Clustered Sovereign Defaults

Anurag Singh

Instituto Tecnológico Autónomo de México (ITAM)

July, 2019

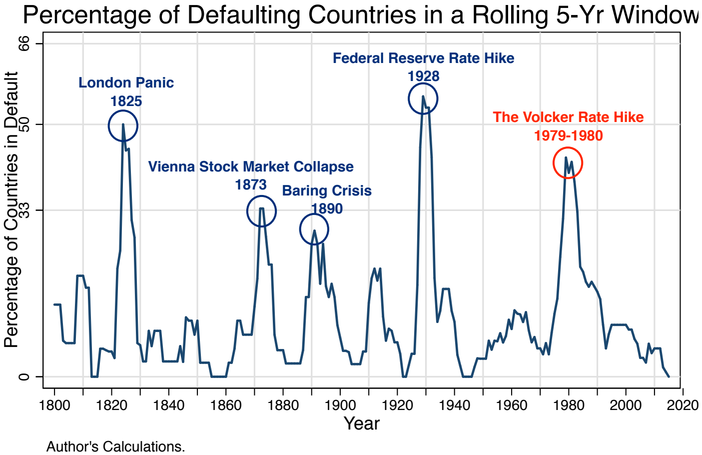
Definition: Clustered Defaults

Given a set of countries that have defaulted at-least once in history, if more than one-third of these countries default in a 5-year window, the window is called a clustered default window and all the defaults in the window are called clustered defaults.[1]

Kaminsky and Vega-García (2016)

[1] The definition of a default follows the definition from Standard and Poor's.

Motivation



▸ Summary Stats: Clustered & Idiosyncratic Defaults

The Question

- Countries defaulting in clusters is both recurring and frequent
- What kinds of shocks cause clustered defaults?
    - Global vs country-specific shocks
    - Global output shocks vs world interest rate shocks
        - For example, did the Volcker interest rate hike cause the clustered default of 1980s?
- To answer these question, a relevant framework is needed which allows for:
    - Disentangling country-specific shocks from global shocks faced by different countries
    - Identifying the mechanism through which different shocks may cause clustered defaults

▸ Volcker interest rate hike

This Paper

Estimation, and the Reduced Form Analysis

- Performs a joint Bayesian estimation to decompose the output of 24 countries into unobservable global and country-specific shocks
- Uses the estimated shocks processes to conduct a reduced form analysis to identify which shocks predict the clustered default in 1980s
- The findings of the reduced form analysis show that:
    - Global shocks, rather than country-specific shocks, are important to predict clustered defaults
    - Global shocks to transitory component of output and world interest rate shocks are both important

This Paper

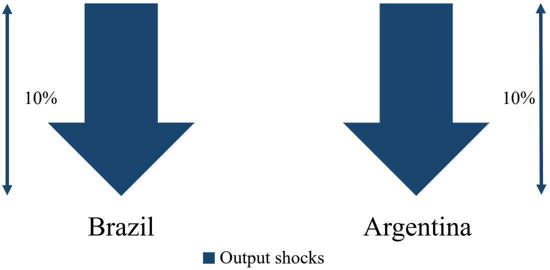
Quantitative Model

- Builds a model to rationalize the reduced form findings & to uncover the mechanism through which various shocks cause clustered defaults
    - Introduces two channels—debt pricing channel and endogenous output channel—through which world interest rate fluctuations affect defaults
    - Debt Pricing Channel
        - Government is borrowing at the world interest rate after adjusting for the probability of default
        - An increase in world interest rate leads to a decrease in the price of government debt as borrowing becomes expensive
    - Endogenous Output Channel
        - Firms take working capital loans in the domestic economy
        - If interest rate goes up, working capital loans become expensive
        - Labor demand in the country goes down leading to decreased equilibrium output

Simulation Results from the Model

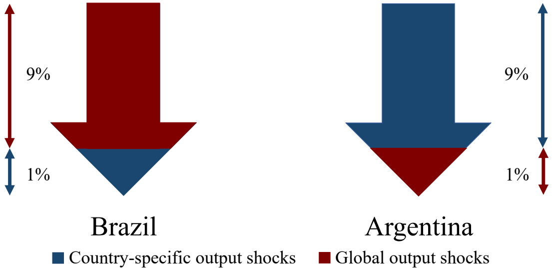
- The quantitative model allows for five types of shocks—country-specific transitory & permanent shocks to output; global transitory & permanent shocks to output; world interest rate shocks—to show:
- Global transitory shocks to output matter the most for the observed cluster of 1980s
- World interest rate fluctuations may cause clustered defaults
  - However, the Volcker interest rate hike had little to do with the cluster of 1980s
- Model replicates the cluster of 1980s which matches the data

Illustration: Disentangling the Shocks



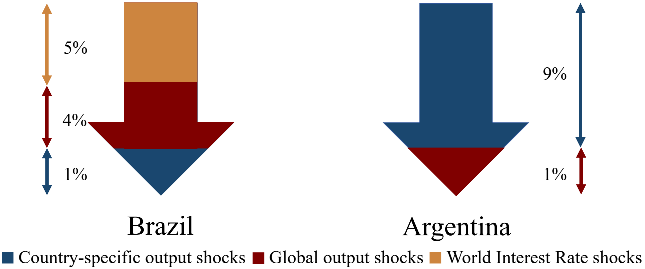
- Both countries face same output drop $\implies$ Defaults look same

Illustration: Disentangling the Shocks



- Brazil defaulted due of global reasons, Argentina due to idiosyncratic ones

Illustration: Disentangling the Shocks



- World interest rate fluctuations can endogenously affect borrower output too

Literature

- Effects of interest rate changes in the US on emerging economies
  - Iacoviello & Navarro (2018); Georgiadis (2016); Dedola, Rivolta, & Stracca (2017)
  - Get output elasticity of interest rate with the Bayesian method
- Empirical literature on clustered defaults
  - Kaminsky & Vega-García (2016); Bordo & Murshid (2000); Reinhart & Rogoff (2011)
  - Use data on 92 defaulters and 148 default episodes
- Models of idiosyncratic default and contagion
  - Eaton & Gersovitz (1981); Aguiar & Gopinath (2006); Arellano (2008)
  - Arellano, Bai, & Lizarazo (2017); Benjamin & Wright (2009); Borri & Verdelhan (2009); Pouzo & Presno (2011); Lorenzoni & Werning (2013); Park (2013)
  - Incorporate global & country-specific shocks in estimation & the model
  - Build a framework to study the impact of the Volcker interest rate hike

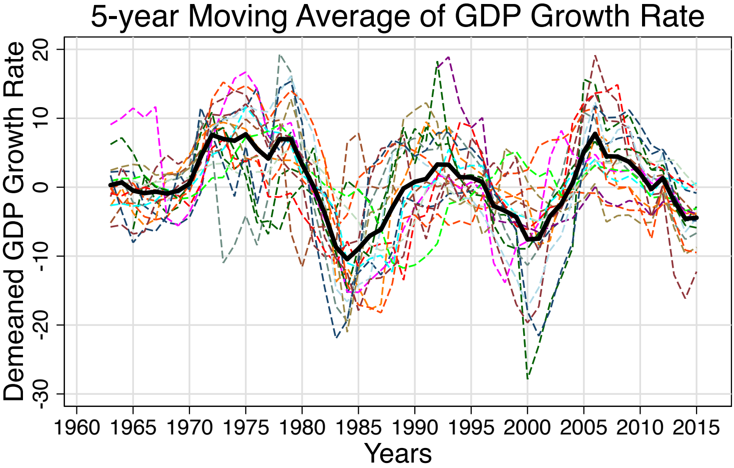
Roadmap

1. Estimation
   - The Baseline Version
   - Full Version (explained in the model part)
2. Preliminary Tests
   - Graphs: Shocks Near Default Episodes
   - Logistic Regressions
3. Model
   - Financial Frictions & the "Endogenous Output Channel"
   - The "Debt Pricing Channel"
4. Results
   - Which Output Shock Matters?
   - Intuition: Transitory and not Permanent Shocks
   - Intuition: Global and not Country Specific Transitory Shocks
   - Interest Rate Shocks & the Volcker Hike

Roadmap

1. Estimation
   - The Baseline Version
   - Full Version (explained in the model part)
2. Preliminary Tests
   - Graphs: Shocks Near Default Episodes
   - Logistic Regressions
3. Model
   - Financial Frictions & the "Endogenous Output Channel"
   - The "Debt Pricing Channel"
4. Results
   - Which Output Shock Matters?
   - Intuition: Transitory and not Permanent Shocks
   - Intuition: Global and not Country Specific Transitory Shocks
   - Interest Rate Shocks & the Volcker Hike

Estimation: A Motivation



Note: Dashed line represents individual countries and solid line represents average acorss 19 countries

Estimating the Output Process

- Estimation procedure
  - Multi-country setup with a set of 24 countries
  - Estimation is independent of the sovereign default model
  - Use dynamic factor model approach and Bayesian method to estimate the parameters of the output process
- Start with a baseline version and later build a full version over it:
  - Baseline Version: Output of country c is given as

$$Y_t^c = e^{z_t^c + \alpha_z^c \cdot z_t^w} X_t^c \cdot (X_t^w)^{\alpha_X^c}$$

where

	Global Component	Country-Specific Component
Transitory Component	z_t^w	z_t^c
Permanent Component	X_t^w	X_t^c

The Output Process: Details

Detrended Output: $\tilde{Y}_t^c = e^{z_t^c + \alpha_z^c \cdot z_t^w} \cdot \left(\frac{g_t^c}{g_{ss}^c}\right) \cdot \left(\frac{g_t^w}{g_{ss}^w}\right)^{\alpha_X^c}$

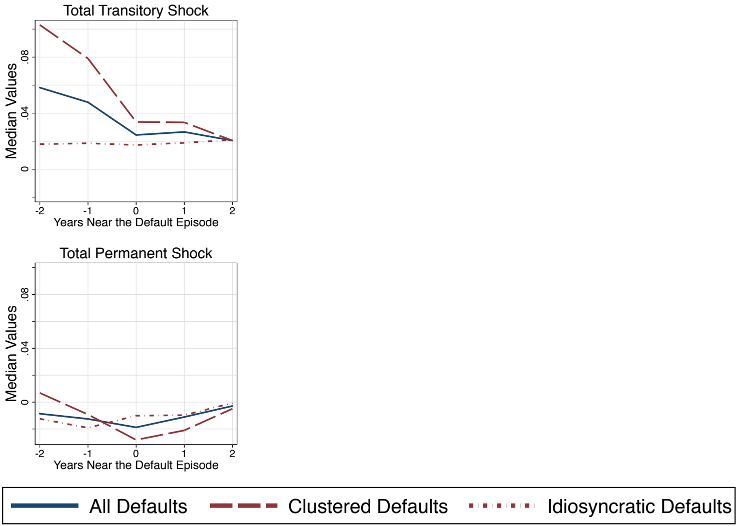
- The growth rates: $g_t^c = X_t^c / X_{t-1}^c$ and $g_t^w = X_t^w / X_{t-1}^w$
- z^c, $\log\left(g^c / g_{ss}^c\right)$, z^w and $\log\left(g^w / g_{ss}^w\right)$ follow AR(1) process
  - with persistence ρ_z^c, ρ_g^c, ρ_z^w and ρ_g^w
  - and error standard deviation σ_z^c, σ_g^c, WLOG $\sigma_z^w = 1$ and $\sigma_g^w = 1$
- Get the mean values from the posterior distribution of estimated parameters
- Use these mean values and the Kalman smoothing algorithm to back out the time series of all country-specific and global shocks

State-Space Form | State-Space Form: Full Version | Priors | Posteriors | Time Series: The Global Shocks

Roadmap

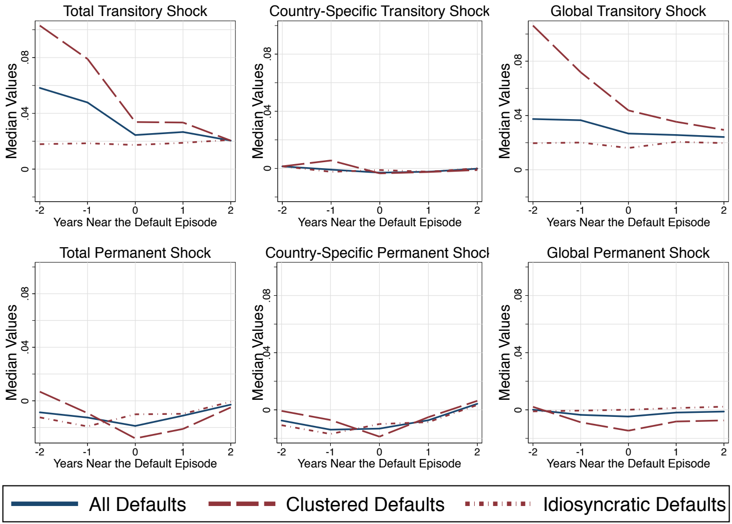
Shocks Near Default Episodes

Global Transitory Shocks Matter



Shocks Near Default Episodes

Global Transitory Shocks Matter



Regression Specifications

Specification 1:

$$D_{c,t} = \beta X_{c,t} + \mu_c + e_{c,t}$$

- $D_{c,t}$: Indicator variable indicating default status of country c at time t
- $X_{c,t}$: Country specific variables

Specification 2:

$$D_{c,t} = \beta X_{c,t} + \gamma X_{w,t} + \mu_c + e_{c,t}$$

- $X_{w,t}$: Global/World specific variables

Employ Logistic regression framework

Predicted Probabilities

- Predict the probability of default conditional of default & specification

$$Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_1)$$

$$Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_2)$$

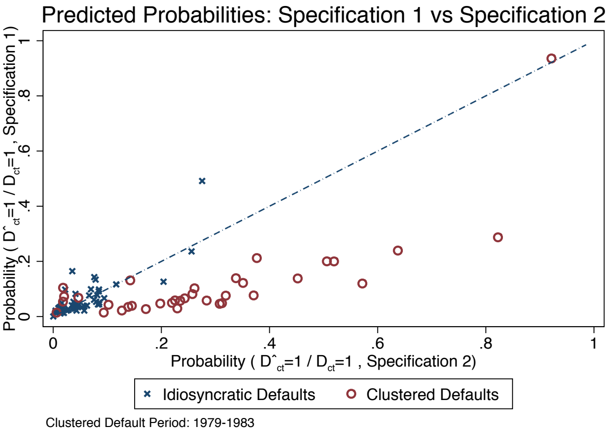
- Hypotheses
  - For idiosyncratic default episodes,

$$Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_1) \approx Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_2)$$

  - For clustered default episodes,

$$Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_2) > Pr(\hat{D}_{c,t} = 1 | D_{c,t} = 1, S_1)$$

Results: Predicted Probabilities



▸ Predicted Probability: In Numbers ▸ Regression Results

Summary of the Empirical Analysis

- Global transitory component shows a steep decline leading up to the default for clustered defaults
- Adding global variables increases the probability of default by 2.5 times for clustered default episodes
- Adding global variables decreases the probability of default for idiosyncratic default episodes
- Global transitory shocks to output and real interest rate shocks are important to explain clustered defaults

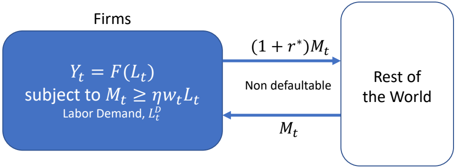
Roadmap

Overview of the Model

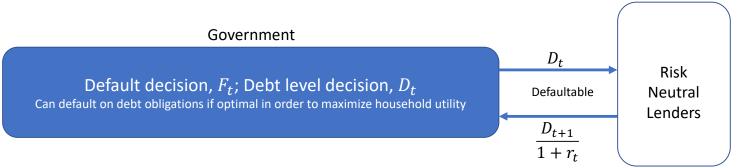
Households

Consumption, C_t
Labor Supply, L_t^S
GHH Preferences

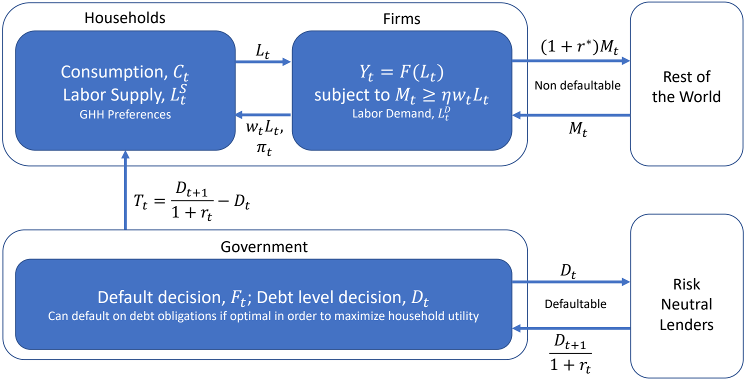
Overview of the Model



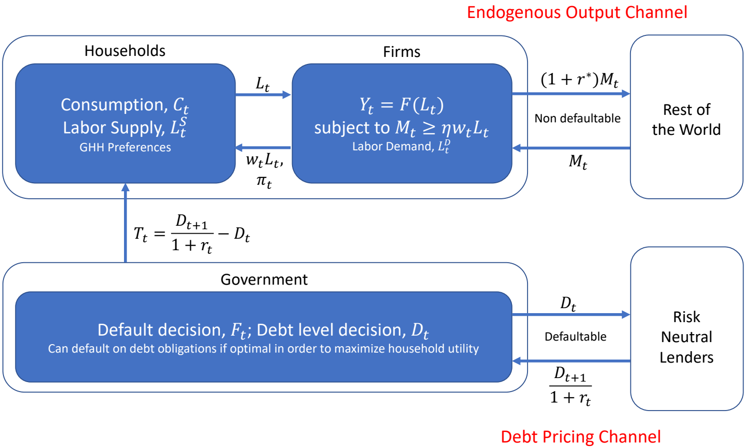
Overview of the Model



Overview of the Model



Overview of the Model



Sovereign Default Model

- Agents in the model:
  - Households
  - Firms
  - Domestic government
  - Foreign risk-neutral lenders
- Allows for:
  - Labor supply and demand decisions in equilibrium
  - Output dependent on four shocks to output and equilibrium labor
  - Stochastic world interest rate
  - Financial frictions at the firms level

Agents in the Model: Households

- GHH preferences: Get utility from consumption and disutility from labor

$$U(C_t, L_t^s) = \left[\frac{\left(C_t - \frac{\Gamma_{t-1}(L_t^s)^\omega}{\omega} \right)^{1-\gamma}}{1-\gamma} \right]$$

- Earn wage income, profits from firms and transfers from government:

$$C_t = w_t L_t^s + \Pi_t^f + T_t$$

- Do not borrow directly from rest of the world
- FOC with respect to labor and consumption gives labor supply equation

$$\Gamma_{t-1}(L_t^s)^{\omega-1} = w_t$$

Agents in the Model: Firms

- Demand labor to produce output

$$Y_t^c = A_t^c (L_t^{d,c})^{\alpha_L^c}$$

- Hiring labor requires working capital which calls for intra-period loans
- M_t is intra-period loan that satisfies the working capital requirement:

$$M_t \geq \eta w_t L_t^d$$

- No default on intra-period loans
- Profit: $\Pi_t^f = A_t (L_t^d)^{\alpha_L} - w_t L_t^d + M_t - (1 + r_t^*) M_t$
- FOC with respect to labor and loan gives labor demand equation

$$\alpha_L A_t (L_t^d)^{\alpha_L - 1} = (1 + \eta r_t^*) w_t$$

Households & Firms: Equilibrium in Labor Market

Detrended Output: $\tilde{Y}_t^c = \left(e^{z_t^c + \alpha_z^c \cdot z_t^w} \cdot \left(\frac{g_t^c}{g_{ss}^c} \right) \cdot \left(\frac{g_t^w}{g_{ss}^w} \right)^{\alpha_X^c} \right)^{\psi^c} \cdot \left(\frac{1+\eta^c \bar{r^*}}{1+\eta^c r_t^*} \right)^{\psi^c - 1}$

where $\psi^c = \frac{\omega^c}{\omega^c - \alpha_L^c}$

- If $\alpha_L^c = 0$ and $\eta^c = 0$, we go back to the basic version
  - World interest rate fluctuations have no impact borrowing country output
- If $\alpha_L^c \neq 0$ and $\eta^c \neq 0$, we are in the extended version
  - World interest rate fluctuations do impact borrowing country output
  - World interest rate fluctuations affect the default decision of borrowing countries through "endogenous output channel"

What is ψ^c | Equations: Baseline and Full Model

Agents in the Model: Government

- Borrows single period non state-contingent debt from foreign lenders
- Can default on debt obligations if optimal
- Makes debt and default decision in order to maximize household utility
- A government is considered to be in good state at the start of a period if:
    - It can choose to borrow from the lenders at the start of the period
- If the government is in good state, it has 2 options:
    - Option 1: Continue to borrow new debt, repay old debt and enter the next period in good state again:

$$V_t^C = \max_{d_{t+1}}[u(A_t(L_t)^{\alpha_L} - \eta r_t^* w_t L_t + q_t d_{t+1} - d_t, L_t) + \beta \cdot E_t\{V_{t+1}^G\}]$$

    - Transfers by the government to the households

$$T_t = q_t d_{t+1} - d_t$$

Agents in the the Model: Government

- If the government is in good state, it has 2 options:
    - Option 2: Default on the existing debt, lose access to credit markets and enter the bad state
    - If it enters the bad state, it can't borrow and suffers an output loss[2]
    - Households consume output net of the exogenous output loss
    - The next period it can be in good state with an probability λ and 0 initial debt, and with probability $(1-\lambda)$ it will be in bad state again:

$$V_t^B = u(Y^a, L_t^a) + \beta \cdot E_t\{\lambda V_{t+1}^G(d_{t+1} = 0) + (1-\lambda)V_{t+1}^B\}$$

- Value of being in good financial standing

$$V_t^G = \max\{V_t^C, V_t^B\}$$

[2] Output loss takes the form of TFP drop, TFP goes down by: $\{a_1 + a_2 \cdot f(z^c, z^w, g^c, g^w; r^*)\}A$

Agents in the Model: Risk-Neutral Foreign Lenders

- Large number of risk neutral lenders
- Price of debt is adjusted for probability of default:

$$q_t(d_{t+1}; z_t^c, g_t^c, z_t^w, g_t^w; r_t) = \frac{Prob\{F_{t+1} = 0\}}{1 + r_t^*}$$

where F comes from the default rule and is given as:

$$F(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \begin{cases} 1 & \text{if } V_t^B > V_t^C \\ 0 & \text{otherwise} \end{cases}$$

- World interest rate fluctuations affect the default decision of borrowing countries through "debt-pricing channel"

Equilibrium Definition

Calibration

Table: Calibrated Parameter Values

	Parameter Value	Example	Comments
γ	2	Standard	
$\bar{r}^*$	3.67% pa	Standard	Average value from 1960 to 2014
μ_g^c	C-specific	1.025 for Arg	
λ^c	C-specific	0.095 for Arg	Matched 10.5 years in default on an average in 200 years
β^c	C-specific	0.83 for Arg	$\sim$ 0.95 quarterly; Matches defaults/100yr, NFA/Y
a_1^c	C-specific	-0.26 for Arg	Matches defaults/100yr, NFA/Y
a_2^c	C-specific	0.27 for Arg	Matches defaults/100yr, NFA/Y

(1) The countries in the estimation process are 24

(2) 19 defaulting countries from Latin America & Caribbean and 5 developed countries

Model Solution & Performance

- Solving the Model
  - Use value function iteration in discrete state space
  - Solve optimal debt, default choice for every country separately
- Evaluating model performance
  - Targeted Moments:
    - Average default Frequency per 100 year
    - Average debt level in non-default years
  - Non-targeted moments
    - Average spread, Volatility of spread
    - Correlations: Spread & Output, Trade Balance to Output Ratio & Spread

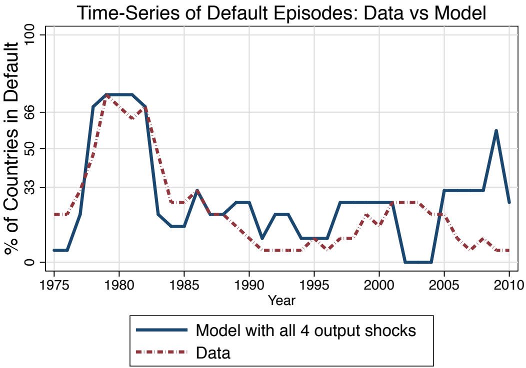
▸ Discretization of State Space ▸ Simulation on Grid Points ▸ Targeted Moments ▸ Non-Targeted Moments

Roadmap

1. Estimation
   - The Baseline Version
   - Full Version (explained in the model part)
2. Preliminary Tests
   - Graphs: Shocks Near Default Episodes
   - Logistic Regressions
3. Model
   - Financial Frictions & the "Endogenous Output Channel"
   - The "Debt Pricing Channel"
4. Results
   - Which Output Shock Matters?
   - Intuition: Transitory and not Permanent Shocks
   - Intuition: Global and not Country Specific Transitory Shocks
   - Interest Rate Shocks & the Volcker Hike

Baseline Model: Simulating the Default Decisions

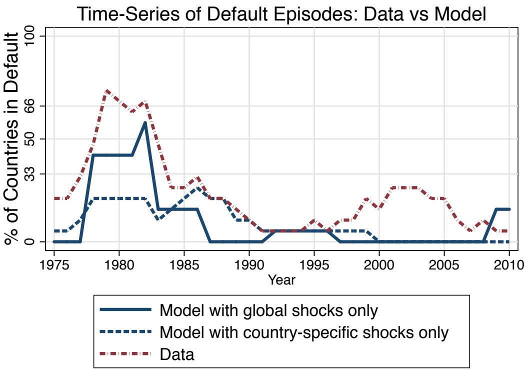
Baseline Model, Constant World Interest Rate



- Baseline version of the model does well to match the clustered default
- But is it because of global shocks or country-specific shocks?

The Cluster of 1980s: Global or Country-specific Shocks?

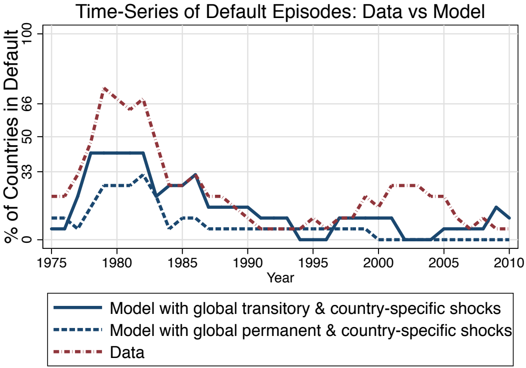
Baseline Model, Constant World Interest Rate



- The version with global shocks does generate a cluster
- But global shocks alone can't replicate the full extent of the cluster
- Which global shocks is more important?

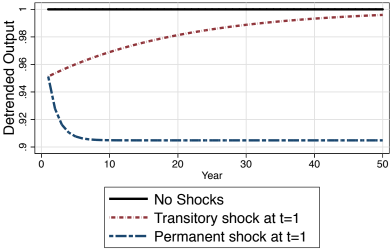
The Cluster of 1980s: Which Global Shock is Important?

Baseline Model, Constant World Interest Rate



- Adding global transitory shock to country-specific shocks causes more defaults and generates a small cluster
- Global transitory shock more important only because of bigger amplitude?

Transitory and not Permanent Shocks

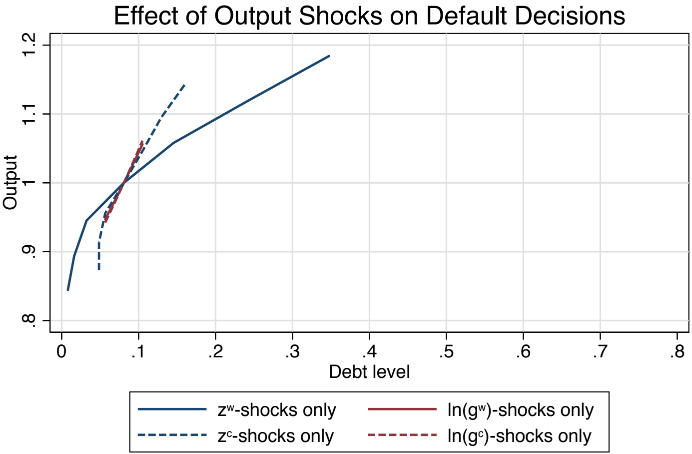


(1) A shock of -5% hits at t=1
(2) Persistence levels used: ρ_z=0.95 and ρ_g=0.5

- After a negative transitory-shock
  - Output today ↓, but tomorrow ↑
  - Convex default cost $\Longrightarrow$ cost of defaulting tomorrow ↑
  - Default relatively more today
- After a negative permanent-shock
  - Output today ↓, tomorrow ↓↓
  - Convex default cost $\Longrightarrow$ cost of defaulting tomorrow ↓
  - Default relatively less today

Sources of Global Transitory Shocks

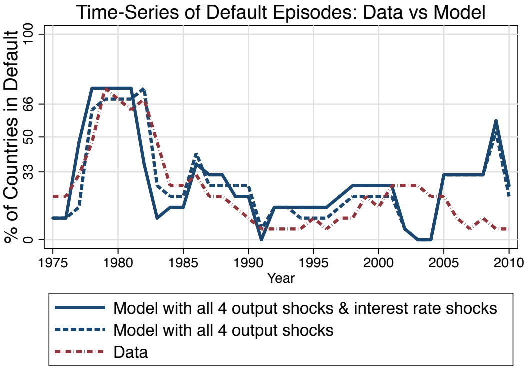
Global and not Country-Specific Transitory Shocks



Note: (1) Right side of the line represents the default region and left side represents non-default region. (2) Only one of z^w, z^c, $\ln(g^c)$ and $\ln(g^w)$ vary at a time. Others remain 0.

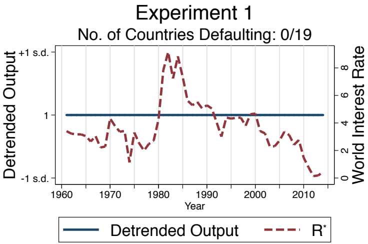
Effect of the Volcker Hike Through Debt Pricing Channel

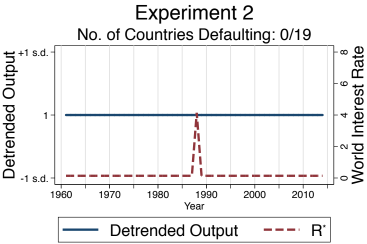
Baseline Model, Stochastic World Interest Rate

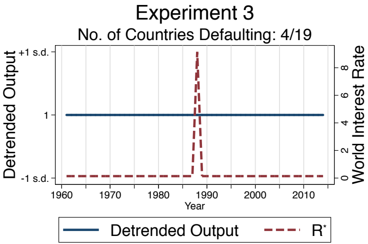


- The Volcker hike had virtually no impact through the debt pricing channel
- Do interest rate shocks matter then?

Experiments: Only Interest Rate Shock, No Output Shock

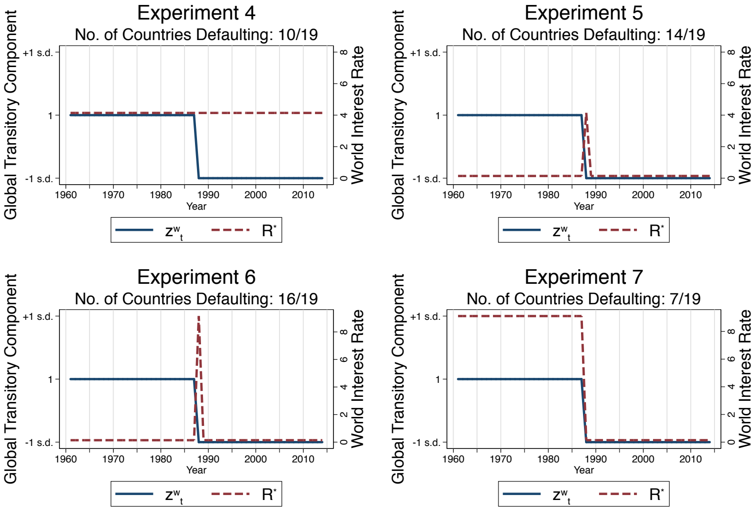






Note: Every country receives same output and world interest rate series

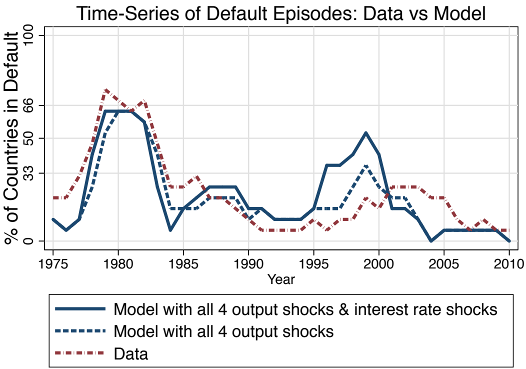
Experiments: Both Interest Rate & Output Shocks



Note: Every country receives same output & world interest rate series

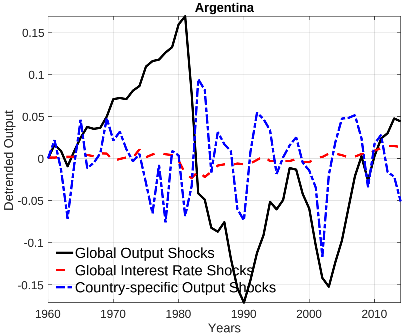
Effect of the Volcker Hike Through Output Channel

Full Model, Stochastic World Interest Rate



- Real interest rate has no impact even through the output channel

Why Did the World Interest Rate Fluctuations Not Matter?



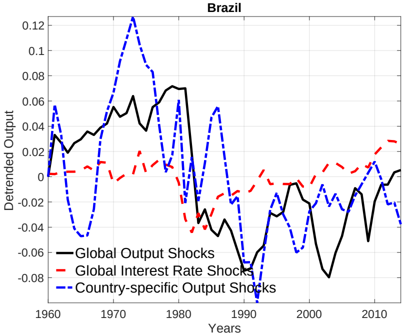


Figure: The **solid black** line represents the contribution of global output shocks to the detrended output. The dashed navy line represents the contribution of country-specific output shocks to the detrended output. The dashed red line represents the contribution of world interest rate fluctuations to the detrended output.

Attenuated Effect of World Interest Rate Fluctuations?

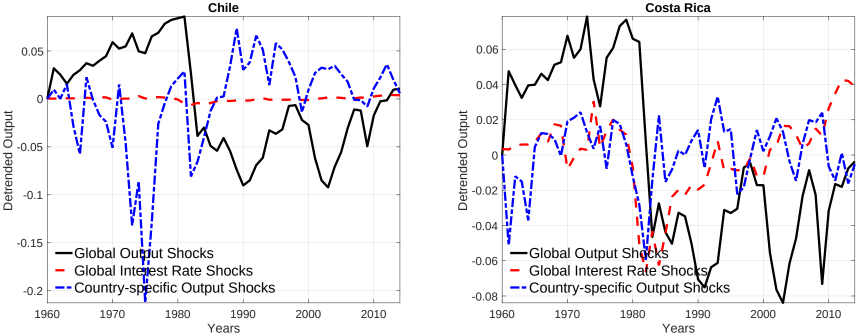


Figure: The **solid black** line represents the contribution of global output shocks to the detrended output. The dashed navy line represents the contribution of country-specific output shocks to the detrended output. The dashed red line represents the contribution of world interest rate fluctuations to the detrended output.

Why Did the World Interest Rate Fluctuations Not Matter?

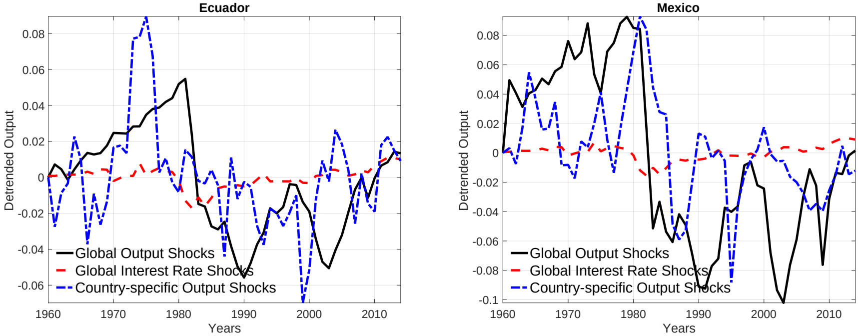


Figure: The **solid black** line represents the contribution of global output shocks to the detrended output. The dashed navy line represents the contribution of country-specific output shocks to the detrended output. The dashed red line represents the contribution of world interest rate fluctuations to the detrended output.

Why Did the World Interest Rate Fluctuations Not Matter?

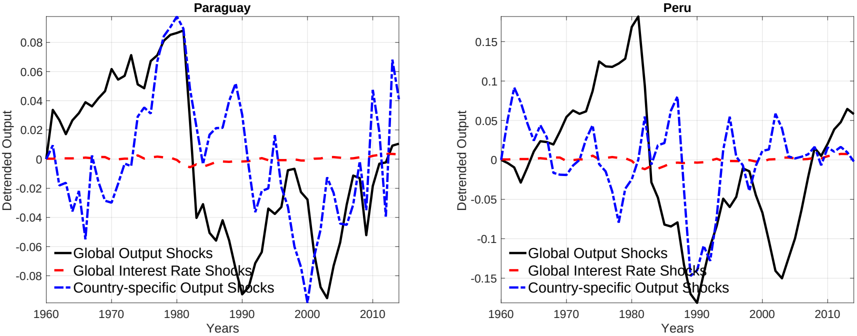


Figure: The **solid black** line represents the contribution of global output shocks to the detrended output. The dashed navy line represents the contribution of country-specific output shocks to the detrended output. The dashed red line represents the contribution of world interest rate fluctuations to the detrended output.

Why Did the World Interest Rate Fluctuations Not Matter?

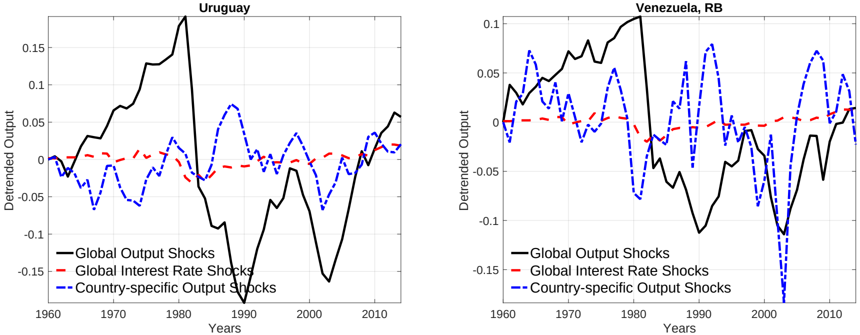


Figure: The **solid black** line represents the contribution of global output shocks to the detrended output. The dashed navy line represents the contribution of country-specific output shocks to the detrended output. The dashed red line represents the contribution of world interest rate fluctuations to the detrended output.

Conclusion

- Global transitory shocks are important in generating clustered defaults
- World interest rate shocks matter but Volcker shock was not responsible for the cluster of 1979-1983
- Before world interest rate changes, it is important to consider the composition of output shocks that highly indebted countries face
- The estimation and model are stepping stone for future research on bailout policies

Thank You

Summary Statistics: Clustered vs Idiosyncratic Defaults

Table: Defaulting Countries and Total Number of Defaults

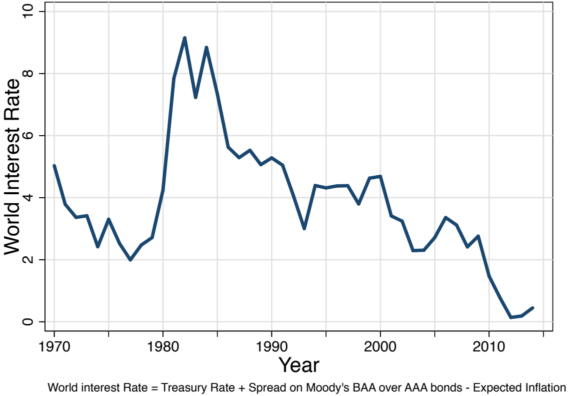
Region Name	Total Number of Defaulting Countries	Total Number of Defaults	Number of Clustered Defaults	Start Year of Clustered Default Window
World	92	146	48	1979,..,1983
Africa & Middle East	42	65	34	1979,..,1985
Europe & Central Asia	15	19	8	1988,..,1991
Latin America & Caribbean	28	51	22	1978,..,1983
Rest of Asia & Pacific	7	11	4	1981,..,1983,1993,..,1997

Author's Calculations. Data Source: Schmitt-Grohè & Uribe (2017): World level data, 92 defaulters, 146 defaults in 1975-2014

- At world level, there are five 5-year rolling windows with clustered defaults
- These windows are 1979-1983, 1980-1984, 1981-1985, 1982-1986, 1983-1987
- Defaults in 1979, 1980, 1981, 1982 and 1983 are considered as clustered defaults.

Back

The Volcker Interest Rate Hike of Early 1980s



- Volcker raised the federal funds rate, which had averaged 11.2% in 1979, to a peak of 20% in June 1981

◂ The Question

Predicted Probabilities: In Numbers

Table: Predicted Probability of Default for Default Episodes

		Average(Predicted probability of default conditional on default)		t-stat
Default Type	N0.	Specification 1	Specification 2	$\hat{P}(D=1\|S_1)=\hat{P}(D=1\|S_2)$
Idiosyncratic Default	52	0.0634	0.0561	1.2078
Clustered Default	35	0.1146	0.2853	-7.0813

Table: Predicted Probability of Default for Non-Default Episodes

		Average(Predicted probability of default conditional on no default)		t-stat
Period	N0.	Specification 1	Specification 2	$\hat{P}(D=1\|S_1)=\hat{P}(D=1\|S_2)$
Non Clustered Default Period	968	0.0360	0.0254	11.0789
Clustered Default Period	165	0.0354	0.0635	-5.2251

◂ Predicted Probability: Figure

Regression Results

Table: Logistic Regression Results

	Specification 1		Specification 2	
	Coefficient	$\frac{d(Prob)}{dx_i}\sigma_{x_i}$	Coefficient	$\frac{d(Prob)}{dx_i}\sigma_{x_i}$
Country-Specific Variables				
(NFA as a % of GDP)$_t^c$	-0.008***	-0.0897	-0.007**	-0.0680
$\log(g_t^c/g_{ss}^c)$	-19.39***	-0.1325	-17.51***	-0.0949
$\Delta z_{t,t-2}^c$	-1.672	-0.0142	-2.774	-0.0188
Global Variables				
(Real interest rate in US)$_t$			0.282***	0.0960
$\log(g_t^w/g_{ss}^w)$			21.99	0.0215
$\Delta z_{t,t-2}^w$			-20.06**	-0.0554
(Inflation Adjusted Oil Prices)$_t$			-0.006	-0.0271
Country Fixed Effects	Yes		Yes	
N	1220		1220	
pseudo R^2	0.100		0.218	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

◂ Predicted Probability: Figure

State Space Form: Basic Version

Observables:[3]

$$\ln(r_t^*/\bar{r}^*) = e_t^r + \alpha_z^r z_t^w + \alpha_g^r \ln(g_t^w/g_{ss}^w)$$

$$\Delta y_t^c = \Delta z_t^c + \alpha_z^c \Delta z_t^w + \log(g_t^c) + \alpha_X^c \log(g_t^w)$$

- Measurement Equation:

$$[r_t^*, \Delta y_t]^T = W + V \cdot \theta_t$$

- Transition Equation:

$$\theta_t = K \cdot \theta_{t-1} + \lambda_t$$

Back

[3] $e_t^r = \rho^r e_{t-1}^r + \epsilon_t^r$

State Space Form: Full Version

Observables:[4]

$$\ln(r_t^*/\bar{r}^*) = e_t^r + \alpha_z^r z_t^w + \alpha_g^r \ln(g_t^w/g_{ss}^w)$$

$$\Delta y_t^c = \psi^c \Delta z_t^c + \psi^c \alpha_z^c \Delta z_t^w + \psi^c \ln(g_t^c) + \psi^c \alpha_X^c \ln(g_t^w) - (\psi^c - 1)\ln(g_{t-1}^c) - (\psi^c - 1)\alpha_X^c \ln(g_{t-1}^w) - (\psi^c - 1)\eta^c(r_t^* - r_{t-1}^*)$$

- Measurement Equation:

$$[r_t^*, \Delta y_t]^T = W + V \cdot \theta_t$$

- Transition Equation:

$$\theta_t = K \cdot \theta_{t-1} + \lambda_t$$

Back

[4] $e_t^r = \rho^r e_{t-1}^r + \epsilon_t^r$

Measurement Equation: Details

- $[r_t^*, \Delta y_t]^T = [r_t^*, \Delta y_t^1, \cdot, \Delta y_t^c, \cdot, \Delta y_t^n]^T$
- $W = [\bar{r}^*, \ln(g_{ss}^1) + \alpha_X^1 \ln(g_{ss}^w), \cdot, \ln(g_{ss}^c) + \alpha_X^c \ln(g_{ss}^w), \cdot, \ln(g_{ss}^{nc}) + \alpha_X^{nc} \ln(g_{ss}^w)]^T$
- $V = \begin{bmatrix} 1 & \alpha_z^r & 0 & \alpha_X^r & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\ 0 & \alpha_z^1 & -\alpha_z^1 & \alpha_X^1 & 1 & -1 & 1 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & \alpha_z^c & -\alpha_z^c & \alpha_X^c & 0 & 0 & 0 & \cdot & 1 & -1 & 1 & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & \alpha_z^{nc} & -\alpha_z^{nc} & \alpha_X^{nc} & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 1 & -1 & 1 \end{bmatrix}$
- $\theta_t = [e_t^r, z_t^w, z_{t-1}^w, \ln(g_t^w/g_{ss}^w), z_t^1, z_{t-1}^1, \ln(g_t^1/g_{ss}^1), \cdot, z_t^n, z_{t-1}^n, \ln(g_t^n/g_{ss}^n)]^T$

Back

Transition Equation: Details

- $$K = \begin{bmatrix}
\rho^r & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & \rho_z^w & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_g^w & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_z^1 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_g^1 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & \rho_z^c & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 1 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^c & \cdot & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & \rho_z^{nc} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^{nc}
\end{bmatrix}$$
- $\lambda_t = [\epsilon_t^r, \epsilon_{z,t}^w, 0, \epsilon_{g,t}^w, \epsilon_{z,t}^1, 0, \epsilon_{g,t}^1, \cdot, \epsilon_{z,t}^c, 0, \epsilon_{g,t}^c, \cdot, \epsilon_{z,t}^{nc}, 0, \epsilon_{g,t}^{nc}]^T$

Back

Estimation Procedure: Priors

Table: Prior Distribution for Bayesian Estimation: Full Model

	Uniform Prior Distributions	
Parameter	Min	Max
ρ_z^c	0.0001	0.99
ρ_g^c	0.0001	0.99
σ_z^c	0.0001	0.9
σ_g^c	0.0001	0.9
ρ_z^w	0.0001	0.99
ρ_g^w	0.0001	0.99
ψ^c	1.01	4
η^c	0.0001	0.9999
α_z^{VEN}	0.0001	2
α_X^{VEN}	0.0001	2
α_z^c	-2	2
α_X^c	-2	2

σ_z^w and σ_g^w are normalized to 1

◂ The Output Process

Estimation Procedure: Posteriors

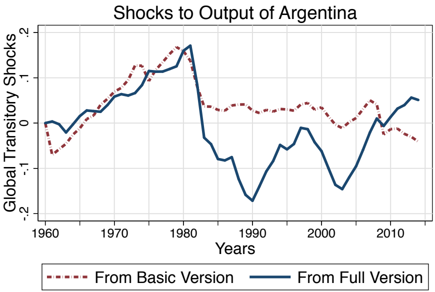
Table: Bayesian Estimation Results from Full Model: Posterior means

Country	Posterior (Means)							
	ρ_z^c	ρ_g^c	σ_z^c	σ_g^c	ψ^c	η^c	α_z^c	α_X^c
Argentina	0.2813	0.6431	0.0134	0.0141	2.0832	0.3924	0.0196	0.0029
Belize	0.4934	0.7748	0.0028	0.0138	2.5386	0.3669	0.0041	0.0017
Bolivia	0.9477	0.2448	0.0136	0.0036	2.3502	0.0713	0.0086	-0.0003
Brazil	0.2023	0.8617	0.0025	0.0122	2.2738	0.6329	0.0078	0.0065
Chile	0.9267	0.6321	0.0110	0.0210	1.7075	0.1645	0.0126	0.0082
Costa Rica	0.2902	0.5339	0.0039	0.0069	2.3393	0.9032	0.0073	0.0092
Dominican Republic	0.3735	0.5430	0.0135	0.0235	1.7342	0.8289	0.0078	0.0089
Ecuador	0.4392	0.7825	0.0084	0.0142	1.4405	0.7039	0.0092	0.0020
Guatemala	0.7671	0.7034	0.0025	0.0083	1.7201	0.6772	0.0054	0.0090
Guyana	0.3798	0.6713	0.0037	0.0125	2.9785	0.3414	0.0159	-0.0035
Honduras	0.4223	0.6674	0.0043	0.0096	2.0775	0.5282	0.0050	0.0103
Mexico	0.7295	0.7787	0.0057	0.0104	2.0862	0.2603	0.0105	0.0107
Nicaragua	0.9303	0.7011	0.0152	0.0254	2.0281	0.7145	0.0073	-0.0019
Panama	0.5375	0.8314	0.0039	0.0141	2.5912	0.4966	0.0129	-0.0016
Paraguay	0.5385	0.6997	0.0047	0.0162	1.8303	0.1220	0.0121	0.0081
Peru	0.4378	0.7591	0.0051	0.0205	1.8000	0.2680	0.0239	-0.0020
Trinidad and Tobago	0.1823	0.8532	0.0040	0.0177	1.9957	0.0632	0.0054	0.0079
Uruguay	0.9247	0.7466	0.0088	0.0117	1.7514	0.7631	0.0261	0.0001
Venezuela, RB	0.8535	0.5335	0.0174	0.0105	2.0829	0.3363	0.0129	0.0080

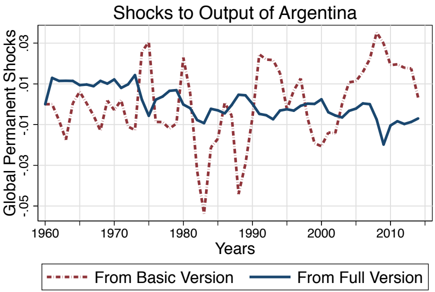
Posterior means for ρ_z^w and ρ_g^w are 0.8897 and 0.7555 respectively
The countries included in the estimation process are 24. 19 defaulting countries from Latin America & Caribbean and 5 non-defaulting developed countries. Parameter estimates are reported only for 19 Latin America & Caribbean countries.

◂ The Output Process

Estimating the Output Process: The Global Shocks



Correlation between these two: 0.54



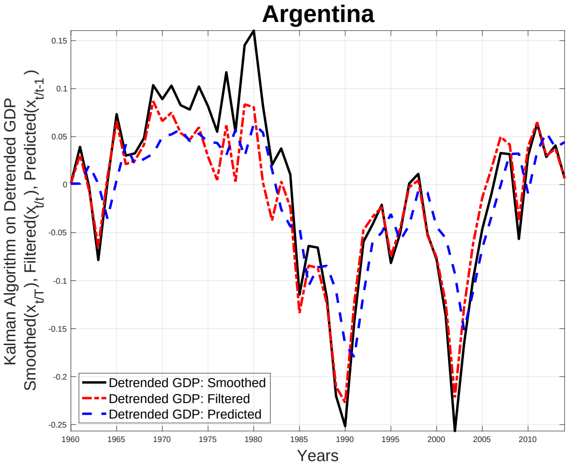
Correlation between these two: -0.34

Figure: Kalman Smoothed time series from Bayesian estimation. The left panel shows $\alpha_z^c z^w$ from the Basic Version and $\psi^c \alpha_z^c z^w$ from the Full version. The right panel shows $\alpha_X^c \ln(g^w)$ from the Basic Version and $\psi^c \alpha_X^c \ln(g^w)$ from the Full version.

Back
Kalman Smoothing, Filtering and Prediction

Kalman Smoothing, Filtering and Prediction

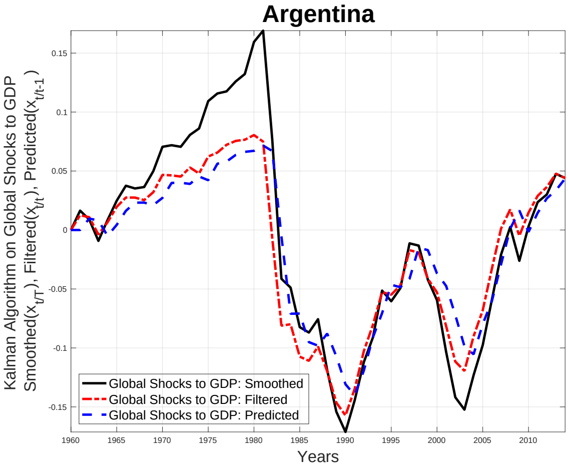
Detrended Output: All shocks



The Global Shocks

Kalman Smoothing, Filtering and Prediction

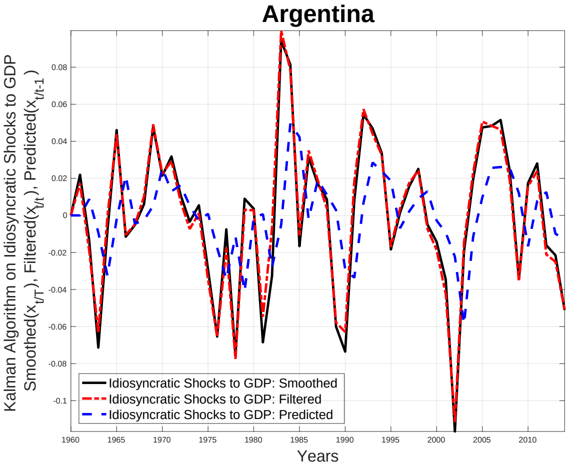
Detrended Output: Global shocks Only



◂ The Global Shocks

Kalman Smoothing, Filtering and Prediction

Detrended Output: Idiosyncratic shocks Only



◂ The Global Shocks

What is ψ^c

ψ^c governs the response of equilibrium quantity of labor to shocks in the labor market $\psi^c = \frac{\omega^c}{\omega^c - \alpha_L^c}$

- If ω is high, Frisch elasticity of labor supply will be low
  - Labor supply curve will be vertical
  - Changes in interest rate will shift labor demand but will not have big effect on equilibrium labor
  - Changes in interest rate will not have big effect on equilibrium output
  - This is evident in the equation if $\psi = 1$
- If α_L is low, labor share is small
  - Labor demand will respond less to fluctuations in interest rate
  - Changes in interest rate will not have big effect on equilibrium labor or output
  - This is evident in the equation if $\psi = 1$

Back

Equations: Baseline Model and Full Model

Baseline Model:

$$\ln(r_t^*/\bar{r}^*) = e_t^r + \alpha_z^r z_t^w + \alpha_g^r \ln(g_t^w/g_{ss}^w)$$

$$\Delta y_t^c = \Delta z_t^c + \alpha_z^c \Delta z_t^w + \ln(g_t^c) + \alpha_X^c \ln(g_t^w)$$

Full Model:

$$\ln(r_t^*/\bar{r}^*) = e_t^r + \alpha_z^r z_t^w + \alpha_g^r \ln(g_t^w/g_{ss}^w)$$

$$\begin{aligned}\Delta y_t^c = {} & \psi^c \Delta z_t^c + \psi^c \alpha_z^c \Delta z_t^w + \psi^c \ln(g_t^c) + \psi^c \alpha_X^c \ln(g_t^w) \\ & - (\psi^c - 1)\ln(g_{t-1}^c) - (\psi^c - 1)\alpha_X^c \ln(g_{t-1}^w) - (\psi^c - 1)\eta^c(r_t^* - r_{t-1}^*)\end{aligned}$$

Back

Equilibrium Definition

- A sequence of variables: $\{C_t, L_t, M_t, \Pi_t^f, d_{t+1}, F_t, T_t, w_t, q_t\}$ and value functions $\{V_t^C, V_t^B, V_t^G\}$ constitute a recursive equilibrium given the initial debt level, d_t, TFP processes: $\{z_t, z_t^w, g_t, g_t^w\}$ and the world real interest rate process, $\{r_t^*\}$, if:
  - Households choose $\{C_t, L_t^S\}$ given the wage rate, w_t, profits from the firms, Π_t^f, and government transfers, T_t.
  - Firms choose $\{\Pi_t^f, M_t, L_t^D\}$ given the wage rate, w_t, and the world interest rate, r_t^*.
  - Wage rate, w_t, clears the labor market i.e. $L_t^S = L_t^D$.
  - The government chooses $\{d_{t+1}, F_t, T_t\}$ to maximize household utility given the starting debt level, d_t, the world interest rate, r_t^*, equilibrium price of debt, q_t, and the solutions to household and firm problems.
  - The equilibrium price of debt, q_t, clears the debt market i.e. the risk-neutral international lenders obtain zero expected profits.

Back

Discretization of State Space

Table: Grid Points

	Grid Specification		
State Variable	Number	Min	Max
z^c, Country-specific transitory shock to output	7	$-3 \cdot \sigma^c_{z,LR}$	$3 \cdot \sigma^c_{z,LR}$
z^w, Global transitory shock to output	7	$-3 \cdot \sigma^w_{z,LR}$	$3 \cdot \sigma^w_{z,LR}$
$\ln(g^c)$, Country-specific permanent shock to output	7	$-3 \cdot \sigma^c_{g,LR}$	$3 \cdot \sigma^c_{g,LR}$
$\ln(g^w)$, Global permanent shock to output	7	$-3 \cdot \sigma^w_{g,LR}$	$3 \cdot \sigma^w_{g,LR}$
r^*, World real interest rate	10	0.14%	9.15%
d, Debt level	100	0	d_{max}

Notes:

1. Number of grid points for output become $7 \times 7 \times 7 \times 7 \times 10 = 24,010$
2. The minimum and maximum values on the grid of z^c and $\ln(g^c)$ are country specific based on the estimated parameters. For example, Argentina has $\sigma^c_{z,LR} = 0.0452$ and $\sigma^c_{g,LR} = 0.0198$
3. $\sigma^w_{z,LR} = 2.9648$ and $\sigma^w_{g,LR} = 1.1576$, but the output grid points also depend on the coefficients α^c_z and α^c_X. For example, Argentina has $\alpha^c_z \cdot \sigma^w_{z,LR} = 0.0563$ and $\alpha^c_X \cdot \sigma^w_{g,LR} = 0.0182$
4. The maximum value for the debt grid is also country specific and depends on the average debt level in the country. For example, d_{max} for Argentina is 0.8
5. LR represents long run standard deviations

Back

Simulation on Grid Points

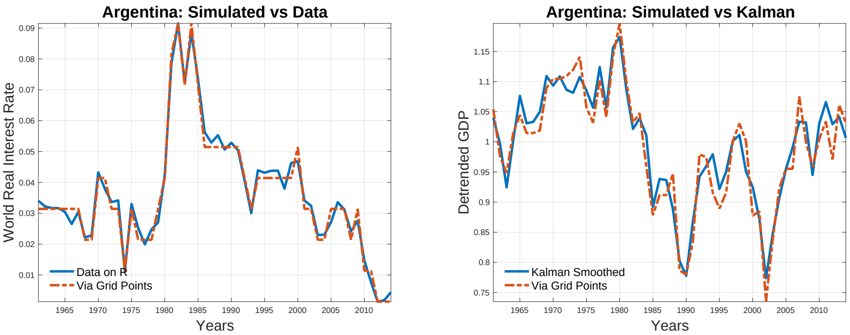
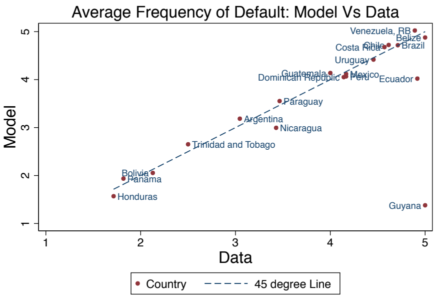


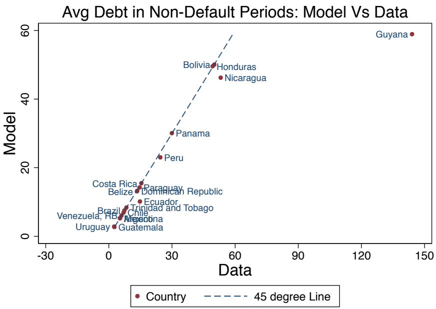
Figure: Left panel shows the world interest rate r_t^* from data and the one that is simulated in the model using the 10 grid points. Right panel shows the detrended output series resulting from the time series of shocks backed out using Kalman smoothing algorithm and the same when simulated on $7 \times 7 \times 7 \times 7$ grid.

Back

Model Performance: Targeted Moments



Average frequency of default is measured as defaults per 100 years

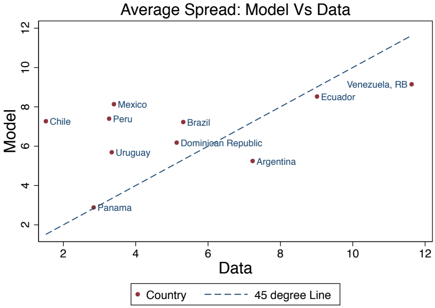


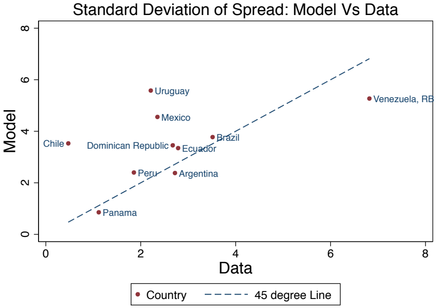
- Targeted moments are matched well except for Guyana[5]

Back

[5] Guyana has a NFA of -144% of it's output and default frequency of 5 times per 100 year

Model Performance: Non-Targeted Moments

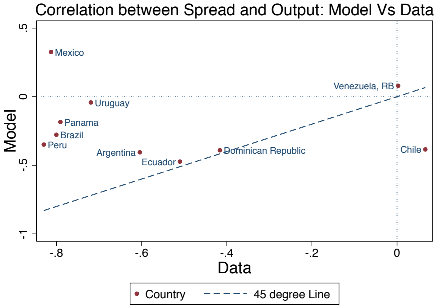


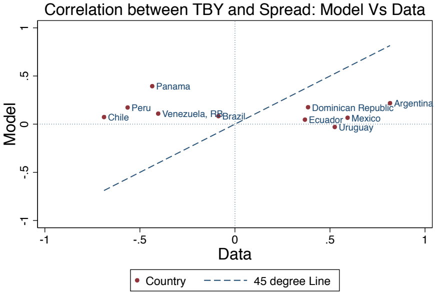


- EMBI global has spread information on 10 out of 19 countries
- For average spread, most of the countries are still in the neighborhood of the 45-degree line except for Chile, Mexico and Peru
- Standard deviation of spread in non-default periods is matched much more closely except for Chile and Uruguay

Back

Model Performance: Non-Targeted Moments





- The model does well to explain the counter-cyclicality of country premium except for Mexico and Chile
- Model doesn't do very good in terms of predicting the correlation between trade balance to output ratio and output

Back

Adjusting for the Output Loss

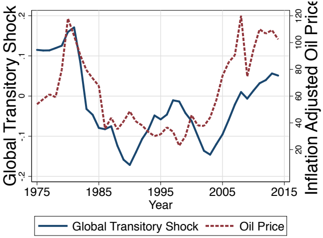
- The concern:
  - Assumed output loss specification: $L(y) = a_1 * y + a_2 * y^2$
  - Let us say Argentina defaults in 1982 and the de-trended output in 1982 goes down from 10% above trend to 5% above trend[6]
  - 1982 onward Argentina's output went down partly because of default and partly because of output/interest rate shocks
  - In the estimation, all the decrease in output is assumed to be from output/interest rate shocks
  - Later on while simulating, I add the output cost on top of the observed output decrease
  - Thus, in simulations, output inclusive of default costs goes down 5% plus the default cost, say, 2%
  - Need to make sure that estimation should include this extra cost (at least for period in which Argentina remained in default status)

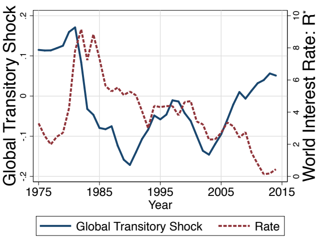
[6] Default costs are high when output is high. That is why we assume output to be 5% above trend. Sometime 2-3% below trend might not have any output loss at all.

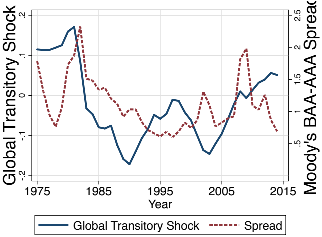
Adjusting for the Output Loss

- The solution:
  - Start with the time-series of shocks that was smoothed out without incorporting output loss.
  - Using Kalman smoothing, we have series for z^w, z^c, $\ln(g^w)$, $\ln(g^c)$
  - Let us say for 1982, the series of four shocks look like: $\exp\left(z^w_{1982}\right) = 0.97$, $\exp\left(z^c_{1982}\right) = 0.99$, $g^w_{1982} = 1.05$, $g^c_{1982} = 1.07$, and $\mu_g = 1.025 \implies \tilde{y}^c_{1984} = 0.97 * 0.99 * 1.05 * 1.07/1.025 = 1.0525$
  - Parameters of output loss function for Argentina: $a_1 = -0.26$, $a_2 = 0.266$
  - Total output loss suffered in 1982 due to default: $-0.26 + (0.266 * 0.97 * 0.99 * 1.05 * 1.07/1.025) = 0.02$ i.e. 2%
  - How to adjust the 4 shocks to get the same output loss?

Sources Global Transitory Shock







Back

Decomposing Global Transitory Shock

Table: Regression of Global Transitory Shock and Variance Decomposition

Common Shock	Statistic	Regressor			R^2
z_t^W		P_{Oil}	Spread	R*	
	Coefficient	0.0014	0.0499	-0.0064	
	t-stat	2.49	1.21	-0.87	
	Var Decomp	0.2425	0.0375	0.0975	0.3639

- Average Marginal R^2 is used for variance decomposition
- Oil price fluctuations are highly correlated with the global transitory shock
- Oil price fluctuations also explain a big portion of the R^2

Back

Adjusting for the Output Loss

- Adjusting individual shocks:
  - Since output costs are convex, the shocks that are higher should share a higher fraction of output loss
  - Threshold shocks for 0 Output loss: $a_1 + a_2 * (s^4/1.025) = 0 \implies s = 1$
  - Any shock less than 1 doesn't get any deduction in terms of output, shocks more than 1 do
  - Thus, no loss coming from z^w and z^c in the current example
  - Let us now say that g^c and g^w went down partly because of output loss of default
  - Thus, $g^w = 1.05(1+f)$ and $g^c = 1.07(1+f)$ without output loss[7]
  - $(1+f)^2 * 0.97 * 0.99 * 1.05 * 1.07/1.025 - 0.97 * 0.99 * 1.05 * 1.07/1.025 = 0.02$
  - $f = 0.0094$. Thus, $g^c = 1.0599$ $g^w = 1.0801$
  - Ideal method will be: Output loss from specification = Output loss calculated from (1+f) series and Kalman smoothed series

[7] Proportional can be assumed as output inclusive of loss is $y(1 - a_1 - a_2 * y)$

Re-estimating the interest rate process

$$\ln(r_t^*) = \ln(\bar{r^*}) + \alpha_z^r * z_t^w + \alpha_g^r \cdot \ln(g_t^w / g_{ss}^w) + e_t^r$$

where

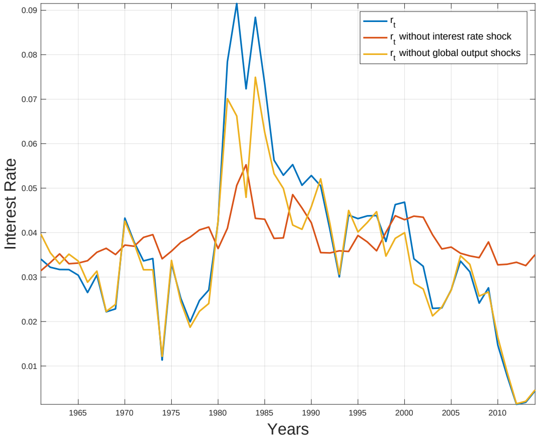
$$e_t^r = \rho_r \cdot e_{t-1}^r + \epsilon_t^r$$

and

$$\Delta y_t^c = \Delta z_t^c + \alpha_z^c \Delta z_t^w + \ln(g_t^c / g_{ss}^c) + \alpha_X^c \ln(g_t^w / g_{ss}^w)$$

Decomposing the Interest Rate Process

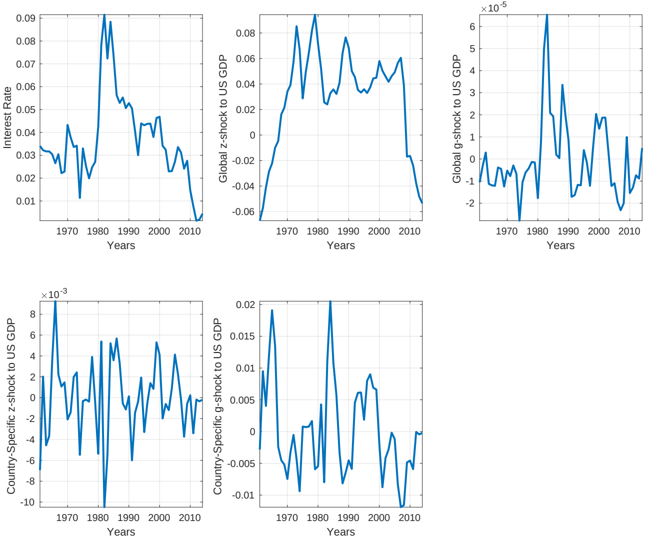
- $\ln(r_t^*) = \ln(\bar{r^*}) + \alpha_z^r * z_t^w + \alpha_g^r \cdot \ln(g_t^w / g_{ss}^w) + e_t^r$
- Plot r_t^*, $\ln(\bar{r^*}) + \alpha_z^r * z_t^w + \alpha_g^r \cdot \ln(g_t^w / g_{ss}^w)$, and $\ln(\bar{r^*}) + e_t^r$



Decomposing the Interest Rate Process

- Global variables do not explain the interest rate process a lot
- A big part is still an AR(1) shock
- But, the Volcker increase in interest rate or the decrease in interest rate during the great recession was probably ‘not’ a shock
- Is this pure shock, e_t^r, in the interest rate process correlated more to US economic activity than to world shocks?

Decomposing the Interest Rate Process



Decomposing the Interest Rate Process

- Interest rate changes are correlated to permanent shocks
  - $\text{corr}(r_t, \alpha_z^{US} z_t^w)$=0.33
  - $\text{corr}(r_t, \alpha_X^{US} \ln(g_t^w))$=0.63
  - $\text{corr}(r_t, z_t^{US})$=0.02
  - $\text{corr}(r_t, \ln(g_t^{US}))$=0.27
- Interest rate after 1975 are also correlated to global temporary shocks
  - $\text{corr}(r_t, \alpha_z^{US} z_t^w)$=0.40
  - $\text{corr}(r_t, \alpha_X^{US} \ln(g_t^w))$=0.60
  - $\text{corr}(r_t, z_t^{US})$=0.03
  - $\text{corr}(r_t, \ln(g_t^{US}))$=0.36
- Need to include US specific shocks in the estimation equation to get pure shocks in interest rate?