt rises)
- *Prop. 5*: If the trade balance is sufficiently large relative to oil profits, default incentives strengthen as y falls

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Similar results extend to (s, p):

- *Prop. 3*: Default and repayment payoffs are non-decreasing in s
- *Prop. 4*: Default sets shrink as s rises (i.e. grow as reserves fall)
- *Prop. 6*: If the trade balance is sufficiently large and reserves chosen under default at high p exceed those chosen under repayment at low p, default incentives strengthen as oil prices fall

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Still hold in calibrated model w. persistent shocks, $\lambda > 0$ and $\hat{p} < p$

Definitions and debt-reserves resource tradeoffs

- Definitions (assuming internal x choice)
  - Asset price of oil: $q_t^O \equiv p_t - e_x(x_t, s_t)$
  - Oil dividends: $d^O \equiv -e_s(x_t, s_t)$
  - Physical rate of return on oil: $R_{t+1}^O \equiv [q_{t+1}^O + d_{t+1}^O]/q_t^O$

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  - Debt repayment is non-state contingent but defaultable
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- Trading off b and s for date-t resources (**debt is better hedge**)
  - Debt repayment is non-state contingent but defaultable
  - Oil revenues rise with p (bad hedge)
- Trading off b' and s' for date-t resources (**reserves are better**)
  - Resources from borrowing ($\downarrow b'$) follow debt Laffer curve $-q(\cdot)b'$ so that $\partial c/\partial s' = -(q(\cdot) + \partial b' q(\cdot)/\partial b') \lesseqgtr 0$
  - "*Borrowing from reserves*" ($\downarrow s'$) adds resources without Laffer curve ($\partial c/\partial s' = -(p - e_x(x,s)) < 0$)
  - ... and it also adds resources under default, but less than under repayment ($\partial c/\partial s' = -(h(p) - e_x(x,s)) < 0$)

Sovereign's optimal extraction plans: Intuition

- Without default risk, RBC-SOE model with oil instead of capital:

$$p - e_x(x,s) = E_t\left[\frac{\beta\, u'(c')}{u'(c)}\left(p' - e_x(x',s') + d^{O\prime}\right)\right]$$

  - As in standard extraction models, $\downarrow x$, $\uparrow s'$ when $p < E[p']$
  - Oil is a risky asset with a (small) equity premium

$$E_t\left[R^O_{t+1}\right] = R^* - \frac{\mathrm{cov}_t\left(u'(c_{t+1}), R^O_{t+1}\right)}{E_t\left[u'(c_{t+1})\right]}$$

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- In our model, planner internalizes effect of b', s' on bond prices. If we give $q(b', s', y, p)$ to a sovereign committed to repay:

$$E_t\left[\tilde{R}^o_{t+1}\right] = \frac{1}{q(t+1) + q_b(t+1)b_{t+1}} - \frac{\mathrm{cov}_t\left(u'(c_{t+1}), \tilde{R}^o_{t+1}\right)}{E_t\left[u'(c_{t+1})\right]}$$

where $\tilde{R}^o_{t+1} \equiv \frac{q^O_{t+1} + d^O_{t+1}}{\left[q^O_t + q_s(t+1)b_{t+1}\right]}$

Quantitative Analysis

Calibration: Exogenous shocks

$$\begin{bmatrix} p_t \\ y_t \end{bmatrix} = \begin{bmatrix} c_0 \\ c_1 \end{bmatrix} + \begin{bmatrix} \rho_p & \rho_{yp} \\ \rho_{py} & \rho_y \end{bmatrix} \begin{bmatrix} p_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \sigma_p & \sigma_{yp} \\ \sigma_{py} & \sigma_y \end{bmatrix} \begin{bmatrix} \varepsilon_{pt} \\ \varepsilon_{yt} \end{bmatrix},$$

VAR Process for Non-Oil Output and Oil Prices

Parameter	Description	Value
ρ_p	oil price auto-correlation	0.90
ρ_y	non-oil output auto-correlation	0.37
ρ_{py}	oil price non-oil output correlation	0.05
ρ_{yp}	non-oil output oil price correlation	0.04
σ_p^2	variance oil price innovations	0.006
σ_y^2	variance non-oil output innovations	0.007
σ_{py}, σ_{yp}	covariance non-oil output, oil price	-0.002

Calibration: Parameters

- $\mu = 2$ standard, $r^* = 0.78\%$ 1955-2014 3 mo. Tbills ex-post return
- Oil sector (γ, ψ, κ) calibrated to non-defaulters' $\sigma(x), s, px/(px - e(.) + y)$
- $\beta, \hat{p}$ calibrated to defaulters' debt & def. freq.

Parameter	Description	Value
β	discount factor	0.82
μ	risk aversion coefficient	2.00
q^*	risk-free debt price	0.99
$\hat{p}$	oil-price default cost threshold	0.64
k	discovery rate	0.33
λ	re-entry probability	0.33
γ	extraction costs curvature	1.56
ψ	extraction costs scale	124.6
A	autonomous spending	0.40

Data

Targeted moments

Data vs Model Moments

Description	Data	Model		
		Benchmark	Constant Extraction	Risk Free
Average External Debt to GDP	0.225	0.229	0.276	0.517
Default Rate	1.14%	1.19%	1.08%	0%
Standard Deviation of Oil Extraction	0.122	0.120	0.000	0.123
Average Reserves (in years)	62	43	42	42

Estimates of the proven reserves for the average oil exporting country correspond to those of the US Energy Information Administration.

Long-run moments - Data vs. Model

	Variability relative to DI			
	(1)	(2)	(3)	(4)
	Data	Benchmark	Constant Extraction	Risk Free
Gross Oil Output	2.4	1.74	1.16	1.73
Total GDP	0.67	0.61	0.61	0.61
Disposable Income (DI)	0.10	0.17	0.17	0.16
Extraction	1.20	0.70	*na*	0.75
Consumption	0.48	1.07	1.08	0.98
Trade Balance/GDP	0.88	0.26	0.28	0.05
Debt/GDP	1.41	0.62	0.72	0.33
Spread	6.29	15.74	16.62	*na*

* Actual data are for the 1979-2016 period, logged and HP-detrended, except for the TB/GDP, Debt/GDP ratios and the EMBI, which is in levels (basis points). Model data are not detrended because the model is stationary by construction. Variability in the data of the Disposable Income (DI) corresponds to the standard deviation of the HP cyclical component, and in the model corresponds to the coefficient of variation. The rest of the variables report the relative variability to DI.

Long-run moments - Data vs. Model, contn'd

	Correlation with DI			
	(1)	(2)	(3)	(4)
	Data	Benchmark	Constant Extraction	Risk Free
Gross Oil Output	0.51	0.69	0.72	0.66
Total GDP	0.62	1.00	1.00	1.00
Disposable Income (DI)	1.00	1.00	1.00	1.00
Extraction	0.52	0.53	*na*	0.50
Consumption	0.34	0.97	0.91	0.99
Trade Balance/GDP	0.39	0.03	0.04	0.20
Debt/GDP	−0.07	−0.42	−0.44	0.98
Spread	−0.09	−0.28	−0.25	*na*

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Long-run moments - Data vs. Model, contn'd

	Correlation with Oil Price			
	(1)	(2)	(3)	(4)
	Data	Benchmark	Constant Extraction	Risk Free
Gross Oil Output	0.34	0.96	1.00	0.96
Total GDP	0.11	0.72	0.72	0.69
Disposable Income (DI)	0.12	0.72	0.72	0.69
Extraction	0.04	0.75	*na*	0.77
Consumption	0.12	0.73	0.74	0.71
Trade Balance/GDP	0.19	−0.15	−0.16	−0.03
Debt/GDP	−0.61	−0.79	−0.80	0.66
Spread	−0.46	−0.14	−0.10	*na*

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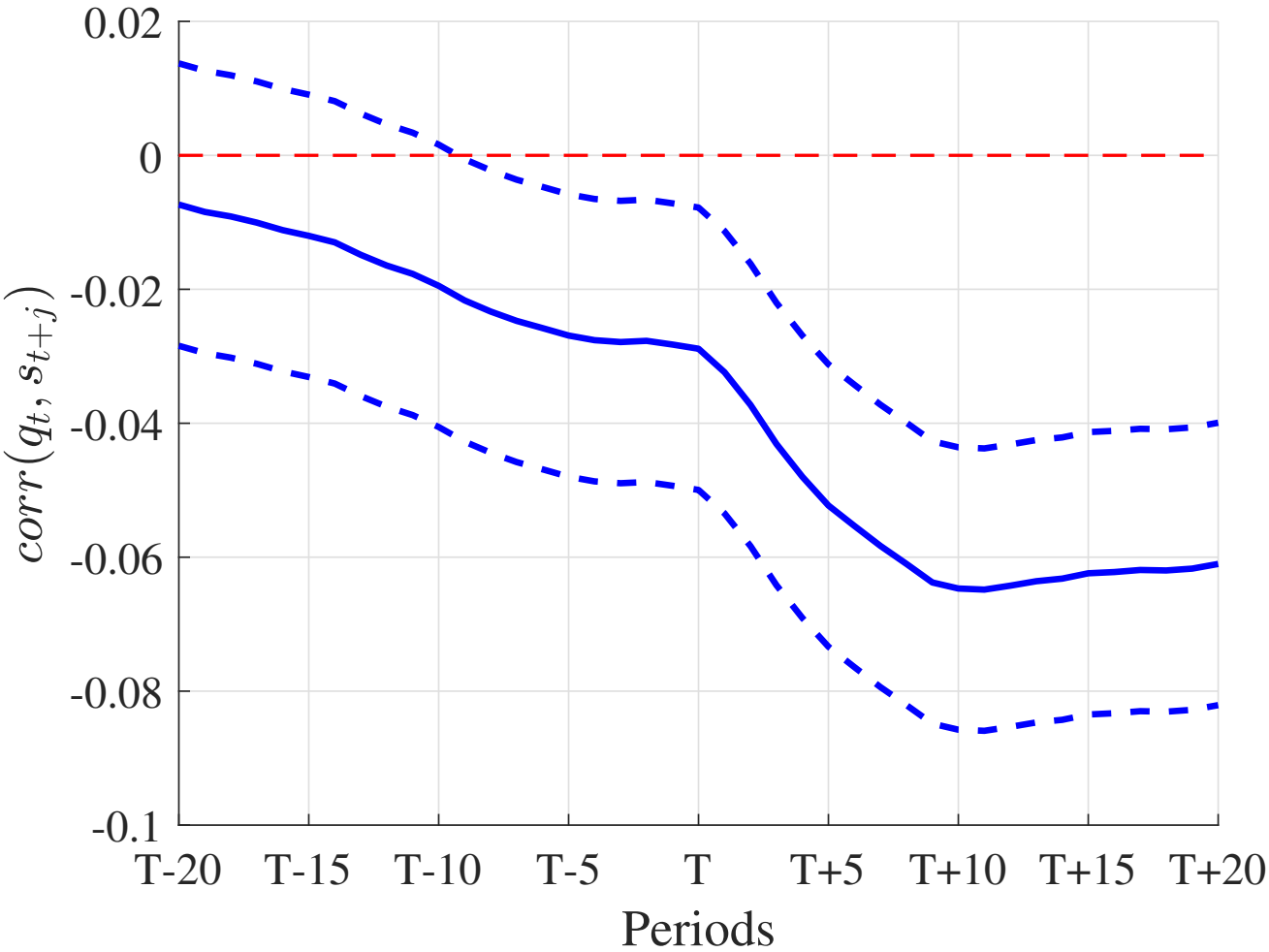
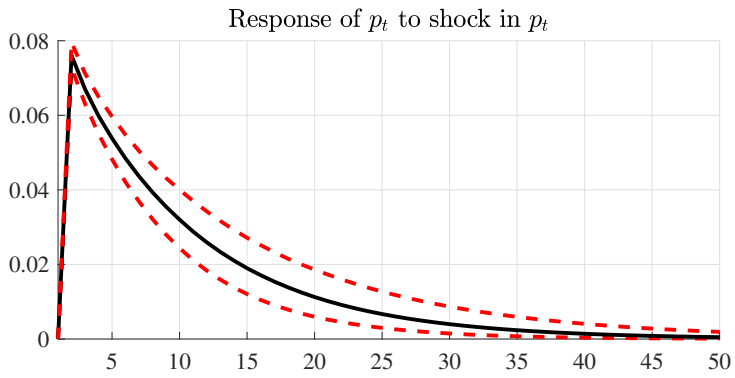
Current bond prices (risk) negatively (positively) correlated with future reserves

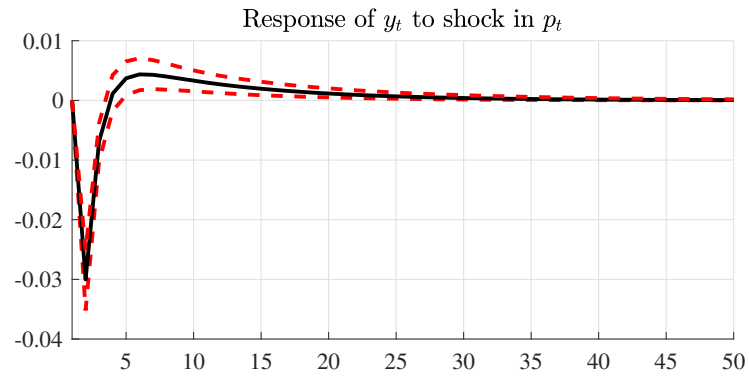
Cross-Correlation Function of Bond Prices and Oil Reserves in the Model



Impulse response functions to oil price shock

a) Exogenous variables

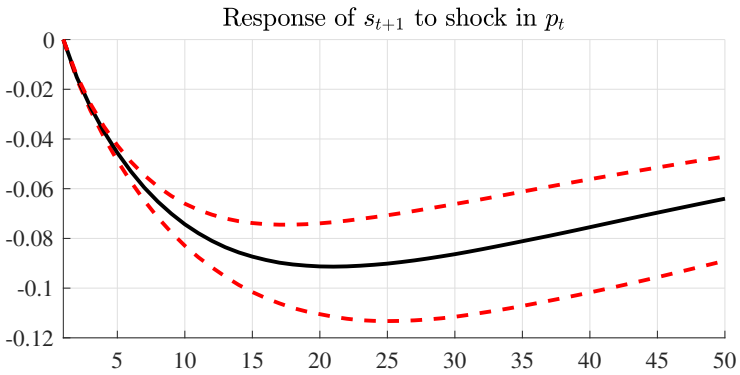


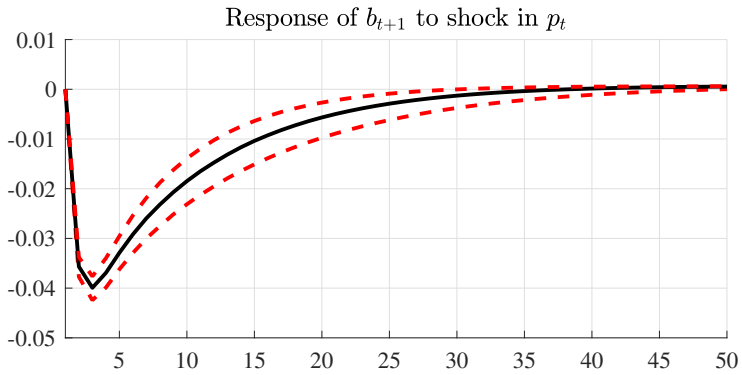


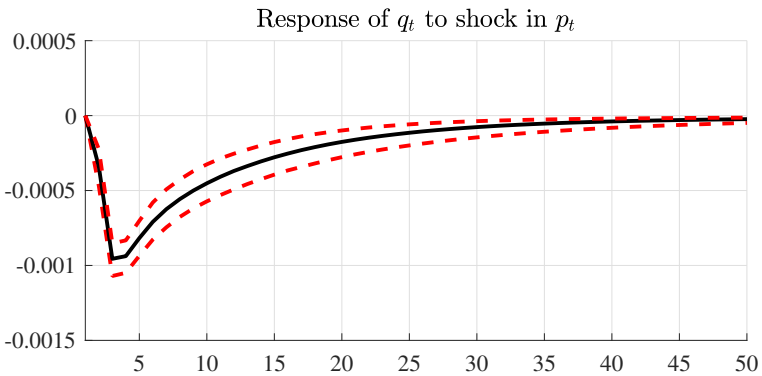
Note: Monte Carlo simulation for error bands (confidence level set to 95%): sample size of 1000 periods and 1000 replications.

Impulse response functions to oil price dhock, contn'd

b) Endogenous variables







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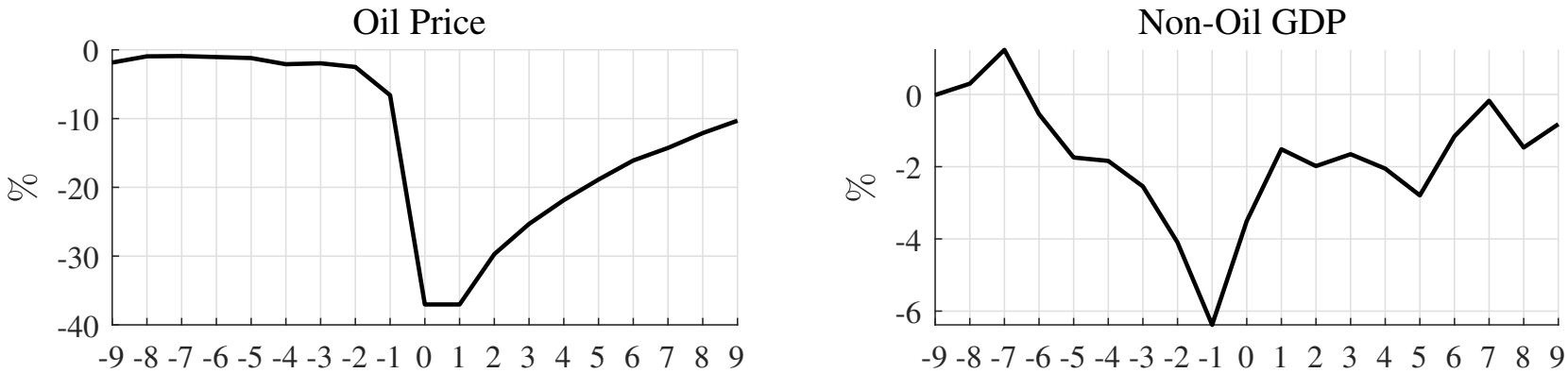
Endogenous extraction and default risk matter

- Identify defaults in 10,000-period simulation (107, 1.1% freq.)
- Construct comparable paths for constant extraction (CE) and risk-free (RF) models

a) p, y sequences that trigger defaults at date 0

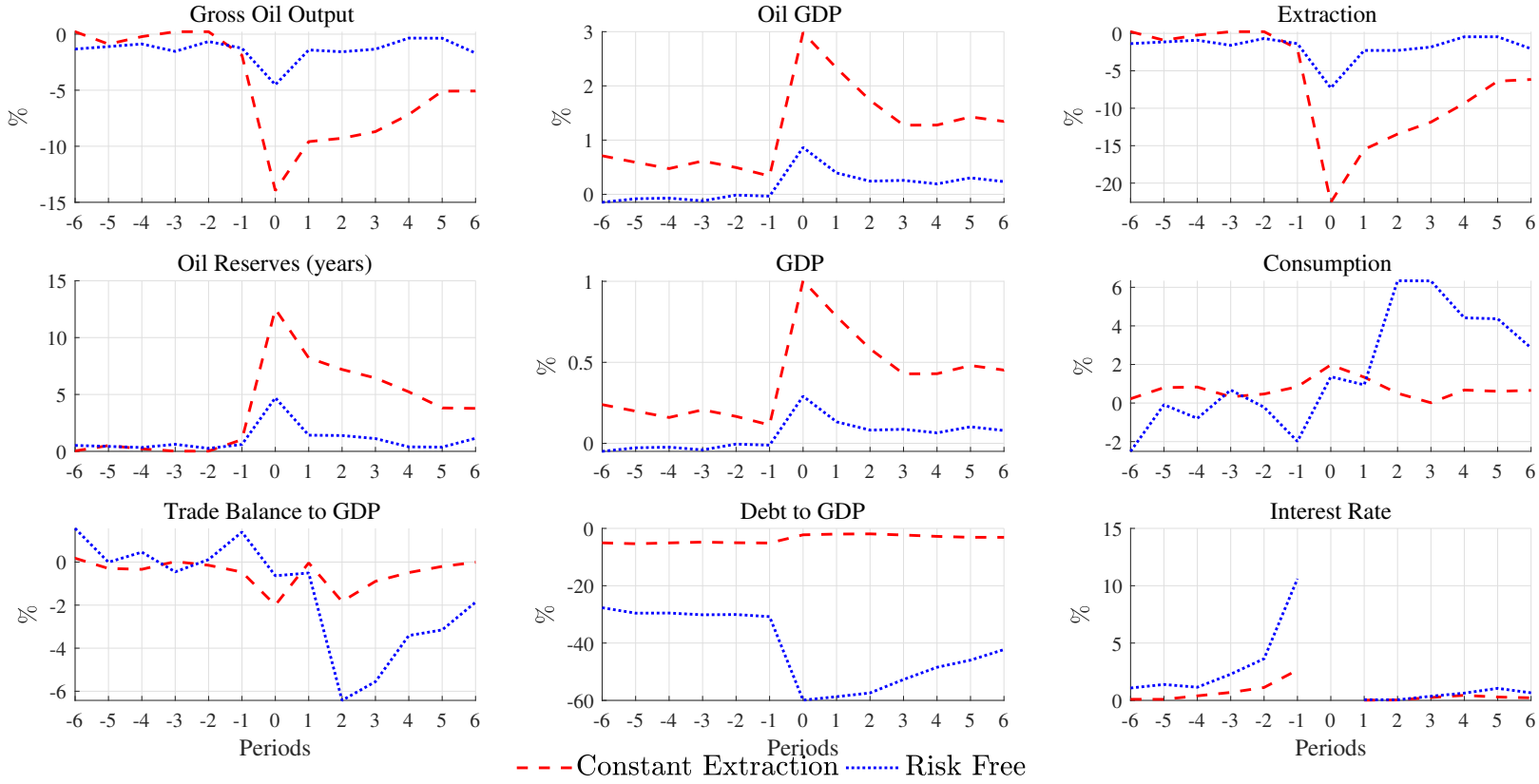


Note: All variables relative to benchmark model, except for oil price and non-oil GDP which are plotted relative to their long-run average.

Endogenous extraction and default risk matter, contn'd

Default event windows: benchmark, CE and RF models

b) Relative responses (benchmark model minus CE or RF model)



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Decomposition of default costs

- Oil GDP under repayment and default:

$$y^{O,nd}(b,s,y,p) = px^{nd}(b,s,y,p) - e(x^{nd}(b,s,y,p),s)$$

$$y^{O,d}(s,y,\hat{p}) = \hat{p}x^{d}(s,y,\hat{p}) - e(x^{d}(s,y,\hat{p}),s)$$

- Total cost:

$$-[y^{O,d}(\cdot)/y^{O,nd}(\cdot) - 1]$$

- Exogenous (effect of $\hat{p}$):

$$-(\hat{p}-p)x^{nd}(\cdot)/y^{O,nd}(\cdot)$$

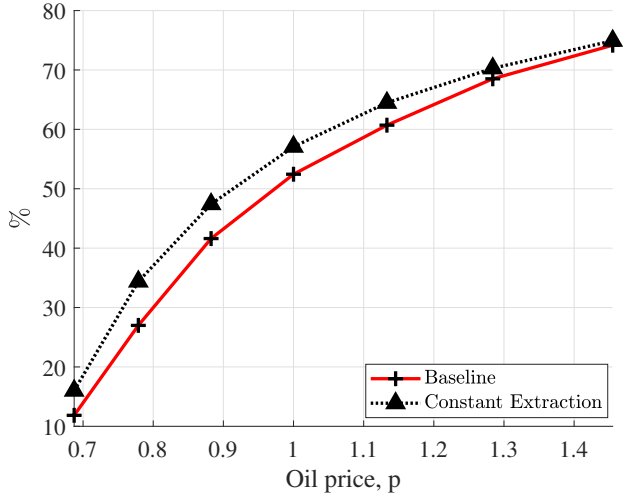
- Endogenous (effect of changes in x, $e(.)$):

$$-\left[\hat{p}\left(x^{d}(\cdot)-x^{nd}(\cdot)\right)-\left(e(x^{d}(\cdot),s)-e(x^{nd}(\cdot),s)\right)\right]/y^{O,nd}(\cdot)$$

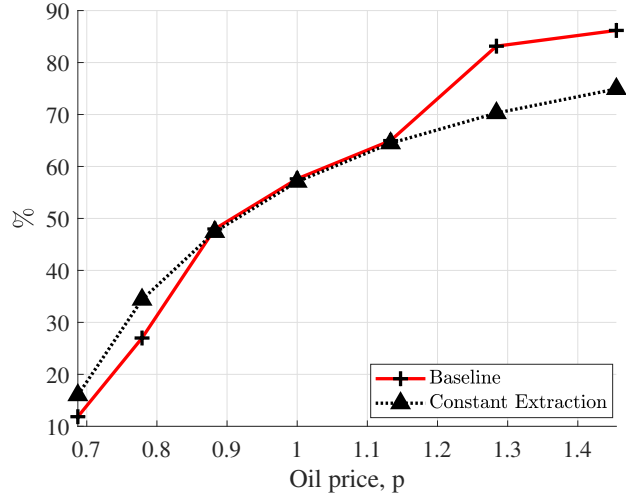
  - Change in oil revenues as x changes
  - Change in $e(.)$ due to change in x

Strategizing over reserves reduces default costs

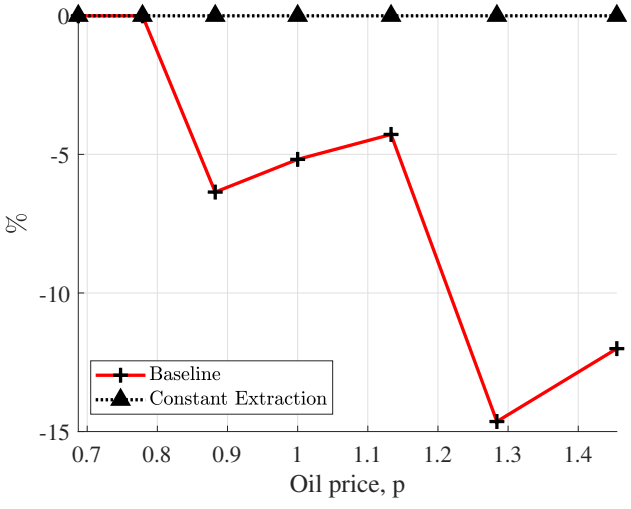
a) Total Default Costs



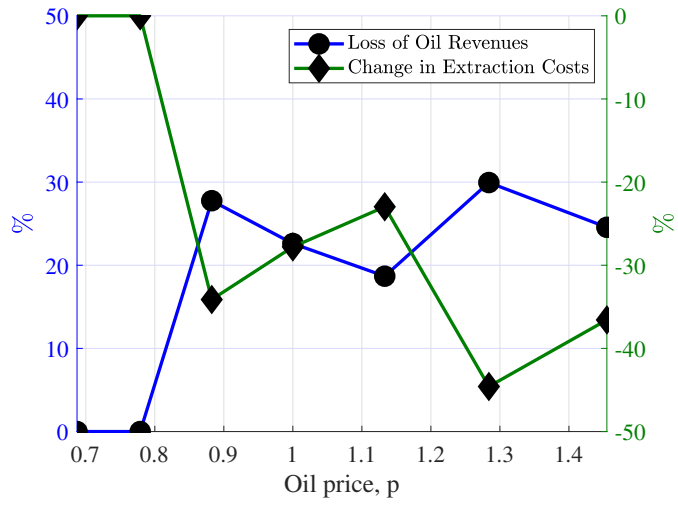
b) Exogenous Component



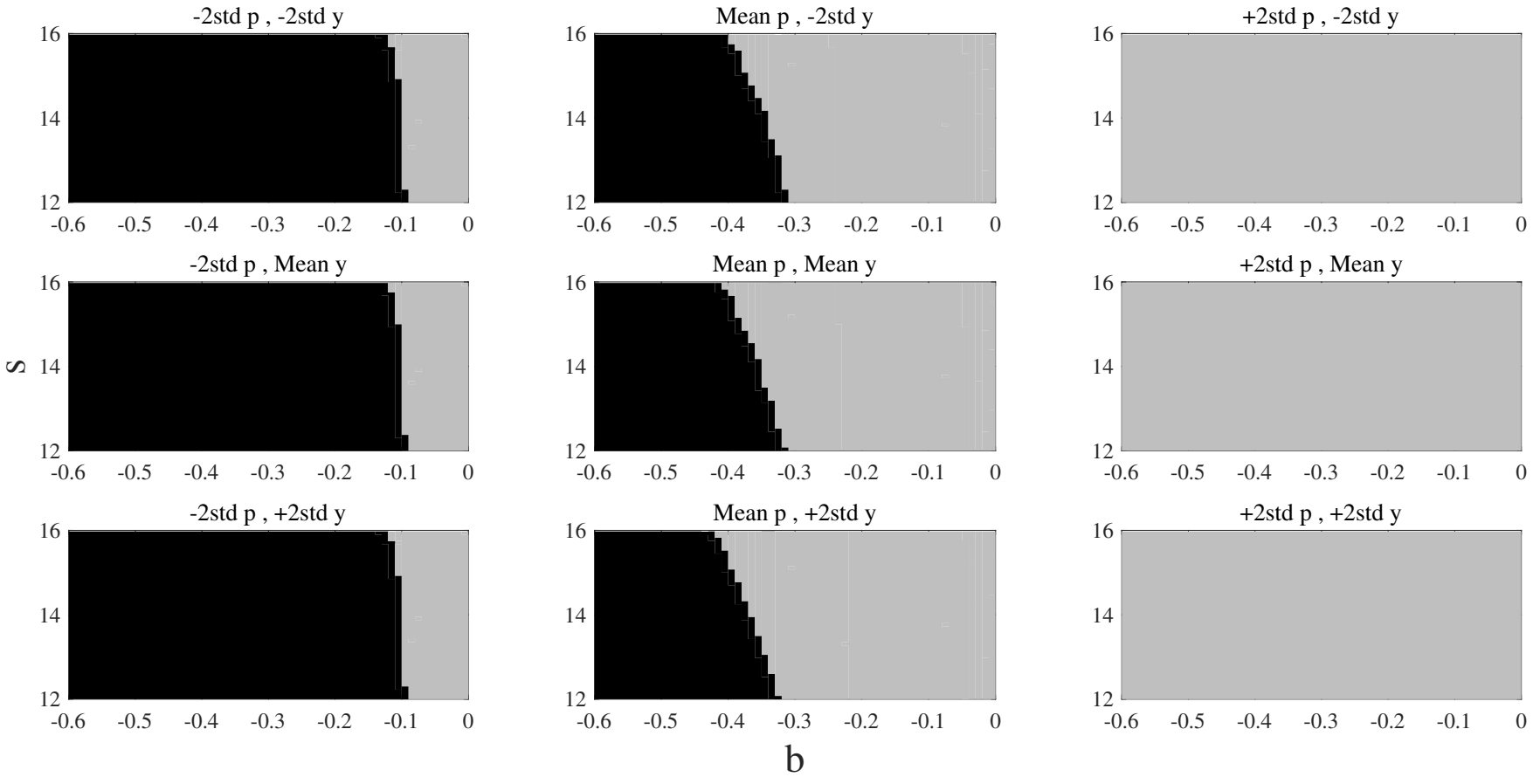
c) Endogenous Component



d) Oil Revenues & Ext. Costs



Default sets



Conclusions

- New stylized facts relating sovereign debt and country risk with oil prices, reserves and extraction
  - Reserves *increase* country risk in the long run
- Model of sovereign default with endogenous oil extraction
  - Sovereign makes default less costly by strategizing over reserves available during exclusion (sustainable debt falls)
  - Oil is a risky asset with real and financial returns (sovereign internalizes effect of oil reserves on bond prices)
  - Lower oil prices or reserves increase default risk
- Model consistent with dynamic relationship between country risk and oil reserves (weak on impact, turns negative over time)
- Framework applies more generally to other commodities
- Potential use to value costs of restricting fossil fuel extraction

Largest 30 Net Oil Exporters

Algeria	China	India	Kuwait	Oman	Syria
Angola	Colombia	Indonesia	Libya	Qatar	U.A.E.
Argentina	Ecuador	Iran	Malaysia	Russian Fed.	Venezuela
Azerbaijan	Egypt	Iraq	Mexico	Saudi Arabia	Vietnam
Brazil	Gabon	Kazakhstan	Nigeria	Sudan	Yemen

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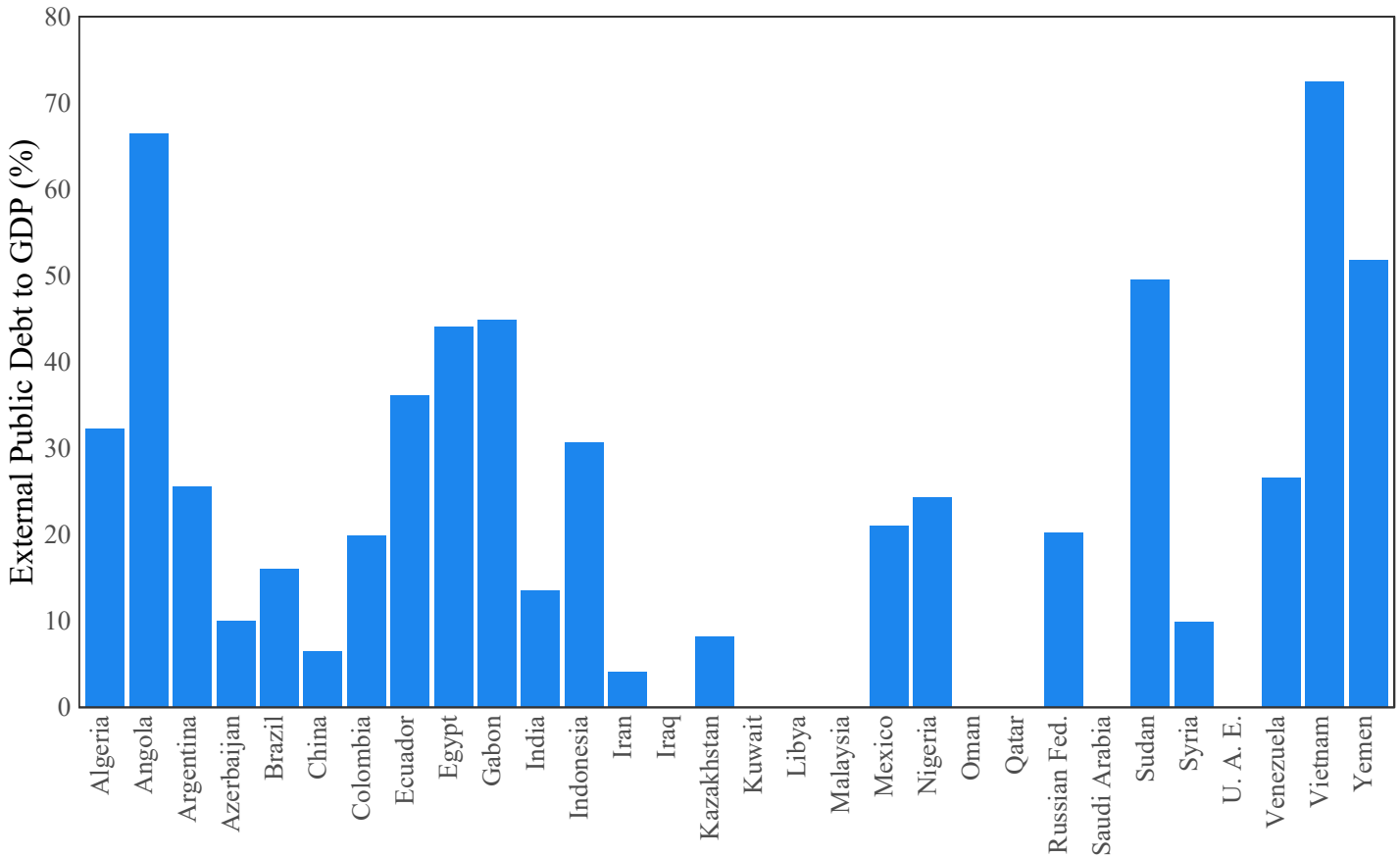
Average Ext. Public Debt (1971-2015)



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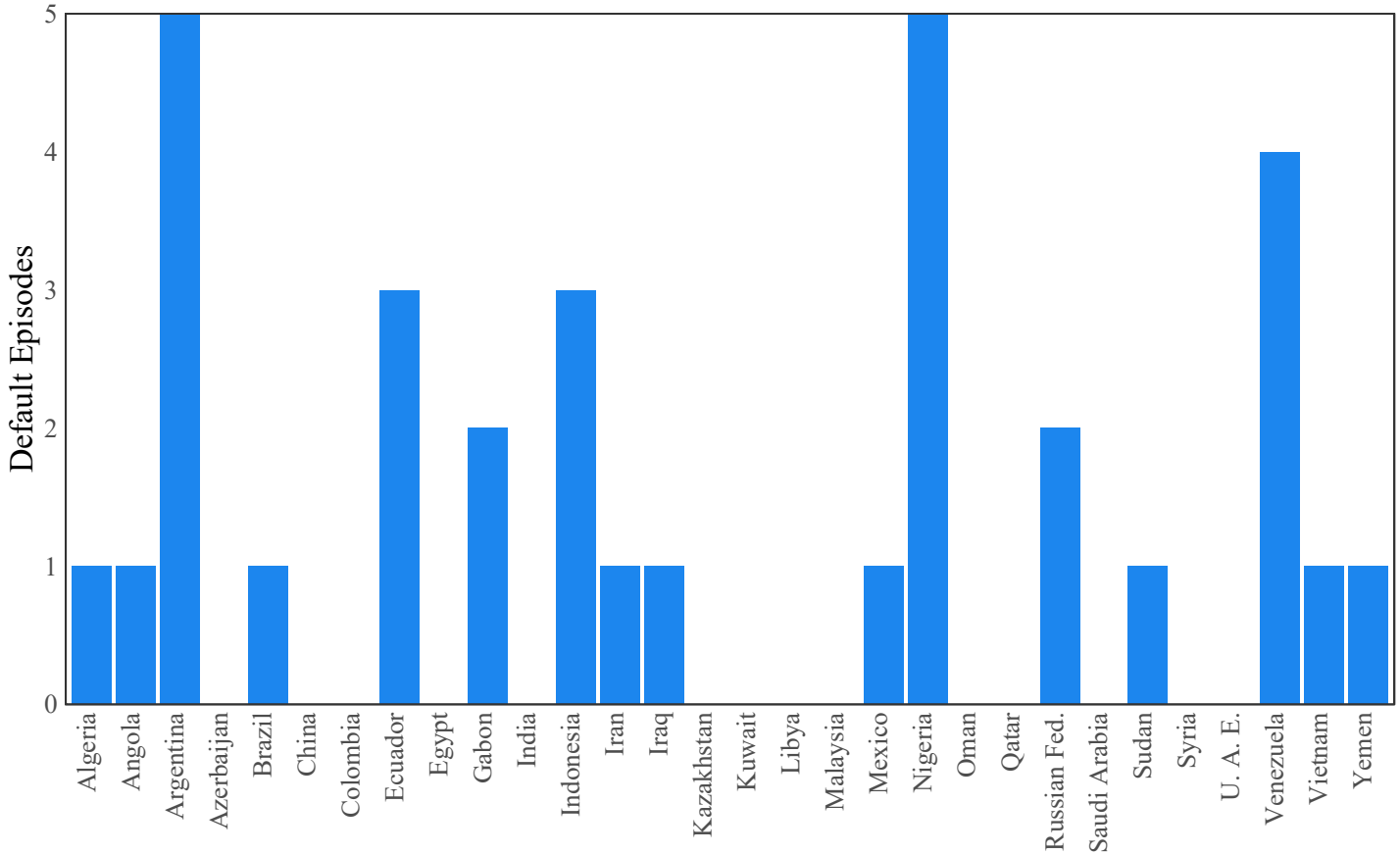
Number of Default Episodes (1979-2014)



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Data

- Country risk : Institutional Investor's country credit ratings. Annual data from 1979 to 2016.
- Oil reserves, oil production (thousand barrels per day): US Energy Information Administration dataset (EIA). Annual data from 1980 to 2020
- Brent spot oil price (USD per barrel): US Energy Information Administration dataset (EIA). Annual data from 1980 to 2020.
- Total public debt to GDP: World Development Indicators tables (WDI) and World Economic Outlook database (WEO). Annual data from 1979 to 2015.
- Net Foreign Assets: Lane and Milesi-Ferreti (2007). Annual data from 1970 to 2011.
- Default data: Borensztein and Panizza (2006). Annual data from 1979 to 2014.
- GDP: World Economic Outlook database (WEO). Annual data from 1979 to 2015.

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Table 1: Oil Prices and Business Cycle Moments

	Mean	Standard Dev.	Corr(i,GDP)	Corr(i,Oil Price)	Corr(i,Reserves)	Autocorr.
Oil price	0	0.182	0.111	1	0.131	0.847
Non-oil GDP	0	0.093	0.631	-0.043	-0.05	0.385
GDP	0	0.069	1	0.111	0.074	0.523
Oil production	0	0.123	0.624	0.041	0.149	0.502
Consumption	0	0.049	0.523	0.120	0.048	0.523
Gross oil output	0	0.235	0.492	0.342	0.110	0.276
Trade balance to GDP	0.073	0.090	0.106	0.190	0.133	0.630
Institutional Investor Index	47.494	11.486	0.208	0.693	0.084	0.869
Debt to GDP	0.224	0.144	-0.284	-0.612	-0.179	0.836
Reserves	76.969	20.088	0.074	0.131	1	0.833

* Note: Business cycle moments are weighted averages across the thirty countries included in the dataset. The weights were set by first computing the average of each country's share of oil production in the combined oil production of the thirty countries over the 1979-2014 period, and then normalizing the country averages so that they add to 1.

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Dynamic Fixed Effects

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	Δ Inst. Investor Index		
	Model (1)	Model (2)	Model (3)
Convergence coefficient			
Inst. Investor Index (-1)	-0.175***	-0.156***	-0.183***
	(0.019)	(0.020)	(0.020)
Short-run coefficients			
Δ Oil Production	0.052**	0.047**	0.055**
	(0.021)	(0.022)	(0.022)
Δ Non-Oil GDP	0.199***	0.231***	0.198***
	(0.058)	(0.059)	(0.057)
Δ Oil Reserves	0.006	0.014	0.010
	(0.020)	(0.020)	(0.020)
Δ Ext. pub. debt to GDP	-0.104***	-0.094*	-0.107**
	(0.038)	(0.052)	(0.051)
Δ Oil Discoveries	-0.003	-0.003	-0.003
	(0.003)	(0.004)	(0.003)
Δ NFA		-0.040	-0.046
		(0.035)	(0.034)
Long-run coefficients			
Oil Production	0.048	0.048	0.038
	(0.041)	(0.049)	(0.041)
Non-oil GDP	0.095	-0.027	0.101
	(0.106)	(0.120)	(0.100)
Oil Reserves	-0.162***	-0.141**	-0.141***
	(0.051)	(0.060)	(0.050)
Ext. pub. debt to GDP	-0.810***	-1.226***	-1.001***
	(0.140)	(0.219)	(0.178)
Default	-0.369***		-0.379***
	(0.072)		(0.068)
Oil Discoveries	0.045	0.048	0.039
	(0.028)	(0.033)	(0.027)
NFA		-0.003	-0.119
		(0.141)	(0.116)
Constant	0.245	0.767	0.219
	(0.542)	(0.546)	(0.537)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Econometric Approach

We recover the MG, PMG and DFE estimators for the following model (Pesaran and Smith (1995)):

$$\Delta III_{it} = \phi_i \left(III_{i,t-1} - \hat{\theta}_{0i} - \hat{\theta}_{1i} OilGDP_{it} - \hat{\theta}_{2i} NonOilGDP_{it} - \hat{\theta}_{3i} OilR_{it} - \hat{\theta}_{4i} X_{it} - \hat{\theta}_{5i} Default_{it} \right) - \delta_{11i} \Delta OilGDP_{it} - \delta_{21i} \Delta NonOilGDP_{it} - \delta_{31i} \Delta OilR_{it} - \delta_{41i} \Delta X_{it} + \varepsilon_{it}$$

where

$$\hat{\theta}_{0i} = \frac{\mu_i}{1-\lambda_i}; \hat{\theta}_{1i} = \frac{\delta_{10i} + \delta_{11i}}{1-\lambda_i}; \hat{\theta}_{2i} = \frac{\delta_{20i} + \delta_{21i}}{1-\lambda_i}$$

$$\hat{\theta}_{3i} = \frac{\delta_{30i} + \delta_{31i}}{1-\lambda_i}; \hat{\theta}_{4i} = \frac{\delta_{40i} + \delta_{41i}}{1-\lambda_i}; \hat{\theta}_{5i} = \frac{\theta_{5i}}{1-\lambda_i}; \phi_i = -(1-\lambda_i)$$

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Defaulter vs Non-Defaulter's Moments

Oil Prices and Business Cycle Moments Defaulters

	Mean	Std.dev.	Corr(i,GDP)	Corr(i,Oil Price)	Acorr
Oil Price		0.182	0.14	1.00	0.85
Non-Oil GDP		0.072	0.72	0.00	0.42
GDP		0.064	1.00	0.14	0.50
Oil Production		0.114	0.62	0.06	0.52
Consumption		0.052	0.72	0.15	0.56
TB/GDP	0.048	0.063	0.03	0.03	0.54
III	37.60	13.70	0.27	0.62	0.87
Debt/GDP	0.249	0.161	-0.32	-0.61	0.82
Gross Oil Output/GDP	0.237	0.157	0.07	0.37	0.67

Oil Prices and Business Cycle Moments Non-Defaulters

	Mean	Std.dev.	Corr(i,GDP)	Corr(i,Oil Price)	Acorr
Oil Price		0.182	0.08	1.00	0.85
Non-Oil GDP		0.117	0.52	-0.10	0.34
GDP		0.074	1.00	0.08	0.54
Oil Production		0.133	0.62	0.01	0.49
Consumption		0.046	0.26	0.08	0.47
TB/GDP	0.102	0.120	0.19	0.37	0.72
III	58.80	8.9	0.13	0.77	0.86
Debt/GDP	0.139	0.081	-0.16	-0.60	0.88
Oil Rents/GDP	0.335	0.132	0.16	0.56	0.60

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