# Clustered Sovereign Defaults *

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**Abstract**

Clustered sovereign default is a recurring phenomenon, yet there is a lack of quantitative models to study them. This paper builds a quantitative framework that investigates the nature of shocks and the mechanism through which these shocks lead countries to clustered defaults. The paper performs a joint estimation of structural parameters that drive the output process of 24 countries. The postulated output process includes global as well as country-specific components. The paper then builds a sovereign default model augmented with financial frictions. The model and the estimation process of driving forces are validated jointly when the shocks, estimated independently of the model or of default data, are fed into the model and the model reproduces the clustered default of 1980s. The main finding of the paper is that contrary to what is commonly believed, the Volcker interest rate hike was not a decisive factor for the 1980s clustered default.

***JEL classification***: F34, F44, H63.
***Keywords***: Sovereign default, Clustered default, Latin-American debt crisis, Sovereign debt

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# 1 Introduction

Historical data on sovereign defaults shows that *clustered* defaults, where multiple countries default in a relatively short period of time, is a recurring phenomenon that has generally followed global output slumps or world interest rates hikes.[1] The biggest and the most recent clustered default of 1982 was no exception as the defaults followed the Volcker interest rate hike. Despite the frequent recurrence of clustered defaults, a quantitative framework studying the contributions of various global and country-specific shocks in causing clustered defaults is still lacking. In the absence of such a framework, it becomes impossible to disentangle the impact of interest rate hikes—like the Volcker interest rate hike—from the effect of output shocks in causing the clustered defaults. This paper, therefore, builds a quantitative framework, complementing a multi-country econometric estimation with an accordingly tailored sovereign default model, that caters the need to understand clustered defaults.

The plausibility of global shocks playing a central role in causing clustered defaults requires the framework to include global shocks in addition to country specific-output shocks to studying clustered defaults.[2] Thus, this paper incorporates global shocks to transitory and permanent components of output, country-specific shocks to transitory and permanent component output as well as world interest rate fluctuations in the framework. The role of these shocks in causing clustered defaults is then investigated by asking three important questions: First, are global shocks necessary in order to explain clustered defaults? Second, which global shocks—global shocks to transitory or permanent components of output or world interest rate fluctuations—matter? Third, was the Volcker interest rate hike responsible in leading countries to default? The first main finding of the paper is that the primary driver of clustered defaults is global shock to the transitory component of output. The second result shows that a world interest rate hike can lead to clustered defaults but contrary to what is commonly believed, the Volcker interest rate hike was not a decisive factor for the clustered default of 1982.

The paper, divided into two independent but complimentary parts, investigates the impact of various shocks and the mechanism through which these shocks lead countries to clustered defaults. The first part performs an estimation process that takes country-level output as an observable and disentangles it into various unobservable shocks that different countries face. This first part, therefore, produces a time series of all these global and country-specific

[1] Periods in the late 1820s, early 1870s, early 1930s and early 1980s have all been periods where a huge number in countries defaulted in a relatively short time. In aggregate, there have been six clustered defaults between the years of 1800 and 2015.

[2] The empirical literature by Reinhart and Rogoff (2011), Bordo and Murshid (2000), Kaminsky and Vega-Garcia (2016) have likewise suggested an important role of global shocks in causing clustered defaults using reduced form analysis.

shock processes. In the second part, the paper develops a quantitative sovereign default model based on Eaton and Gersovitz (1981) to capture the mechanism through which these shocks lead countries to clustered defaults. When fed with the shocks, estimated independently of the model or of default data, the model reproduces the clustered default of 1982. This success proves to be a joint validation of the model as well as the estimation process.

The first part is crucial as it deviates significantly from the existing literature on sovereign defaults to capture the effect of global shocks on output of borrowers. It postulates an output process for every country and accommodates for the presence of five shocks—country-specific transitory and permanent shocks to output; global transitory and permanent shocks to output; and world interest rate fluctuations. Both global output shocks enter the output process of every country as well as the process of the world real interest rate. Thus, the estimation of the structural parameters requires a joint estimation with the output growth of all the countries and the world interest rate as observables. The estimation is done using the Bayesian method and the time series of all country-specific and global shocks are backed out using the Kalman smoothing algorithm.

The second part, which is built on the quantitative models of Arellano (2008) and Aguiar and Gopinath (2006), makes several departures from the existing literature. The biggest departure pertains to the world interest rates. Unlike most of the existing default literature where world interest rates are assumed to be fixed, the paper assumes a fluctuating world interest rate. Fluctuating world interest rate enables this paper to study the quantitative impact of the Volcker interest rate hike on the clustered defaults of 1980s, a first to the best of my knowledge.

The model introduces two channels through which world interest rate fluctuations can influence the default decisions: the *debt-pricing channel* and the *endogenous output channel*. The first channel works by making borrowing more expensive for the countries, and the second channel allows for the Volcker interest rate hike to endogenously affect the output of the borrowing country. The presence of the second channel is made possible by introducing endogenous labor supply and demand decisions in the economy as well as financial frictions in the form of working capital constraints at the firm level. These channels provide a novel way to capture the effect of interest rate movements on default decisions. In the first channel, an increase in risk free rate also raises the interest rate on the debt of the borrowers in order for lenders to remain indifferent between holding risk-free and risky assets. This increase causes a decrease in the price of government debt, thereby making borrowing costly and influencing the default decisions through *debt-pricing channel*. The second channel is captured through the labor market and the financial friction. The presence of working-capital constraint requires firms to borrow a fraction of their wage bill in advance. This borrowing through intra-period loans becomes more costly whenever the world interest rate rises. This causes labor demand to decrease for a given level of wage. In equilibrium, the quantity of labor as well as output goes down. Thus, an increase in the interest rate endogenously affects output and influences the default decision through the *endogenous output channel*.

In spite of incorporating two channels through which interest rate can have an effect on default decisions, countrywise simulation of the model on the time series of all the shock processes shows that the Volcker interest-rate hike was not a decisive factor for the clustered default of 1982. Moreover, the paper finds that global shock to the transitory component of output is most important in generating the clustered defaults. This result contradicts the finding of Aguiar and Gopinath (2006), who attribute defaults to permanent rather than transitory shocks.[3] The mechanism that drives this counterintuitive result depends on three features: the convex output costs of default, the high standard deviation and the high persistence of global shocks to transitory component of output. The convex output cost assumption makes transitory shocks more important than permanent shocks in leading countries to default; while high amplitude and persistence makes global transitory shocks more important than the country-specific transitory shocks.[4]

Last, a word on the complementarity between the estimation part and the model remains. The complementarity provides a structure to this quantitative analysis and, at the same time, keeps the results independent of the model. In the absence of the estimation part, a claim playing down the effect of the Volcker interest rate hike and attributing the clustered default of 1980s to the output shocks would have been incomplete. This is because the possibility of output decline being an endogenous response to increased interest rate. By capturing the effect of interest rate fluctuations on output process of borrowers, the estimation process not only makes an important contribution to this literature but also solves this problem. At the same time, the estimation does not attribute this endogenous effect to a particular channel. Thus, labor market frictions work as a simplified mechanism to generate a parallel mechanism in the model, yet the paper remains open to the possibility that the endogenous effect could have manifested through the capital market or any other phenomena. This is evident as the

[3]Though, the result and the reason of getting results contradictory to Aguiar and Gopinath (2006) are important, it is reassuring that the importance of transitory shocks highlighted in this paper concurs with papers in different strands of macroeconomics literature like Chang and Fernández (2013) and Garcia-Cicco et al. (2010).

[4]The literature assumes convex default cost to match the empirical finding that defaults happen in bad times. In more recent paper, like Hébert and Schreger (2017), the output cost of default is estimated for the Argentinean default of 2001, and the results support the assumption. In recent theoretical papers, such as Mendoza and Yue (2012) and Na et al. (2015), convex costs arise endogenously through the model, hence providing some microfoundations for the assumption of the convex output cost of default. The convex output cost assumption used in this paper is similar to the one used by Chatterjee and Eyigungor (2012), Uribe and Schmitt-Grohé (2017), and most of the papers in the quantitative literature.

results from the *endogenous output channel* rely solely on the Kalman smoothed time series from the estimation part.

**Related Literature** The model built in this paper is founded on the seminal work of Eaton and Gersovitz (1981); and the subsequent works of Arellano (2008) and Aguiar and Gopinath (2006). In contrast to those papers, this paper focuses on clustered defaults by studying the impact of global shocks on default decisions. The model captures the effect of global shocks by introducing global output shocks and stochastic world interest rates in a multicountry setup. To best of my knowledge, (1) the introduction of two global output shocks and a real interest rate shock, (2) the joint estimation of the shocks processes in a multicountry setup, and (3) capturing the effect of world interest rate shocks (through the *debt pricing channel* and the *endogenous output channel*) on default decisions; have not been done in the sovereign default literature. This paper is also a first in the sovereign default literature to quantitatively study the impact of the Volcker interest-rate hike on the clustered default episode of 1982. The result that the Volcker interest rate hike was not a decisive factor for the clustered default of 1982 concurs with Almeida et al. (2018) who also conclude, for the Mexican default of 1982, that Mexico would have defaulted even in the absence of an interest rate hike.

The joint Bayesian estimation of 196 parameters with data on the output of 24 countries and world interest rate is also unique, both in type and scale, in the sovereign default literature. This idea of the estimation process is borrowed from Kose et al. (2003), Kose et al. (2008), Miyamoto and Nguyen (2017) etc, that use a similar dynamic factor method approach to disentangle different global and country-specific shocks. Among various parameters, interest rate elasticity of output is also estimated for all 24 countries. This elasticity, estimated using the Bayesian methodology, matches with the ones obtained in the empirical literature on monetary policy transmission, thereby providing another validation to the model and the estimation procedure. Georgiadis (2016) and Dedola et al. (2017) use VAR methodology to estimate the effect of monetary shocks in the US on the rest of the world, while Iacoviello et al. (2018) use the local projections method. In contrast, this paper microfounds a transmission mechanism in a general equilibrium model and estimates the structural parameters of the model to capture the effect of interest rate changes, making a methodological contribution to the literature.

To capture the effect of changes in world interest rate shocks through a model, this paper uses working-capital constraints, which is borrowed from the small open economy setting of Neumeyer and Perri (2005) and Uribe and Yue (2006). Papers such as Mendoza and Yue (2012), Padilla (2013), and Mallucci (2015) use working-capital constraints in the sovereign default literature as well. This constraint is specifically important here because it enables a parallel between the estimation and the model by capturing the *endogenous output channel* in both the places.

The multicountry setup used in this paper differs from recent contagion papers such as Arellano et al. (2017) and Park (2014) who study the risk contagion between countries. First, the contagion papers focus mainly on the recent European debt crisis, whereas this paper focuses on clustered defaults of 1980s. The reason being unavailability of the data on sovereign spreads which is a key component to assess the performance of the model. This paper, instead uses a set of 19 countries over a period of 40 years and matches the joint defaults to test the performance of the model. Next, the channel through which interactions between countries work in the contagion papers is the presence of risk-averse lenders. In this paper, there is no direct strategic linkage between countries in the model. All the effect comes either from global output shocks or through world interest rate fluctuations.

There are other papers that illustrate different mechanisms that lead countries to idiosyncratic defaults. For example, in Lizarazo (2013), the mechanism works through the presence of risk-averse lenders, and in Pouzo and Presno (2016), through the presence of uncertainty-averse lenders. Since these mechanisms work through the lender, a shock to the lender can propagate to multiple borrowers in a multicountry setting and can cause clustered defaults. The renegotiation channel studied in Benjamin and Wright (2009) and Arellano et al. (2017) in conjunction with risk-averse lenders can also cause multiple countries to default at the same time. Bocola and Dovis (2016) and Lorenzoni and Werning (2013) study the role of expectations in self-fulfilling defaults and slow-moving crises, respectively. Borri and Verdelhan (2011) features correlated shocks between the borrowing countries and the US. Since these mechanisms work through a lender or the presence of multiple equilibria, they can also generate clustered defaults. This paper neither favors nor rejects any of these explanations. As long as these mechanisms are in place and can slow the output growth of multiple borrowing countries together, this paper captures any or all of such mechanisms.

Lastly, this paper also contributes to the empirical literature on clustered defaults. Kaminsky and Vega-Garcia (2016) is one of the few papers to perform a detailed empirical investigation of the possibility of global shocks in causing clustered defaults. They use a dataset of 7 Latin American countries from 1820 to the great depression that captures a total of 27 defaults to show that global shocks are essential in predicting clustered defaults. The default definitions as well as the preliminary empirical investigation, that is present in the online appendix, follow Kaminsky and Vega-Garcia (2016). The difference in this paper is the use of a dataset on 92 countries and 146 sovereign defaults between 1975 and 2014.

The paper is structured as follows. Section 2 covers the data used in the paper and defines idiosyncratic and clustered defaults. Section 3 discusses the estimation process of global and country-specific shocks. Section 4 builds the model of clustered sovereign default. Section 5 concludes. Section B in the Online Appendix performs an empirical test in the spirit of Kaminsky and Vega-Garcia (2016).

# 2 Clustered and Idiosyncratic Sovereign Defaults

## 2.1 Definition

The idea of clustered defaults follows the definition from Kaminsky and Vega-Garcia (2016). The aim is to capture those defaults as clustered defaults that occur during periods when a great number of countries default on their external debt obligations. The first step is to identify the years in which a large fraction of countries default; then the defaults that occur in those years are classified as clustered defaults.

Following Kaminsky and Vega-Garcia (2016), I constitute 5-year rolling windows for every year from 1975 to 2010.[5] For each window, I count the number of countries that default in the 5-year window.[6] If the total number of countries defaulting in a rolling window is more than one-third of all the countries that defaulted during 1975-2014, I call the 5-year rolling window a "window of clustered default" and all the default episodes that belong to the starting year of that window "clustered default episodes".[7] All the remaining defaults are "idiosyncratic defaults".

## 2.2 Categorizing Defaults as Clustered or Idiosyncratic

Given the definition of clustered and idiosyncratic defaults and a total of 92 countries that defaulted at least once in the period 1975-2014, any 5-year window with 31 or more countries defaulting is classified as a clustered default window. It is evident from Figure 1 that five 5-year rolling windows constitute clustered default windows: 1979-1983, 1980-1984, 1981-1985, 1982-1986, and 1983-1987. Thus, defaults in 1979, 1980, 1981, 1982, and 1983 become clustered defaults.

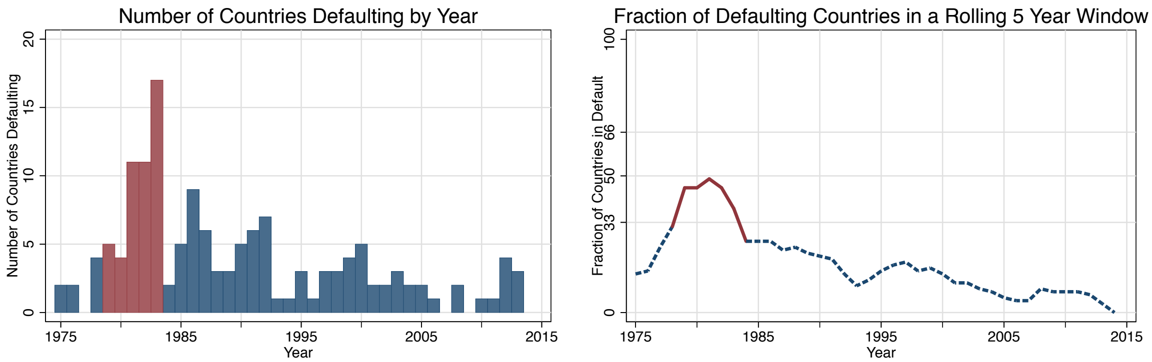
The first row of Table 1 shows that out of 146 defaults, 48 fall in the category of clustered defaults by this definition. Automatically, the remaining 98 become idiosyncratic defaults.

[5] Since the data on default goes from 1975 to 2014, the last rolling window containing 5 years is 2010.

[6] The paper focuses on the number of countries that default and not on the number of defaults. Peru, for example, defaulted in 1978 and 1980. Thus, in the rolling 5-year window starting in 1978, Peru is counted only once.

[7] The window 1983-1987 contains 35 different defaulters. Of the 35, 17 countries defaulted in 1983, 2 in 1984, 5 in 1985, 7 in 1986, and 4 in 1987. Only the defaults in the first year of the window–i.e., 1983–are considered part of a clustered default episode, and not the ones in the subsequent years of this 5-year rolling window.

Figure 1: Countries defaulting in a 5-year rolling window




Notes. The left panel shows the number of countries in default every year from 1975 to 2014. The right panel shows the fraction of countries defaulting in a 5-year rolling window starting every year. The maroon line highlights the period of clustered defaults, and the blue line highlights idiosyncratic defaults. Data source: Uribe and Schmitt-Grohé (2017) with 92 defaulting countries and 146 defaults.

Table 1: Default Classification: World Level and Region Level

| Region Name | No. of Defaulting Countries | Total Number of Defaults | Number of Clustered Defaults | Years of Default for Clustered Defaults |
|---|---|---|---|---|
| World | 92 | 146 | 48 | 1979-1983 |
| Africa & Middle East | 42 | 65 | 34 | 1979-1985 |
| Latin America & Caribbean | 28 | 51 | 22 | 1978-1983 |
| Europe & Central Asia | 15 | 19 | 8 | 1988-1991 |
| Rest of Asia & Pacific | 7 | 11 | 4 | 1981-1983,1993-1997 |

Alternatively, if one believes that the shocks, defaults, business cycles, etc. are more correlated across countries that are geographically near each other, then systemic and idiosyncratic defaults can also be defined at the regional level. To do so, I count the total number of countries defaulting in a particular region between 1975 and 2014 and then look for 5-year rolling windows in every region in which more than one-third of the countries belonging to the respective region default. These 5-year windows will be the clustered default windows for that region.

Table 1 shows that 34 of 65 defaults in ‘Africa and the Middle East’, 22 of 51 in ‘Latin America and the Caribbean’, 8 of 19 in ‘Europe and Central Asia’, and 4 of 11 in ‘Rest of Asia and the Pacific’ are classified as clustered defaults. Thus, with the regional classification, a total of 68 defaults fall into the category of clustered defaults, while the remaining 76 fall into the category of idiosyncratic defaults. Overall, depending on the classification, 33% or 45% of all defaults between 1975 and 2014 were clustered.

For the empirics that are present in the online appendix, I use the world-level classification of clustered and idiosyncratic defaults. All the results obtained remain robust to the regional classification as well. Thus, the results are independent of the classification method.

## 2.3 Data

This paper has two main sections: the estimation section and the model section. Online appendix contains a third section that performs a reduced-form empirical investigation. The estimation section uses the data on country-specific output growth and the world interest rate while the model section uses country-specific data for calibration of different parameters.

For the estimation of the parameters that drive the output process of different countries, I use output growth and world interest rate data as observables. Data on the real GDP per capita of all Latin American defaulting countries as well as some developed countries (that did not default in the sample period) is used.[8] I construct the data on the world real interest rate by using the 5-year constant maturity treasury rate and adding a market risk spread to it. This spread is constructed by using Moody's seasoned BAA-rated corporate bonds and Moody's seasoned AAA-rated corporate bonds. All three rates are retrieved from Federal Reserve Economic Data (FRED), Federal Reserve Bank of St. Louis. I further adjust the interest rate for inflation by using expectations for one-year-ahead annual average inflation measured by the GDP price index from the Survey of Professional Forecasters, Federal Reserve Bank of Philadelphia.

In the model section, I use the same GDP per capita data and the world real interest rate data. To calibrate the model, I use data on default frequency from Reinhart and Rogoff (2011). When the default data is unavailable, I use data from Uribe and Schmitt-Grohé (2017), which covers a shorter period. To obtain an estimate of debt that lenders cannot recover from borrowers, I use average haircut data from Cruces and Trebesch (2013). I use the data on net foreign assets of the borrowers as a fraction of GDP from the full version of Lane and Milesi-Ferretti (2007) to proxy for total external-debt to GDP ratio. The data on average years in default come from Reinhart and Rogoff (2011). If they are unavailable, I again use the data from Uribe and Schmitt-Grohé (2017).

# 3 The Estimation Process

I start by assuming a simple output function that is driven only by exogenous shocks and estimate the parameters governing such an output process. Subsequently, I go to the full version of the output function in which output is also affected by fluctuations in world interest rate. I postulate the time-varying processes for these components and then estimate the parameters governing these processes (and other coefficients of the output process) using the Bayesian method.

[8] The non defaulting countries that are used are: France, Italy, Japan, United Kingdom, and United States; the biggest countries at the start of the data period.

## 3.1 The Basic Version

The output process of every country is assumed to have transitory and permanent shocks, as in Aguiar and Gopinath (2006). The modification here is that each type of shocks has one country-specific component and one global component. Thus, the global shocks enter the output process through both—the transitory and the permanent component.

The output of a country $c$ at a time $t$ (omitted for convenience) is represented as:

$$Y^c = e^{z^c + \alpha_z^c z^w} X^c (X^w)^{\alpha_X^c}$$

where a superscript $c$ represents a country, and a superscript $w$ represents the world. Variables with superscript $c$, $z^c$ and $X^c$, are country-specific transitory and permanent components of output. Similarly, $z^w$ and $X^w$ are global transitory and permanent components of output. As the name suggests, global components are present in the output equation for all the countries but the way these global shocks affect different countries is different. In terms of natural logarithms, the equation can be written as:

$$y^c = z^c + \alpha_z^c z^w + \ln(X^c) + \alpha_X^c \ln(X^w)$$

Thus, the global components—$z^w$ and $\ln(X^w)$—enter with a multiplicative factor of $\alpha_z^c$ and $\alpha_X^c$, respectively.[9] Both the transitory components—$z^c$ and $z^w$—are assumed to follow an $AR(1)$ process with persistence $\rho_z^c$, $\rho_z^w$ and standard deviation $\sigma_z^c$, $\sigma_z^w$ respectively. The long-run mean of both the transitory components is assumed to be 0.

$$z_t^c = \rho_z^c z_{t-1}^c + \epsilon_{z,t}^c$$

$$z_t^w = \rho_z^w z_{t-1}^w + \epsilon_{z,t}^w$$

The growth rate of the permanent components is given as: $g_t^c = X_t^c / X_{t-1}^c$ and $g_t^w = X_t^w / X_{t-1}^w$. The logarithm of the growth rate in the permanent components, $\ln(g^c)$ and $\ln(g^w)$, follows AR(1) with persistence $\rho_g^c$, $\rho_g^w$; standard deviation $\sigma_g^c$, $\sigma_g^w$; and long-run means of $g_{ss}^c$ and $g_{ss}^w$.

$$\ln(g_t^c / g_{ss}^c) = \rho_g^c \ln(g_{t-1}^c / g_{ss}^c) + \epsilon_{g,t}^c$$

$$\ln(g_t^w / g_{ss}^w) = \rho_g^w \ln(g_{t-1}^w / g_{ss}^w) + \epsilon_{g,t}^w$$

[9] Intuitively, a global shock can be transmitted to a local economy, depending on the interaction of the country with the global economy via financial markets, or trade of goods and services, etc. If this interaction is negligible, then the value of both $\alpha$'s should be close to zero. In contrast, if the interaction is sizable, we must find that both $\alpha$'s have a nonzero value.

All the persistence levels are assumed to satisfy $|\rho| < 1$, and the shocks are assumed to be normally distributed, $\epsilon \sim N(0, \sigma^2)$.

**State-Space Form**: The output growth rate for the countries is treated as observable. Therefore, the measurement equation for country $c$ can be written in the state-space form with 3 global state variables—$z_t^w$, $z_{t-1}^w$, $\ln(g_t^w/g_{ss}^w)$—and 3 country-specific state variables—$z_t^c$, $z_{t-1}^c$, $\ln(g_t^c/g_{ss}^c)$.

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

The 3 global state variables—$z_t^w$, $z_{t-1}^w$, $\ln(g_t^w/g_{ss}^w)$—have an effect on the growth rate of output not only for country $c$ but also for all other countries. Since the state-space equation for all the countries will have these global state variables, the contemporaneous observable is an $(nc \times 1)$ (where $nc$ is the total number of countries) vector of output growth of all the individual countries. That is, to estimate the parameters related to these global state variables, the state-space equations of all the countries need to be stacked one over the other for every time $t$ and be treated as an observable at that time $t$. This combined state-space equation can be used to estimate the parameters of all the countries together. The measurement equation of this state-space form therefore appears as:

$$\Delta y_t = W + V \cdot \theta_t$$

The dimension of $\Delta y_t$ is $(nc \times 1)$. $W$ is also $(nc \times 1)$, and it is time invariant. V is $(nc \times (3 * nc + 3))$, and it is time invariant as well. The state variable vector, $\theta_t$, is $((3 * nc + 3)$ $\times 1)$.

Section A.1 in the online appendix reproduces the state-space form and gives formulation of all the vectors and matrices related to the state-space form.

**Estimation of Country-Specific and Global Parameters**: I include the output growth of all the defaulting countries from Latin America and the Caribbean that have an interrupted time series of GDP per capita as observable, thus obtaining a total of 19 countries. A concern with performing the estimation with only 19 of these countries is the possible bias in global output shocks because all the countries are defaulting countries. To avoid a possible bias, I add 5 developed countries—France, Japan, Italy, the United Kingdom, and the United States—that were the biggest countries at the start of the data period.[10]

With the data on 24 countries, I have 96 parameters related to country-specific shocks ($\rho_z^c$,

[10]For the empirical exercise, to have a greater set of defaulting countries, I run the estimation with a set of 49 defaulting and 10 non-defaulting countries. The resulting time series of global and country specific shocks remain very similar.

$\rho_g^c$, $\sigma_z^c$ and $\sigma_g^c$ for every $c$). For global shocks, I normalize the standard deviation of the world shocks to 1 without loss of generality because $\alpha_z^c$ and $\alpha_X^c$ can account for any scale effect arising from a different value of standard deviation.[11] Thus, the direction and the volatility in which global shocks effect a specific country will be governed by country-specific factors: $\alpha_z^c$, $\alpha_X^c$. This adds 48 more parameters. Finally, there are 2 more persistence parameters related to global shock processes. Together there are 146 parameters to estimate.

The average growth rate of countries, $\mu_g^c$, is observable in the data; thus I assume that the steady-state growth rate in the country-specific permanent component, $g_{ss}^c$, is the same as in the former. I also make the assumption that $g_{ss}^w = 1$. One final identification assumption remains: For Venezuela, I restrict $\alpha_z^{VEN} > 0$ and $\alpha_X^{VEN} > 0$.[12]

The paper uses the Bayesian method to estimate the parameters pertaining to the output process of all the countries. I use the output growth data on 24 countries from 1961 to 2014 and assume a uniform prior for all the parameters. Applying Kalman filter produces the likelihood which, using the Metropolis-Hastings algorithm, generates the approximate posterior distribution of all the parameters.

The prior distributions are shown in Table A1 while the posterior means for parameters are shown in Table A2. I use mean values from the posterior estimates of all the parameters and use the Kalman smoothing algorithm to get the latent shocks that different countries face. Figure A1 in the appendix shows the time series of the global transitory and permanent components of output (scaled for Argentina). The figure shows that around 1980s, Argentina faced two global shocks: a negative transitory shock that led to a 9% decline to detrended GDP in 4 years, and the negative permanent shock that led to a 7% decline in 3 years.

## 3.2 The Full Version

The full version of the estimation process is intended to capture the effect of changes in the world interest rate on the output of emerging countries. I start by hypothesizing an output function that is a modified form of the output function used in the basic version. This full version not only captures the effect of output shocks but also fluctuations in the world interest rate on the output of countries. The measurement equation hypothesized here can easily be microfounded in a general equilibrium framework. This is done in Section 4.1 when

[11] Both $z^w$ and $\ln(g^w)$ appear along with the $\alpha_z^c$ and $\alpha_X^c$ for every individual country. Writing the process of $z^w$ in $MA(\infty)$ rather than $AR(1)$ form, we obtain: $\alpha_z^c z^w = \alpha_z^c(\epsilon_{z,t}^w + \rho_z^c \epsilon_{z,t-1}^w + (\rho_z^c)^2 \epsilon_{z,t-2}^w + (\rho_z^c)^3 \epsilon_{z,t-3}^w + ...\infty) = \alpha_z^c \cdot \sigma_z^w (e_{z,t}^w + \rho_z^c e_{z,t-1}^w + (\rho_z^c)^2 e_{z,t-2}^w + (\rho_z^c)^3 e_{z,t-3}^w + ...\infty)$, where $e = \epsilon/\sigma$ is standard normal. This shows that we can observe only the product, $\alpha_z^c \cdot \sigma_z^w$, and hence it is safe to normalize $\sigma_w^z$ as well as $\sigma_w^g$ to 1.

[12] Let us say $z^w$ and $\ln(g^w)$, and the corresponding multiplicative parameter values, $\alpha_z^c$ and $\alpha_X^c$, generate a particular time series of global shocks to every country's output. If there are no restrictions on $\alpha$, a time series that is negative of $z^w$ and $\ln(g^w)$ along with the opposite signs of $\alpha_z^c$ and $\alpha_X^c$ will also generate the same contribution to every country's output.

I discuss the model of sovereign default. The microfoundations, therefore, provide structural interpretation of all the variables that are estimated here.

I assume that the output growth in the full version can be written as:

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

This equation of output growth reduces to the one in the basic version of estimation if $\psi^c = 1$. An additional source of change in output growth is the fluctuations world interest rate where a 1% increase in world interest rate reduces the borrower output by $(\psi^c - 1) \cdot \eta^c$ percent.

**State-Space Form**: With the output growth of the borrowing country as the observable, the measurement equation of country $c$ can be written in the state-space form using the 4 global state variables—$z_t^w$, $z_{t-1}^w$, $\ln(g_t^w/g_{ss}^w)$ , $\ln(g_{t-1}^w/g_{ss}^w)$—and 4 country-specific state variables—$z_t^c$, $z_{t-1}^c$, $\ln(g_t^c/g_{ss}^c)$, $\ln(g_{t-1}^c/g_{ss}^c)$:

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

Again, the presence of global shocks in the output of all the countries makes it necessary for the combined state-space form to contain all the countries stacked one over the other for every time period $t$. The measurement equation of this combined state-space form at time $t$ will appear as:

$$\Delta y_t = W_t + V \cdot \theta_t$$

The dimension of $\Delta y_t$ is $(nc \times 1)$. $W_t$ is not time invariant anymore, as it depends on changes in the world interest rate. The dimension of $W_t$ is also $(nc \times 1)$. $V$ is $(nc \times (4 * nc + 4))$ and is still time invariant, as before. The state variable $\theta_t$ is $((4 * nc + 4) \times 1)$.

Section A.2 in the online appendix reproduces the state-space form and gives formulation of all the vectors and matrices related to the state-space form.

**Estimation of Country-Specific and Global Parameters**: The dataset still consists of 19 defaulters from Latin America and the Caribbean plus 5 developed countries. Thus, with 24 countries, I still have the same 146 parameters to estimate as in the basic model. Additionally, in the full model, $\psi^c$ and $\eta^c$ must be estimated for all the countries, which brings the total number of parameters to 194.

The estimation procedure and the dataset remain the same as in the basic version. I retain the normalization assumptions, $\sigma_z^w = 1$, $\sigma_g^w = 1$; and $\alpha_z^{VEN} > 0$, $\alpha_g^{VEN} > 0$, for identification. The prior distributions are shown in Table A3 in the appendix.[13]

Table A4 reports the posterior means of the parameters. Table A4 shows that the values of $\psi^c$ are close to 2 rather than the prior mean of 2.5. Values of $\psi^c$ close to 2 suggest a Frisch elasticity value of 2.5 if we assume that the labor share is 0.7. This value of Frisch elasticity falls in line with other papers in the macroeconomics literature like Mendoza (1991). Values of $\eta^c$ vary from 0.07 to 0.90, showing that, for example, Bolivia needed 7% of wage bills in advance, whereas Costa Rica needed 90%.

Given the values of $\psi^c$ and $\eta^c$, the value of $-(\psi^c - 1) \cdot \eta^c$ represents the elasticity of output with respect to changes in interest rate. This value shows the change in output that a borrower experiences if the world interest rate changes by 1%. Figure A2 in the appendix shows the magnitude of this coefficient for different countries. Most of the countries lie around the -0.5 line, which means that a 1% increase in the world interest rate would cause the output of countries such as Argentina, Guatemala, Belize, and Uruguay to go down by almost 0.5%. Countries such as Brazil, Panama and Nicaragua show higher sensitivity in output with respect to changes in the borrowing rate, while countries such as Mexico, Chile and Peru show lower sensitivity.

Finally, similar to the basic version, I use the Kalman smoothing algorithm to back-out the latent global shocks and the country-specific shocks that different countries face. Figure A1 in the appendix shows the time series of the global transitory and permanent components of output (scaled for Argentina). As expected, the time-series looks somewhat different because some of the effect of transitory and permanent output shocks is captured by world interest rate fluctuations in the full version of the estimation.

# 4 The Model

This section builds a model incorporating global shocks into the transitory and permanent components of output as well as world interest rate shocks. The presence of three global shocks enables the model to assess the impact of these global shocks on default decision through the lens of a sovereign default model.

[13] For the two new parameters, $\psi$ and $\eta$, I look at the corresponding structural parameters in the model. In the model, $\psi = \omega/(\omega - \alpha_L)$ depends on the labor share as well as the Frisch elasticity of labor supply and I assume a uniform prior from 1.01 to 4. The expression of Frisch elasticity of labor supply from the model is $1/(\omega - 1)$. Given that many microeconometric estimates of Frisch elasticity lie between 0.3 and 0.5, while many macroeconomists use an estimate between 2 and 4, I assume $\omega$ to vary from 1.2 to 6. This allows the Frisch elasticity to vary from 0.2 to 5. Additionally, $\alpha_L$ is labor share, which is considered close to 0.7, and I assume it to vary from 0.3 to 0.9. These assumptions about these two parameters result $\psi$ to vary from 1.0526 to 4, which is a subset of the interval of the prior assumed on $\psi$. In the model, $\eta$ is a fraction of the wage bill needed in advance which leads to a uniform prior between 0.0001 and 0.9999 for $\eta$.

The model is built on a standard Eaton-Gersovitz framework. To elicit the role of output shocks (and not the interest rate shocks) on default decisions, the model first assumes a constant risk free rate, as is usually the case with the literature. Thus, neither the *debt-pricing channel* nor the *endogenous output channel* are in play.

Next, departing from the standard literature, the risk free rate is made stochastic so as to capture the importance of the fluctuations in world interest rate in causing defaults. These fluctuations influence default decisions through changes in the price of debt. Thus, this model assesses the contribution of world interest rate shocks, through the *debt-pricing channel* relative to the contribution of output shocks.

Finally, the full version of the model incorporates financial frictions in the form of working-capital constraints at the firm level. The presence of financial frictions enables fluctuations in the world interest rate to affect the default decision through endogenous changes in the output of the borrowing countries. Thus, the full version captures the contribution of world interest rate shocks, through the *debt-pricing channel* and the *endogenous output channel*, in causing defaults.

Despite the fact that the shocks are estimated independently of the model or of the default data, once fed into the model, they reproduce the clustered default of 1982, providing a joint validation of the model and the estimated driving forces. The model predicts that the global shocks to the transitory component of output are most important in leading countries to default in clusters. Interest rate shocks are also important and can lead multiple countries to default, but in contrast to common belief, the Volcker interest rate hike was not a determinant factor of the 1982 developing country debt crisis.

## 4.1 The Model Economy

This section outlines the model of sovereign default. The model is based on the standard Eaton-Gersovitz framework and is closely related to the work of Arellano (2008) and Aguiar and Gopinath (2006). The framework of most sovereign default models is built on the assumption of exogenous but stochastic output realizations. I begin with the same assumption in the baseline model but relax the assumption by including endogenous labor choice in the model, which determines the level of output in the full version. Since the full version encapsulates the basic version, I explain the full version of the model here and present equations related to the basic version in Section C.1 of the online appendix.

The agents involved in the full model are similar to those described in most papers in the literature—households, firms, a benevolent planner or a government, and a foreign lender. Households are not directly involved in borrowing from the rest of the world. The government issues debt and transfers the proceeds to households every period. Households make consumption and labor supply decision. Firms produce the final good by employing labor, but the amount of labor that can be demanded at a given wage is constrained by the working-capital requirement. To finance working-capital, firms obtain intraperiod loans, and they do not default on these loans. The government, however has no commitment device and is free to default if defaulting is optimal. Foreign lenders charge a rate from the government that is adjusted for default-risk. The model features incomplete markets due to the presence of single-period non-state-contingent debt that countries use to borrow.

**Households**: The household gains utility from consuming the final good and disutility from supplying labor. The utility function takes the form of GHH preferences from Greenwood et al. (1988) and is concave, strictly increasing and twice differentiable.

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

where $\gamma$ represents the Arrow-Pratt measure of relative risk aversion, $1/(\omega-1)$ is the Frisch elasticity of labor supply and $\Gamma$ is the scaling factor used to detrend the variables that grow over time. Since consumption grows over time but labor is stationary, the scaling factor is multiplied to the labor term.

Every period, households earn wage income along with the profits earned from the firms that they own. They cannot borrow from the rest of the world, but the government makes the borrowing decision on their behalf, and households receive transfers from the government. The household budget constraint is therefore given as:

$$C_t = w_t L_t^s + \Pi_t^f + T_t \tag{1}$$

Taking wages, profits and transfers as given, households maximize the present discounted value of their lifetime utility subject to the budget constraint. In every period $t$, they make consumption and labor supply decision. Since households are not directly involved in borrowing and holding debt, they make no intertemporal decisions. The Lagrangian of the household problem is given as:

$$\mathscr{L} = \sum_{t=0}^{\infty} \beta^t \left[ \frac{\left( C_t - \frac{\Gamma_{t-1}(L_t^s)^\omega}{\omega} \right)^{1-\gamma}}{1-\gamma} + \lambda_t \Gamma_{t-1}^{-\gamma} \left\{ w_t L_t^s + \Pi_t^f + T_t - C_t \right\} \right]$$

The first order conditions with respect to labor and consumption can be reduced to:

$$\Gamma_{t-1}(L_t^s)^{\omega-1} = w_t \tag{2}$$

which is the labor supply equation. The left side shows the marginal rate of substitution between leisure and consumption, while the right side is wages. Intuitively, if I forgo one unit of leisure, i.e., I supply one more unit of labor, I obtain a disutility of $\left[\left(C_t - \frac{\Gamma_{t-1}(L_t^s)^\omega}{\omega}\right)^{-\gamma}\Gamma_{t-1}(L_t^s)^{\omega-1}\right]$. In contrast, an additional unit of labor provides wages of $w_t$, which can increase consumption. This increase will lead to an increase in utility by $\left[w_t\left(C_t - \frac{\Gamma_{t-1}(L_t^s)^\omega}{\omega}\right)^{-\gamma}\right]$. At the margin, the household must be indifferent between supplying an additional unit of labor and not supplying it. Thus, equating the marginal utility from increased consumption with marginal disutility from increased labor, we obtain Equation 2.

The budget constraint, Equation 1, and the first order condition, Equation 2, constitute the household equilibrium conditions.

**Firms**: Firms are the final good producers that demand labor to produce output in every time period $t$. To hire labor and produce output, firms need working-capital in advance. The working-capital requirement forces firms to keep a fraction of labor wage payments in advance. To finance working-capital, firms obtain intraperiod loans from foreign lenders. Firms do not default on these intraperiod loans and therefore make a payment of $(1 + r_t^*)M_t$ at the end of period $t$ for a loan of $M_t$ that they received at the beginning of period $t$.

Assuming that the technology in country $c$ at time $t$ is $A_t^c = e^{z_t^c + \alpha_z^c z_t^w} X_t^c (X_t^w)^{\alpha_X^z}$ , the output of country $c$ at time $t$ can be written as:

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

where $L_t^{d,c}$ represents the labor demand of country $c$ at time $t$, and $\alpha_L^c$ is the labor share in output. Henceforth, I will omit the country superscript $c$ for convenience. Given the output, the profit of the firm at time $t$ is given as:

$$\Pi_t^f = (1 - \phi(z_t, z_t^w, g_t, g_t^w)) \cdot A_t (L_t^d)^{\alpha_L} - w_t L_t^d + M_t - (1 + r_t^*)M_t \tag{3}$$

where $\phi$ is a function of technology shocks and takes a value of 0 in normal times. When a country defaults, the country suffers a drop in TFP which is governed by the function $\phi$.

Following the literature, I also assume that there is no role for capital accumulation dynamics. This avoids the intertemporal dynamics of capital accumulation. Thus, firms, like households, have no intertemporal decisions to make. Firms maximize the present discounted value of lifetime profit subject to the period-by-period working-capital constraint.

$$\max \sum_{t=0}^{\infty} \beta^t \lambda_t \left[ (1-\phi_t(\cdot)) A_t (L_t^d)^{\alpha_L} - w_t L_t^d + M_t - (1+r_t^*) M_t \right]$$

subject to

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

The firm problem may be described as:

$$\mathscr{L} = \sum_{t=0}^{\infty} \beta^t \lambda_t \left[ (1-\phi_t(\cdot)) A_t (L_t^d)^{\alpha_L} - w_t L_t^d + M_t - (1+r_t^*) M_t + \xi_t \{ M_t - \eta w_t L_t^d \} \right]$$

The first order conditions with respect to $L_t^d$ and $M_t$ are given as:

$$\alpha_L (1-\phi_t(\cdot)) A_t (L_t^d)^{\alpha_L - 1} = (1+\eta \xi_t) w_t$$

$$r_t^* = \xi_t$$

Since the two first order conditions can be condensed into one, and given that the working-capital constraint always binds, the firm equilibrium conditions are given by the profit function and the following two equations:

$$M_t = \eta w_t L_t^d \tag{4}$$

$$\alpha_L (1-\phi_t(\cdot)) A_t (L_t^d)^{\alpha_L - 1} = (1+\eta r_t^*) w_t \tag{5}$$

Equation 5 captures the essence of the working-capital constraint. The marginal benefit from having an extra worker is still the marginal product of labor, but the marginal cost of having extra labor is higher with the working-capital constraint. The firm not only pays the wage, $w_t$, for an extra worker but also pays the interest on the intraperiod loan, $\eta r_t^* w_t$, that it spent in order to hire an extra worker.

Equations 2 and 5 can be solved to get equilibrium quantity of labor which can then be used to get output as a function of technology shocks and the world interest rate. The resulting equation can be used to calculate output growth. It can be shown that this equation is equivalent to the output growth equation of the estimation process. Thus, the model provides structural interpretation to the various estimated variables.

**Government**: The aim of a benevolent social planner or the government is to maximize the utility of households. Unlike households, the government has access to foreign credit markets and can borrow by issuing single-period non-state-contingent debt at a price $q_t$. The government transfers its borrowings to households as a lump-sum transfers. Additionally, the government repays any debt that is outstanding from the previous period.

Repayment of the outstanding debt is costly, especially when the price of new debt is low, as the repayment of old debt must come from either the output or new borrowings. The lower price of new debt causes the total value of new borrowing to be low. Thus, there is a possibility that the benefits of not repaying debt might be high even compared to the cost of not borrowing at all. In such cases, the government might find it optimal to default in some scenarios. When the government does default on its debt, it not only loses access to the credit markets but also suffers an additional output loss because productivity plunges in the country. From the next period on, the government can rejoin the market with a fixed probability $\lambda$ and a debt level of 0. With probability $(1 - \lambda)$, the government stays in the state where it has no access to credit.

Since there is a possibility that the government may find the short-term gain of not repaying higher than the benefit of having continued access to the financial markets and being able to smooth consumption, defaults occur in some states of the world. Depending on the probability of such defaults, the lender may not receive full repayment; thus, the lending is not risk-free. The lenders factor this possibility of default into the price of the debt $q_t$.

If the government chooses not to default and repays its debt, it can choose a new debt level $d_{t+1}$ to borrow. In this case, the amount borrowed, the net of repayments, is transferred by the government to the household.

$$T_t = q_t d_{t+1} - d_t \tag{6}$$

When the government decides to default, there is no additional borrowing, and the government transfer is 0.

The presence of debt makes government optimization an intertemporal problem. Due to the presence of this intertemporal element in the optimization problem, recursive dynamic programming is used in the literature to solve the government's optimization. The first step in solving the problem is to identify the state variables that affect the total value of flow utility received by households in a given period. The value function for a particular period depends on 4 set of state variables: (1) the output shocks in the period, (2) the world interest rate in the period, (3) the debt level with which the country enters the period, and (4) whether the country started the period in good or bad standing, $f_t = \{0, 1\}$.

A country starts a period in good standing, $f_t = 0$, if it has access to credit markets. In this case, the government can decide to repay the debt and have continued access in the next period, $f_{t+1} = 0$, or it can decide to default today. If the government chooses to default today, it will not have access to debt today, but it also will not have to repay the old debt. Additionally, the government can be redeemed with probability $\lambda$ tomorrow. If it is redeemed, the government starts the next period with 0 debt and will have access to financial markets, $f_{t+1} = 0$. If the government remains in the bad standing with probability $(1-\lambda)$, it will not have access to markets in the next period, $f_{t+1} = 1$.

The continuation payoff, i.e., the value function when the agent does not default and continues to repay the debt, is given as:

$$V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \max_{c_t, d_{t+1}} [u(c_t) + \beta E_{y,r}[V^G(d_{t+1}; z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*)] \quad (7)$$

subject to the equilibrium conditions of households and firms along with the government transfer condition. Here, $V^G$ represents the value function when the agent enters the period with good financial standing ($f = 0$).

If the agent enters a period in bad financial standing ($f_t = 1$) or decides to default ($F_t = 1$), it has 0 debt to repay and cannot borrow any new debt. Additionally, the agent faces an exogenous decrease in TFP, governed by a non-zero $\phi$, that reduces its output and hence consumption, $c_t^A$, even further. In the next period, the agent can re-enter the financial markets and be in good standing ($f_{t+1} = 0$) with probability $\lambda$. The value function in this case is given as:

$$\begin{aligned} V^B(z_t, z_t^w, X_t, X_t^w, r_t^*) = u(c_t^A) + \beta E_{y,r}\{\lambda V^G[(0; z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*) \\ + (1-\lambda) V^B(z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*)\} \end{aligned} \quad (8)$$

subject to the household and firm equilibrium conditions and no government transfer, $T_t = 0$.

If the government is in good standing at the start of a particular period, it has two options: continue to repay the debt or default. If it continues to repay the debt, its flow utility for that period will be $V^C$. If the government decides to default, its flow utility for that period will be $V^B$. The government chooses the option that gives it a higher flow utility.

$$V^G(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \max\{V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*), V^B(z_t, z_t^w, X_t, X_t^w, r_t^*)\} \quad (9)$$

The default rule is therefore given as:

$$F(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \begin{cases} 1 & \text{if } V^B(z_t, z_t^w, X_t, X_t^w, r_t^*) > V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

**Lender**: The last piece of the model is the lender side. I assume a large number of risk-neutral lenders.[14] Risk-free return is therefore adjusted for the probability of default to obtain a rate of return on debt.

$$(1+r_t)\times Prob_{y,r}(V^C(d_{t+1}; z_{t+1}, z^w_{t+1}, X_{t+1}, X^w_{t+1}, r^*_{t+1}) > V^B(z_{t+1}, z^w_{t+1}, X_{t+1}, X^w_{t+1}, r^*_{t+1})) = 1+r^*_t$$

Given the price of debt, $q_t = 1/(1+r_t)$, we have

$$q_t(d_{t+1}; z_t, z^w_t, X_t, X^w_t, r^*_t) = \frac{Prob_{y,r}(V^C_{t+1} > V^B_{t+1})}{1+r^*_t} \tag{11}$$

**Equilibrium**: In equilibrium, households, firms, government and the lender solve their respective optimization problem, and the market for consumption goods, labor, and debt clears (lenders choose a price level of debt so that they obtain zero expected profits). Formally:

**Definition 1.** A sequence of variables: $\{C_t, L_t, M_t, \Pi^f_t, d_{t+1}, F, T_t, w_t, q_t\}$ and value functions $\{V^C_t, V^B_t, V^G_t\}$ constitute a recursive equilibrium given the initial debt level, $d_t$, TFP processes: $\{z_t, z^w_t, g_t, g^w_t\}$ and the world real interest rate process, $\{r^*_t\}$, if:

1. Households choose $\{C, L^S_t\}$ to solve equations 1 and 2 given the wage rate $w_t$, government transfers $T_t$ and profits from firms $\Pi^f_t$.

2. Firms choose $\{\Pi^f_t, M_t, L^D_t\}$ to solve equations 3, 4 and 5 given wage rate $w_t$ and world real interest rate $r^*_t$.

3. Wage rate, $w_t$, is such that the labor market clears $L^S = L^D$ in cases of both default and continuation.

4. The government chooses $\{d_{t+1}, F_t, T_t\}$ to solve equations 6, 7, 8, 9 and 10 given the starting debt level, $d_t$, the world real interest rate process, $\{r^*_t\}$, and the solutions to household and firm optimization problems.

5. The equilibrium bond price, $q_t$, is as in equation 11 and is such that households, firms and the government solve their optimization problem and the risk-neutral international lenders obtain zero expected profits, thereby clearing the debt market.

[14] Assuming risk-averse lender makes little difference in results. This is because the *debt-pricing channel* is quantitatively not as important in leading countries to default. The *endogenous output channel*, on the other hand, is independent of the risk preference of the lender. This is because the risk preference does not enter the estimation equations.

### 4.1.1 Model Calibration

The calibration is performed separately for every version of the model: (1) baseline model with a constant world interest rate, (2) baseline model with stochastic world interest rate, and (3) full model with stochastic world interest rate.

The parameters in the model are related to the coefficient of relative risk aversion ($\gamma$), the world interest rate ($r^*$), the average yearly growth rate of the country ($\mu_g^c$), the probability of rejoining the financial markets after default ($\lambda$), and impatience ($\beta$). Additionally, for the basic version, I use the following loss function specification:[15]

$$\phi_t = \max\{0, a_1 + a_2 \cdot e^{z^c + \alpha_z^c z^w} g^c (g^w)^{\alpha_X^c}\}$$

which provides us with two more parameters ($a_1, a_2$). The full version of the model will have an output loss function which will also incorporate the effect of world interest rate on output of the country. Nonetheless, total output net of output loss in either version of the model reduces to: $y - y \cdot \max\{0, a_1 + a_2 \cdot y\}$.

Table 2: Calibrated Parameter Values

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

Notes: (1) Interest rate, $r^*$, is constant only in the first version of the baseline model

(2) The examples for the values of $\beta$, $a_1$, and $a_2$ correspond to the first version of the baseline model

The coefficient of relative risk aversion, $\gamma$, is assumed to be 2 following the existing literature: Mendoza (1991), Arellano (2008) etc. Since a unit of time in the model is a year, the world interest rate, $r^*$, is calibrated to the average value between 1960 to 2014. This provides $r^* = 3.67\%$. This risk free rate includes a risk premium that captures the spread between Moody's AAA-rated vs BAA-rated bonds. This is the rate at which firms make non-defaultable intra-period borrowing. Government pays the default premium on top of this interest rate. Thus, the fluctuations in the price of debt capture fluctuations in the fed-funds rate, fluctuations in risk-premium on non-defaultable corporate debt as well as an

[15]The output loss specification used in this paper is similar to the one used in Chatterjee and Eyigungor (2012) and also explained in Uribe and Schmitt-Grohé (2017) but I modify the specification to incorporate the feature from Aguiar et al. (2016) that loss function depends on individual shocks rather than total output.

endogenous risk premium accounting for default.

Steady state growth rate is different for different countries. Thus, to calibrate $\mu_g^c$, I take the average yearly growth rate from the data spanning 1960 to 2014 for all the countries. For example, $g_{Arg}^{ss} = \mu_{Arg}^{ss} = 1.025$ corresponds to the average yearly growth rate of Argentina from 1960 to 2014.

In order to calibrate the probability of re-entry into the financial markets after a default, $\lambda$, I use data from Reinhart and Rogoff (2011) and Uribe and Schmitt-Grohé (2017). Using an average of 6 years for the exclusion period of Argentina, for example, I estimate the probability of re-entry to be 0.1667 for Argentina.

Three parameters remain: the impatience parameter, $\beta$, and parameters governing the output loss function, $a_1$ and $a_2$. All three parameters are country-specific and are calibrated to match the average number of defaults in 100 years and the average debt-to-GDP ratio when the country is in good financial standing.

### 4.1.2 Grid Size

The model is solved using finite state-space method. Therefore, all the variables are detrended to make them stationary. Since the variables do not grow over time, the state-space needed for the iterations remains fixed. The state variables in the detrended form of the model are: $\{z_t^c, z_t^w, g_t^c, g_t^w\}$. In the full version of the model, $\{r_t^*\}$ is an additional state variable. The debt level, $\{d_t\}$, is an endogenous state variable.

Using 7 grid points for each of the output shocks takes the output grid size to 2,401 points in the basic version of the model. With stochastic interest in the full model, *endogenous output channel* is present and the grid points on the interest rate grid also contribute to changes in output. Thus, an additional of 10 grid points for the interest rate take output grid size to 24,010 points. The number of grid points for the debt level is taken as 100. Thus, the total number of grid points on both, output and debt, seem large enough to alleviate the concerns of Hatchondo et al. (2010) about the inefficiency of the discrete state-space technique.

The grid points are also used in the simulation exercise with the Kalman smoothed times series of state variables. Figure OA8 in the online appendix shows the detrended output time series vis-à-vis the simulated time series using the grid points. Since both the time series match well, it is clear that simulation on the grid does not add any additional noise. In a similar way, interest rate grid points also do well in tracking the actual movements in interest rates as shown in Figure OA9 of the online appendix.

### 4.1.3 Solution Algorithm

The presence of global shocks in the model makes the global output shocks and the interest rate shocks common across countries. Thus, the grid and the transition probability matrices of all the global shocks—2 global output shocks and the interest rate shocks—remain common across all the countries. The grid for the global output shocks are then scaled according to the loading factors, $\alpha_z^c$ and $\alpha_X^c$, for every country. Given these grids and transition probability matrices, the model is solved on country-by-country basis. The remaining algorithm for model solution remains standard.

An addition to the model, and hence the algorithm, is the introduction of firms and thus, labor. This addition doesn't add a big cost because equilibrium quantity of labor can be solved analytically. Therefore, labor can be calculated based on the 5 exogenous state variables—4 output shocks and interest rate. This gives a closed form solution for output based on the values of all 5 state variables.

Once the model is solved, the simulation exercise requires the time series of global and country-specific shocks. These time series are available for every country from the estimation in Section 3. Since these time series start in 1960, the initial debt in 1960 is assumed to be 0.[16] Given the endogenous state—debt level in 1960—and the exogenous states—four output shocks and the interest rate—every country makes the optimal debt and default decision from 1961 onward. The time series of optimal default decision for all the countries is then aggregated across the countries to obtain the plot for the percentage of countries defaulting in a rolling 5-year window for every year.

## 4.2 The Model Performance

Before exploring the results on clustered defaults, the performance of the model is evaluated based on matching a set of moments in the data with their counterparts from model predictions. These moments can be divided in two groups. First, a set of targeted moments. These are the moments that help in calibrating the parameters of the model and thus, are expected to have a good match. Second, a set of non-targeted moments—mean and standard deviation of spread; correlation between spread and output; correlation between trade balance to output ratio and spread—which will provide the real test for the performance of the model. I find that the model does well in matching most of the moments from the data. This shows that apart from matching the clustered default, that I show later, the model exhibits good

[16]The data on government debt or NFA to GDP ratio is mostly available from 1970 onward. If we use this data and change the first year of simulation from 1960 to 1970, the results remain the same. This is because the initial debt level does not have much of an impact 4 or 5 years after the start of the period. Countries leverage and deleverage quickly.

performance in multiple other dimensions too.

Figure A3 shows the targeted moments: average default frequency and average debt.[17] Since both the moments were targeted, the match between model-generated moments and the moments from the data is very good with the exception of Guyana. The data shows that Guyana, on average, held a negative net foreign asset amount equivalent to 144% of its output after accounting for 90% of the average haircut level. A high level of debt coupled with a high default rate (5 times per 100 years) is hard to match.

The next two figures, Figure A4 and Figure A5, exhibit non-targeted moments. Both the figures present moments related to country spread. The country-spread data comes from the J.P. Morgan EMBI database. The database contains the spreads for only 10 of the 19 countries included in the paper. Thus, the moments are matched only for these 10 countries.

Figure A4 displays the means and standard deviations of the spreads. The top panel shows the average spread in non-default periods. Most of the countries, except Chile, Mexico and Peru, are in the neighborhood of the 45-degree line. The standard deviation of spreads in non-default periods is matched much more closely. Other than Chile and Uruguay, other countries are in close proximity to the 45-degree line. The two remaining non-targeted moments pertain to the correlation of spreads. In accordance with the literature, Figure A5 shows that the model does well in explaining the counter-cyclicality of the country premium but not the correlation between trade balance to output ratio and spread.

## 4.3 The Model Results: Simulating the Defaults

For every country, the model provides the optimal debt and default decision for any given set of the state variables (four output shocks, the interest rate shock and an initial level of debt). Thus, feeding the model with Kalman smoothed time series of output shocks and the interest rate movements, the default decision for every country is obtained. Aggregating the time series of default decisions across all the countries produces the percentage of countries defaulting in a 5-year window for every year. Switching different shocks on and off and comparing the model predicted default cluster with the one obtained in data, the paper evaluates the relative importance of various shocks.

Three versions of the model are used in simulations: (1) the baseline model with constant world interest rate, (2) the baseline model with stochastic world interest rate, and (3) the full model with stochastic world interest rate. These three models enable three comparisons. (1) Which output shocks are mainly responsible for the clustered default episode of 1982? (2) What is the marginal impact of introducing the real interest rate fluctuations through

[17] Figure A3 and the subsequent figures compare moments from basic version of the model with data. Model performance remains the same for other version of the model.

the *debt-pricing channel*, on the default decision of countries? (3) What is the marginal impact of having a second channel, the *endogenous output channel*, on the default decisions? Following the three steps, I compare the relative importance of interest rate fluctuations and the output shocks in causing defaults.

### 4.3.1 Baseline Model with Constant World Interest Rate

In the baseline version of the model, the world interest rate is kept constant and the effect of four output shocks is studied. The results show that the global output shocks are important in generating clustered defaults. Moreover, it is global shock to transitory component of output that matters the most.

Figure 2: Aggregated default decisions of all countries: model with both country-specific shocks and global shocks vs data

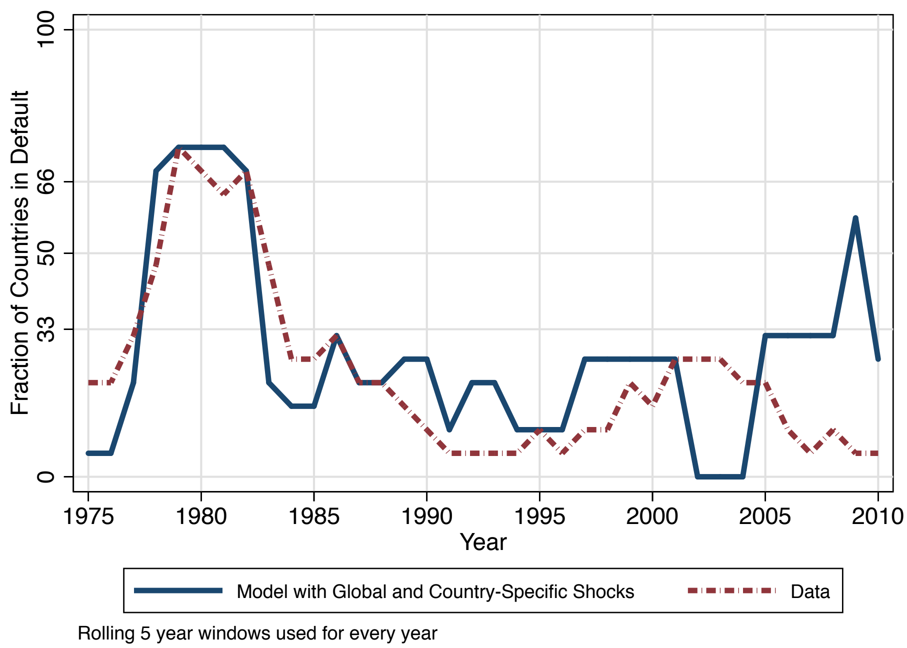



Figure 2 shows that the model predicts the clustered default of 1982 as observed in the data.[18] Though the model succeeds in generating the cluster, it doesn't disentangle the effect of various global and country-specific shocks. To this end, I first shut down all the global shocks (by replacing the global transitory component, $z_t^w$,with 0 and the growth rate

[18]The model also shows a decline and a small subsequent surge in defaults in the early 2000s (slightly preceding the actual defaults in the data). A concern might be the overprediction the defaults at the time of the great recession but this overprediction is not surprising given that the model does not incorporate a bailout mechanism or a lender of last resort, which might have helped multiple countries avoid default after the great recession.

in global permanent component, $g_t^w$,with 1). Next, I do the opposite: I shut down all the country-specific shocks (by replacing the country-specific transitory component, $z_t^c$,with 0 and the growth rate in country-specific permanent component, $g_t^c$, with the average growth rate of the country, $\mu_g^c$).

Figure 3: Aggregated default decisions of all countries: model with only country-specific shocks vs model with only global shocks vs data

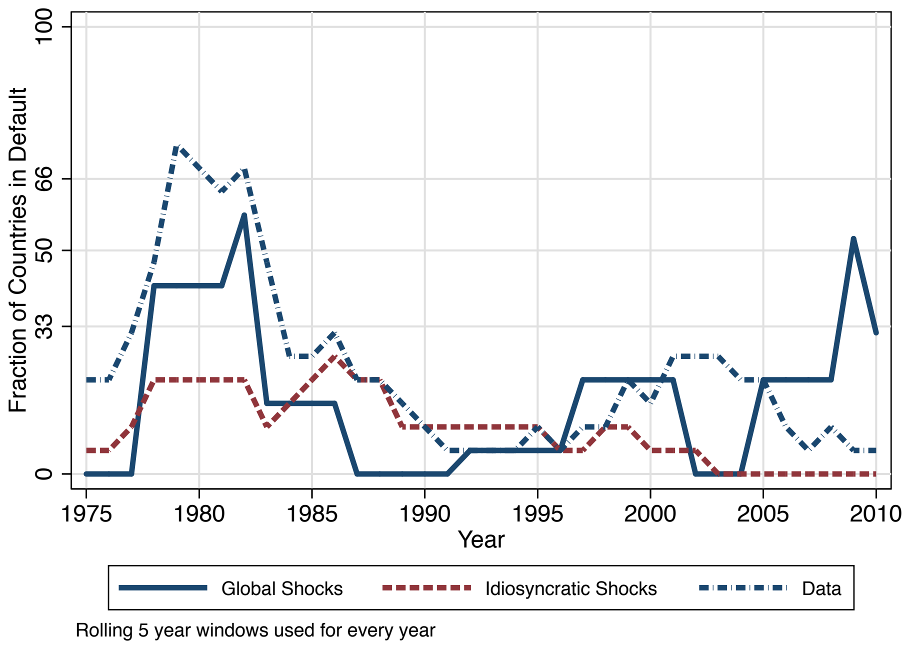
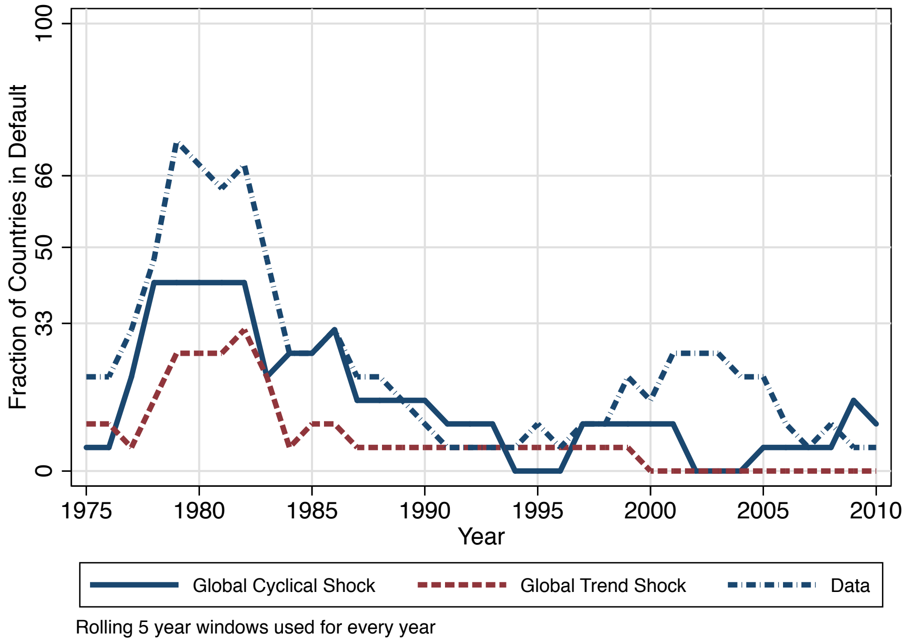



Figure 3 shows that with only country-specific shocks, the percentage of countries defaulting is very small and we do not observe the cluster. With only global shocks, in contrast, the default cluster reappears. For a better insight, the paper next looks at the types of global shocks—global transitory shock or global permanent shock—individually, in conjunction with country-specific shocks. In one exercise, both the country-specific shocks and global transitory shocks move the output of countries. In the other, both the country-specific shocks and the global permanent shocks move the output of countries. Figure 4 illustrates that global transitory shocks are relatively more important in replicating the cluster than global permanent shocks. Though the difference in the Figure from the two exercises is not as stark as in the previous case, the finding that temporary shocks are more important than permanent shocks is surprising and counterintuitive as it contradicts the finding of Aguiar and Gopinath (2006) for sovereign defaults in general. It therefore is interesting to understand the mechanism through which transitory shocks cause relatively more defaults.

Figure 4: Aggregated default decisions of all countries: model with country-specific shocks and transitory global shocks vs model with country-specific shocks and permanent global shocks vs data




## Role of Global Transitory Shocks in Causing Defaults

The three elements that amplify the importance of global transitory shocks in causing clustered defaults are: 1) Bigger fluctuations in global transitory shocks. 2) Convex cost of default. 3) High persistence of global transitory shocks.[19]

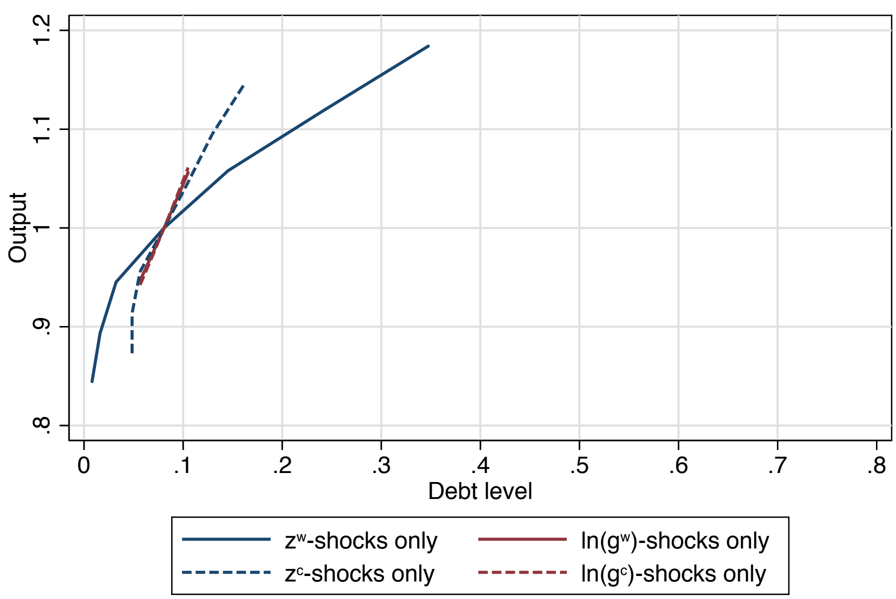
The importance of the first element is reflected in the joint estimation exercise which shows that 1 standard deviation shock to the global transitory component, $z_t^w$, changes the detrended GDP of Argentina by 6%. One standard deviation shock to the global permanent component, $\ln(g_t^w)$, changes the detrended GDP by almost 2%. One standard deviation shocks to the country-specific transitory, $z_t^c$, and permanent components, $\ln(g_t^c)$, changes the detrended GDP by 5% and 2%, respectively. Thus, the global transitory shocks has the greatest impact on the detrended GDP. Though the global transitory shocks are bigger in size, they are more important for default decisions even when compared against shocks of similar size. The reason behind it lies in the convex costs and the persistence of shocks.

Before illustrating the importance of the remaining elements that further strengthen the importance of global transitory shocks, observe the default and non-default regions shown in Figure 5. The y-axis shows the output of Argentina in four different scenarios (represented

[19]Each of these elements are explained by using Argentina, and the corresponding parameters, as an example but the results remain robust to using most of the other countries as well.

by four lines in the figure), while the x-axis represents the debt level, $d$, of the country. The solid navy line corresponds to the case in which the economy is hit by global transitory shocks, $z_t^w$, only. The y-axis, therefore, shows the output in the presence of $z^w$-shocks. The area to the right of this line is the default region while the area to the left is the non-default region, showing different combinations of $z^w$ and $d$ for which the country chooses not to default. According to the solid navy line, after a few consecutive positive shocks to the global transitory component, the country can accumulate much debt and still be in the non-default region. More specifically, with an output of 12% above the detrended mean in the presence of global transitory shocks, Argentina can accumulate a debt of up to 25% and still remain in the non-default region. At this point, if Argentina experiences 2 standard deviations of negative shock to the global transitory component, it will default unless it holds a debt of less than 8% of GDP. Thus, the accumulation of debt after positive $z^w$-shocks leads to a scenario in which Argentina must deleverage substantially when it experiences a negative $z^w$-shock. In some cases, therefore, Argentina might prefer to default than undergo a large deleveraging. The remaining three lines, corresponding to other shocks, are much steeper. Thus, under these shocks, the deleveraging required to stay in non-default region is not high. The countries, therefore, default less under other shocks than under $z^w$-shocks. The behavior illustrated in Figure 5 raises two questions: Why do (1) transitory and permanent shocks behave differently? (2) global and country-specific transitory shocks behave differently?

Figure 5: Default region: effect of output shocks on default decisions




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.

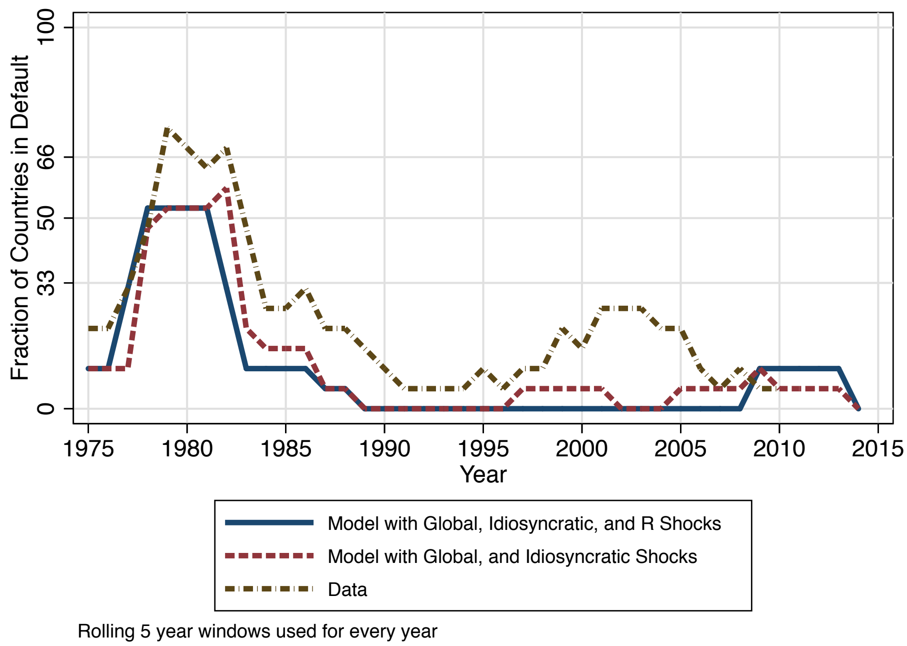
The answer to the first question lies in the assumption of convex default cost and it's interaction with transitory and permanent shocks. When the country faces a negative transitory shock, the detrended output decreases today but increases in the future as it starts recovering. Thus, with the convex cost of default, defaulting tomorrow entails a much higher output cost than defaulting today. Since both the lenders and the borrower know this, the lenders endogenize the situation, and the price of debt today decreases. This causes the debt level to decrease as well. Thus, for a given value of average debt, the debt distribution is very spread out in the case of transitory shocks. After a negative permanent shock, in contrast, the detrended output decreases today and decreases even more in the future, as it is a growth shock. With the convex cost of default, defaulting tomorrow entails a lower output cost than defaulting today. Since both the lenders and the borrower know this, the lenders endogenize this situation, and the price of debt today is relatively higher (even if it goes down). This causes the debt to decrease, but not by much. Thus, for a given value of average debt, the debt distribution is highly concentrated near the mean in the case of permanent shocks. A spread-out distribution of debt, resulting due to transitory shocks, causes countries to accumulate much debt after positive transitory shocks compared to similar levels of permanent shocks. Consequently, when countries face a negative shock after a series of positive shocks, the deleveraging required to stay in non-default status is much greater for transitory shocks than permanent shocks. Thus, countries prefer to default rather than undergo painful and huge deleveraging after negative transitory shocks.

The answer to the second question can be attributed to high persistence of global transitory shocks compared to country-specific transitory shocks. After highly persistent positive shocks, the agents expect output to remain high in near future with a large probability. This leads to a large amount of accumulated debt level compared to a case when shocks are not persistent. This leaves the country more vulnerable to default if a big negative shocks arrives as the required deleveraging to remain in non-default state will be high. The deleveraging required is also larger because negative shocks in the more persistent case will lead to a lower debt level, by a similar argument. Thus, the debt distribution is more spread out with highly persistent shocks, which makes the solid navy line much flatter in Figure 5.

### 4.3.2 Baseline Model with Stochastic World Interest Rate

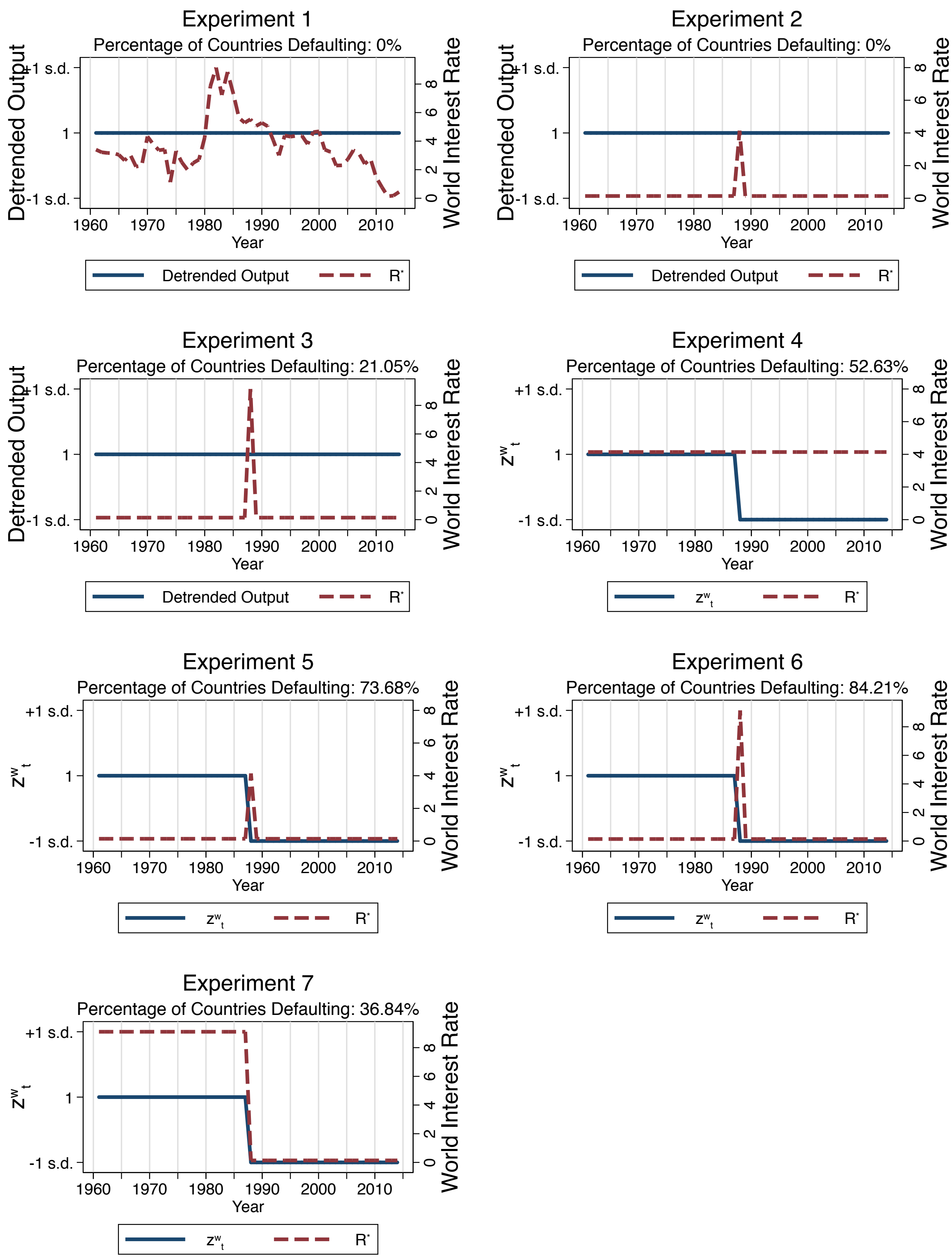
This section investigates the contribution of interest rate shocks, through the *debt-pricing channel*, in causing clustered defaults. This is done by re-calibrating the parameters using the baseline model with stochastic world interest rate. First, the optimal default choices of countries are simulated in the presence of all five shocks—four output shocks and one interest rate shock. Second, the same is done by shutting down the interest rate shock. The comparison is shown in Figure 6, and surprisingly, it shows that the presence of the stochastic interest rate did not cause the clustered default of 1982. Output shocks still explain all the defaults in the clustered default period. This result goes against the commonly held belief that the Volcker interest rate hike in 1980s was mainly responsible for the emerging country debt crisis of 1982.

Figure 6: Aggregated default decisions of all countries: model with world interest rate shocks vs model without world interest rate shocks vs data




Though, the result indicates a negligible role of the Volcker interest rate hike through the debt-pricing channel, it does not rule out the role of interest rate shocks, in general, in causing clustered defaults. This is because of the possibility of output shocks being so large that they ruled out any marginal effect of the interest rate increase during the clustered default of 1982. Therefore, there is a possibility that interest rate shocks can cause multiple countries to default when they arrive in conjunction with smaller output shocks. To capture this, I perform a series of experiments, and the results of those experiments are shown in Figure 7. For the first three experiments, I simulate the time series of all the countries using the detrended output as unity for the entire period from 1961 to 2014. Interest rate shock takes different forms. For the first experiment, the time series of the interest rate is exactly the same as that observed in the data. Experiment 1 in Figure 7, therefore, shows that without any fluctuations in output, the Volcker interest rate hike could not have forced any country to default. Thus, output shocks are important in causing defaults.

Figure 7: Percentage of countries defaulting when faced with different output and interest rate shocks




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

Next two experiments introduce interest rate shocks in the absence of any output shock. In Experiment 2, a single period interest rate increase of 4% is introduced in 1988.[20] In Experiment 3, a single period interest rate increase of 9% is introduced in 1988. It is evident that the 4% increase in the interest rate is still not enough to cause default even in a single country. An interest rate increase of 9% for one period causes 4 of 19 countries to default at the onset of the interest hike: Bolivia, Costa Rica, Guyana and Honduras. The remaining 15 countries prefer to deleverage. The common feature of the countries that default is that they hold high levels of debt, increasing the incentives to default. For example, compare two countries with debt levels of 10% and 30% of GDP. An increase in the risk-free rate of 8% causes the price of debt to decrease by almost 8%, plus any change in the probability of default. Given the same probability of default, this translates into a change in consumption of 0.8% and 2.4% for the two countries, respectively. Thus, if the interest rate increase is high enough, countries with high debt have an incentive to default, and they can default even in the absence of output shocks.

Experiments 1-3 show that output shocks are important but big interest rate shocks can cause defaults, even in the absence of output shocks. The next set of experiments, therefore, look at the effect of moderate increase in the interest rate accompanied by a decrease in the output. In the next four experiments, the global transitory component of output decreases by 1 standard deviation in 1988 and remains there forever. Given this change in the global transitory component of output, I perform different experiments with interest rate changes. Experiment 4 shows that even with constant interest, 10 of 19 countries default. Thus, output shocks have a much greater impact than interest rate shocks. If the interest rate increases by 4% for one period and this period coincides with the period of decrease in output, 4 more countries default. If the interest rate goes up by 9% for one period and this period coincides with the period of decrease in output, 6 more countries default, bringing the total number of defaulters to 16 of 19. Instead of increasing the interest rate, if it decreases by 9%, 3 fewer countries default, bringing the total number of defaulters to 7 of 19. Thus, Experiments 5-7 show that interest rate shocks can be an important driving force that can cause clustered defaults. Both increasing and decreasing the interest rate can be a vital policy measure, depending on the type and size of the output shocks as well as the debt level in countries. Nonetheless, for the clustered default of 1982, interest rate shocks did not matter much because the output shocks during the 1980s were so great that even if there had been no interest rate hike, the countries would still have defaulted. This finding also shows

[20] This increase is similar in magnitude to the Volcker shock but here the interest rate goes up from almost 0. Thus, there is a possibility that the countries might have issued more debt at near 0 rates which can also effect default decision.

that interest rate policy can be redundant in cases when the countries are experiencing huge output shocks.

### 4.3.3 Full Model with Stochastic World Interest Rate

The previous section included the fluctuations in interest rate but their effect on defaults came only from the *debt-pricing channel.* Though the conclusion highlighted that the Volcker interest rate hike was not responsible for causing the clustered default, it also showed that interest rate fluctuations can be an importance source of causing as well as avoiding clustered defaults. The marginal effect of interest rates was absent in 1982 mainly because of the presence of huge output declines that the countries faced. Therefore, it becomes essential to think if part of the output decline for countries was an endogenous response to an increased interest rate. To include the *endogenous output channel* on top of the *debt-pricing channel*, the paper re-calibrates the parameters in the full version of the model with the stochastic interest rate. The simulations, with and without fluctuations in interest rate, reconfirm the result that the Volcker interest rate hike was not the driving force behind the 1982 cluster.

Figure 8: Aggregated default decisions of all countries: full model with world interest rate shocks vs full model without world interest rate shocks vs data

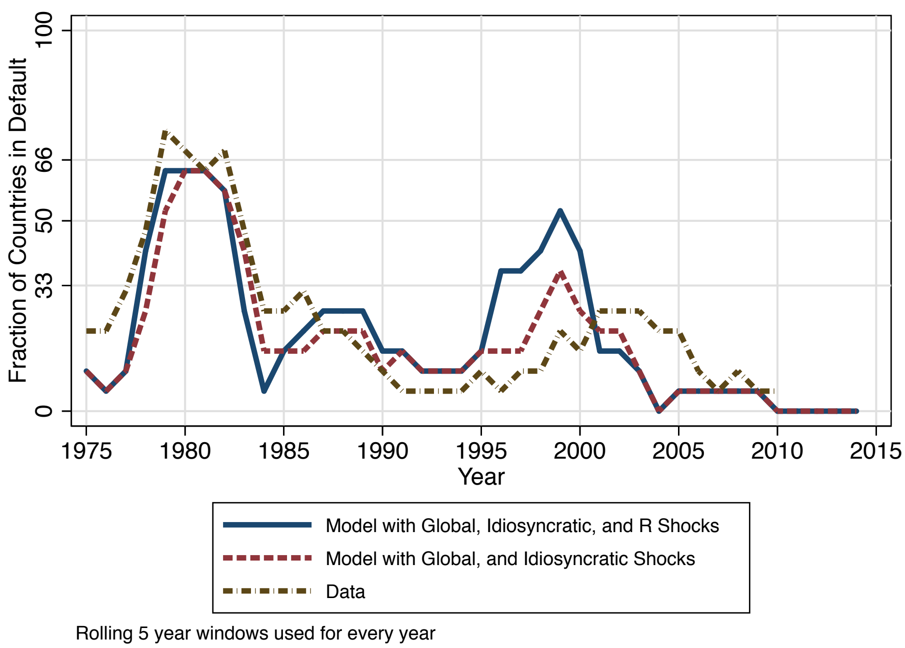
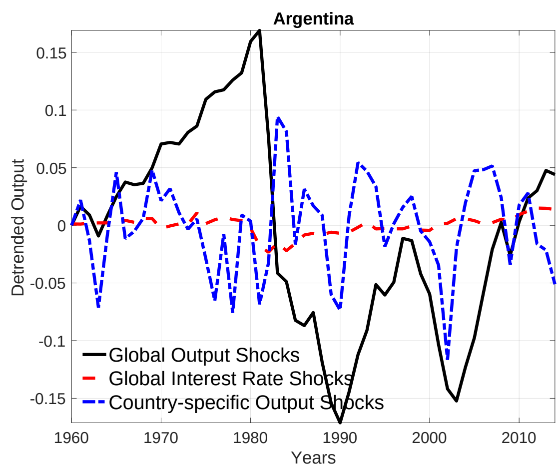



Figure 8 shows that interest rate shocks still have a negligible effect in causing the cluster of 1982.[21] As explained, the effect through the *debt-pricing channel* is quantitatively small

[21] One drawback seems to be a big increase in defaults in the model during 1999-2000. This big increase

and does not effect the budget constraint as much as a 1 standard deviation $z^w$-shock. The effect through *endogenous output channel* is, therefore, explored using the Kalman-smoothed time series of shocks from the estimation part. Figure 9, which is the result of estimation and hence independent of the model, shows that the Volcker interest rate hike had a small effect on output decline compared to global output shocks for Argentina. Figure OA10 to Figure OA18 in the online appendix show the same for remaining 18 countries to confirm a relatively small contribution of the Volcker interest rate hike in decreasing output of these countries.

Figure 9: Decomposition of shocks to detrended output of Argentina




# 5 Conclusion

In spite of clustered defaults being frequent and costly, a multicountry theoretical framework equipped to study the clustered defaults is still lacking. Therefore, this paper studies the clustered defaults in a multicountry setup. The essence of the framework of this paper is in: (1) disentangling the global shocks—global output shocks and world interest rate shocks—that different countries face, and (2) understanding the mechanism through which these global shocks influence defaults. The framework provides a perfect setting not only to quantify the importance of different shocks in causing clustered defaults, but also to study the role of the Volcker interest rate hike on the clustered default of 1982. Equipped with the framework, the paper uncovers two main findings. The first finding shows that global shock to the transitory component of output is the primary driver of clustered defaults. The

might be a result of output decline suffered by countries in the late 1990s but since the default side of the model is simplistic and does not include bailouts, the model predicts the defaults unobserved in the data. These bailouts of Brazil, and Argentina as well as Bolivia, Guyana, Honduras, and Nicaragua , among others, in late 1990s probably led to missing defaults in that period.

second finding shows, contrary to what is commonly believed, that the Volcker interest rate hike was not a decisive factor for the 1982 clustered default.

The first essential element of the framework—capturing global shocks—is crucial in order as it disentangles the effects five shocks: transitory and permanent country-specific shocks to output, transitory and permanent global shocks to output, and world interest rate. Thus, a framework like this can be used not only to figure out which countries are more susceptible to global shocks but also to predict how susceptible the world is to a clustered default. Furthermore, knowing more susceptible countries can make bailout policies more targeted in order to avoid the possibility of having clustered defaults.

The second essential element of the framework deals with the mechanism that drives defaults. A unique feature of the model developed here is that it captures the effect of changes in world interest rates on default decisions of borrowing countries through two channels. I call these channels the *debt pricing channel* and the *endogenous output channel*. The introduction of the two channels makes the default decisions more sensitive to world interest rate changes compared to the existing literature. Thus, a framework like this can also be used to study the interest rate policies of large economies and their spillover effects on the borrowing economies to assess future default probabilities.

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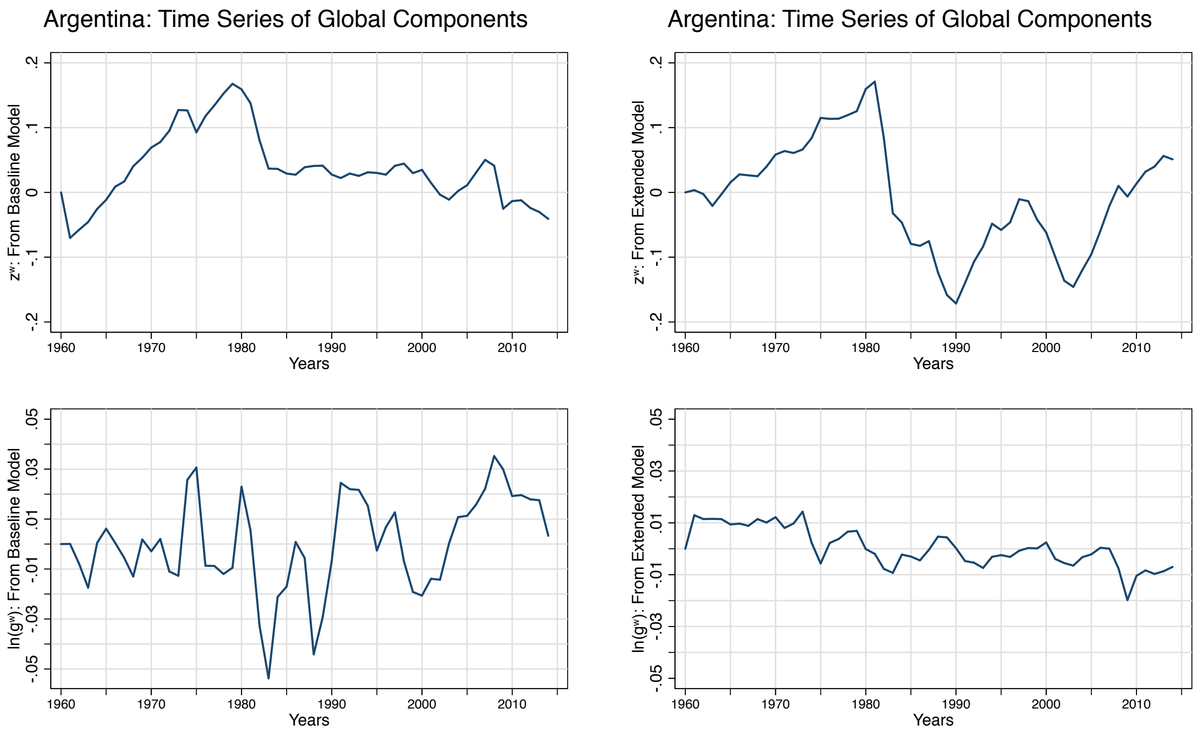
**Uribe, Martin and Vivian Z Yue**, "Country spreads and emerging countries: Who drives whom?," *Journal of international Economics*, 2006, *69* (1), 6–36. (pages 4.)

# Appendix

# A Figures and Tables

Figure A1: Time series of global output shocks from the basic and the full model




All four figures show different shocks scaled for Argentina from different models. The top panel shows $\alpha_z^{ARG} z_t^w$ from the basic model on the left and the same for the full model on the right. The bottom panel shows $\alpha_z^{ARG} z_t^w$ on the left for the basic model while $\psi^{ARG} \alpha_z^{ARG} z_t^w$ on the right for the full model.

Figure A2: Coefficient of $\Delta r^*$ from output growth equation: $-(\psi^c - 1) \cdot \eta^c$

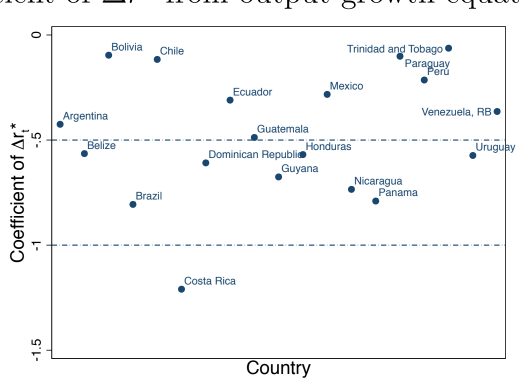
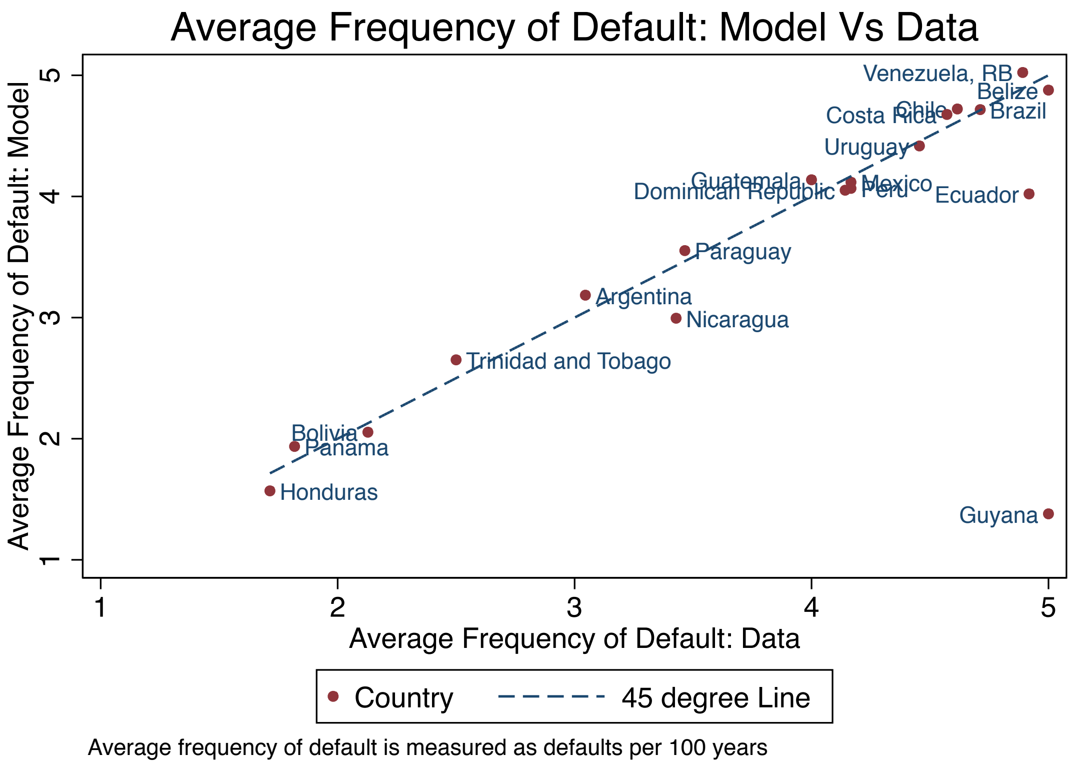


Figure A3: Targeted moments: default frequency and average debt in nondefault periods



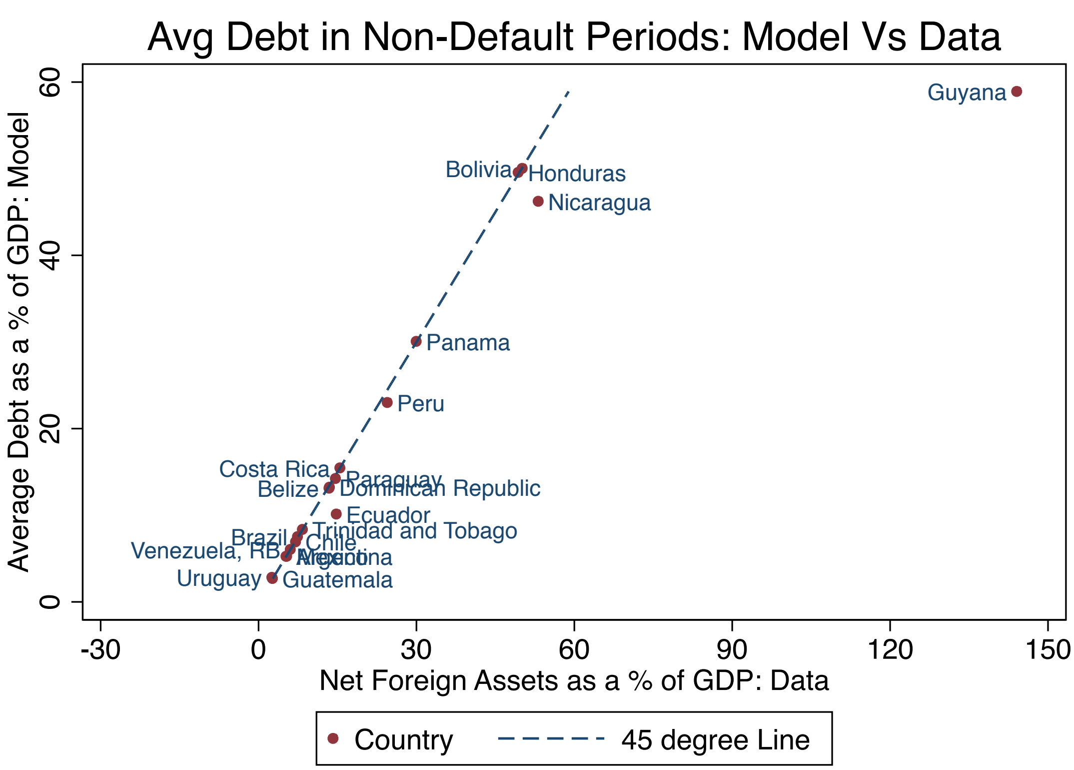
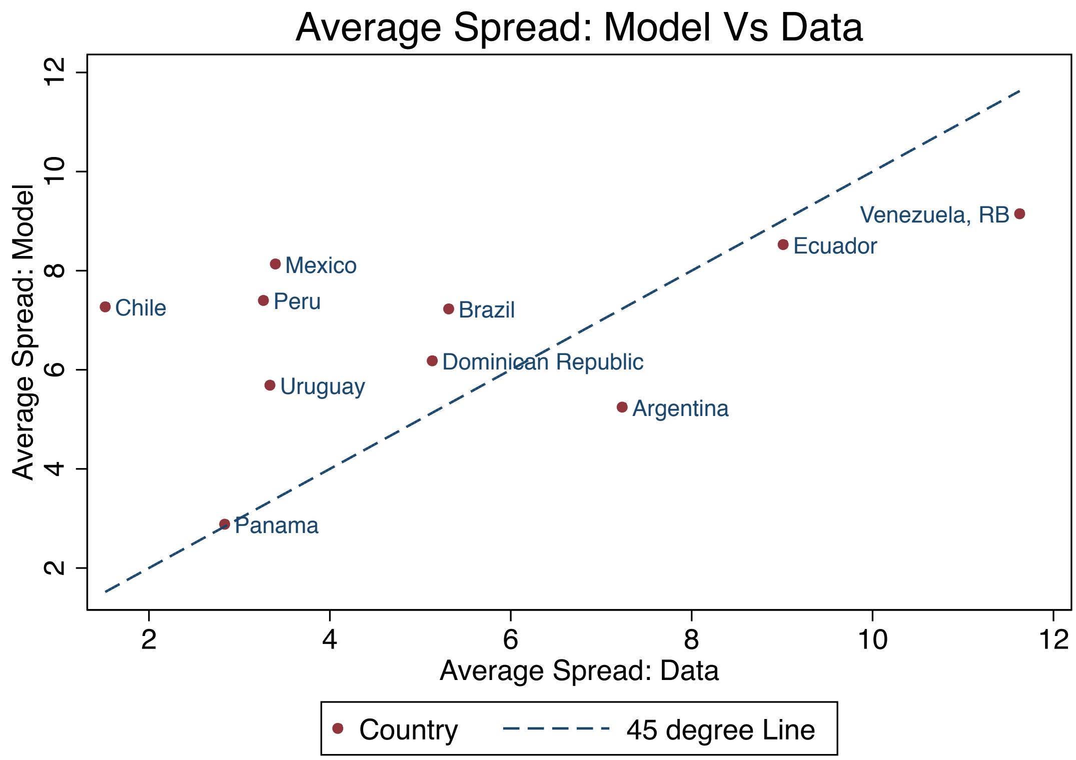



Figure A4: Nontargeted moments: first and second moments of spread



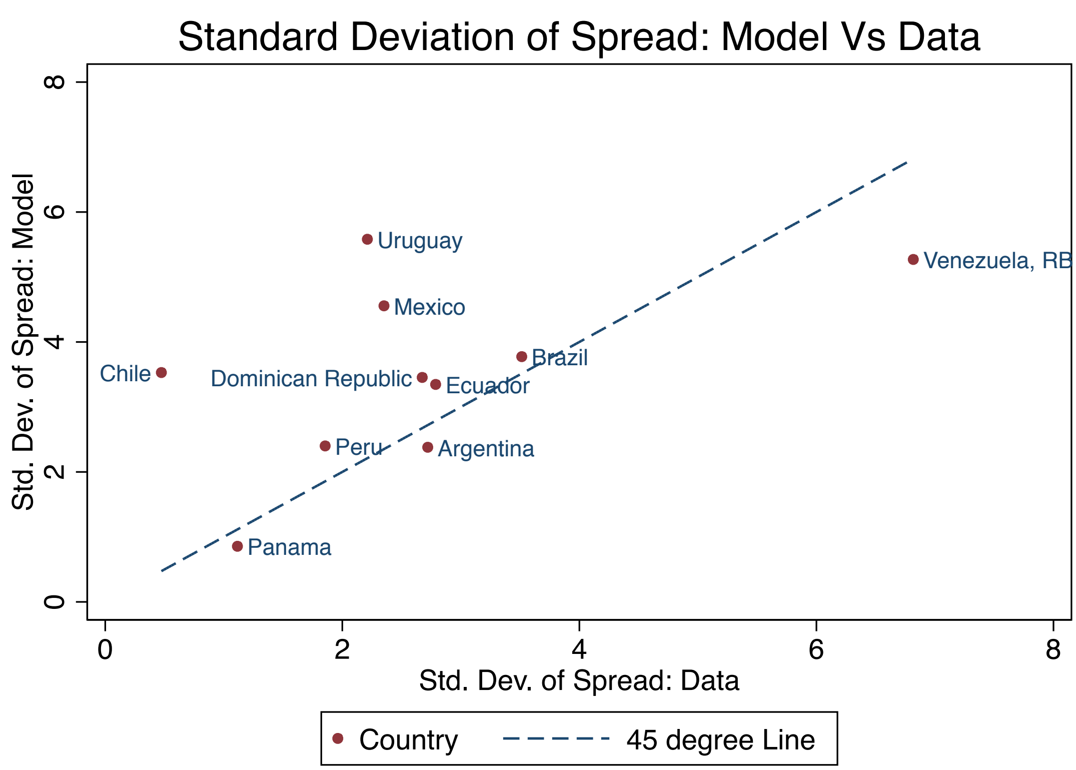
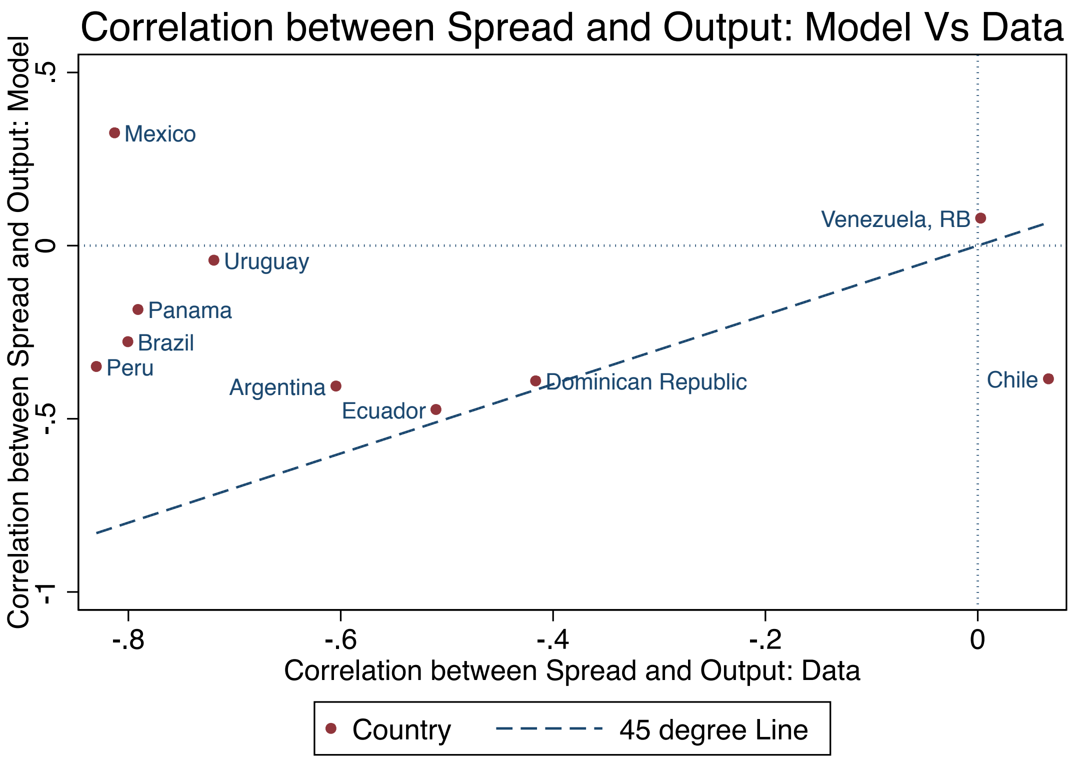



Figure A5: Nontargeted moments: correlations with spread



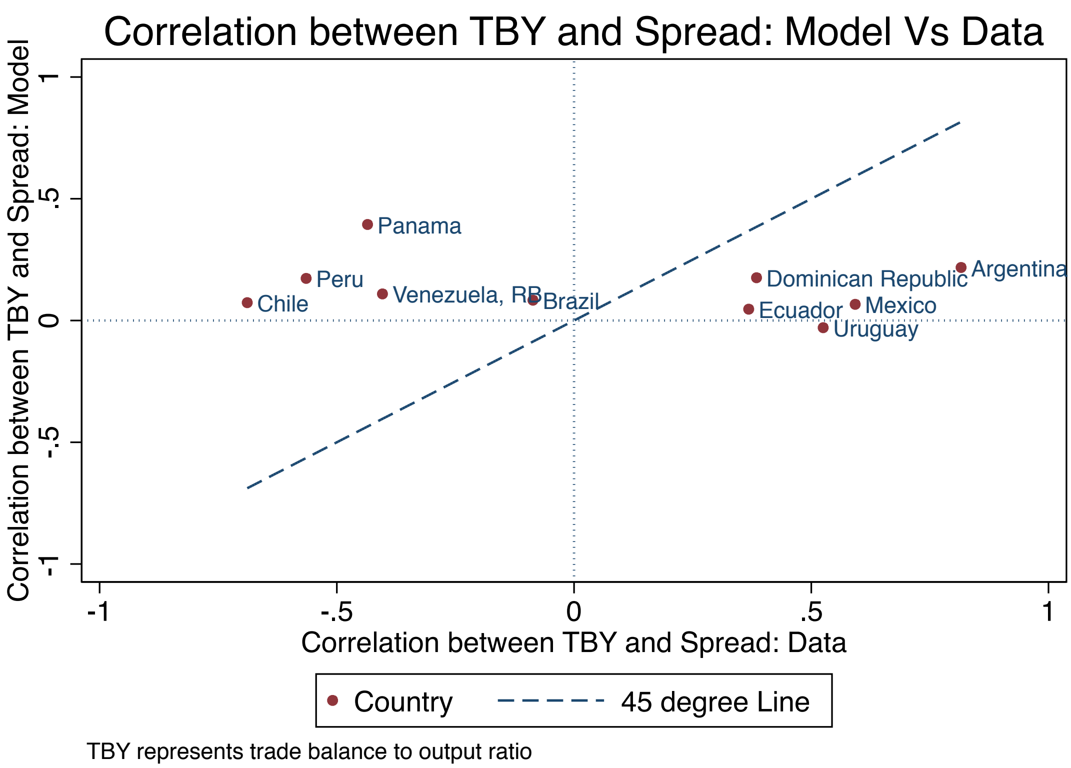



Table A1: Prior Distribution for Bayesian Estimation

| | Uniform Prior Distributions | |
|---|---|---|
| Parameter | Min | Max |
| $\rho_z^c$ | 0.0001 | 0.99 |
| $\rho_g^c$ | 0.0001 | 0.99 |
| $\sigma_z^c$ | 0.0001 | 0.9 |
| $\sigma_g^c$ | 0.0001 | 0.9 |
| $\rho_z^w$ | 0.0001 | 0.99 |
| $\rho_g^w$ | 0.0001 | 0.99 |
| $\alpha_z^{VEN}$ | 0.0001 | 2 |
| $\alpha_X^{VEN}$ | 0.0001 | 2 |
| $\alpha_z^c$ | -2 | 2 |
| $\alpha_X^c$ | -2 | 2 |

$\sigma_z^w$ and $\sigma_g^w$ are normalized to 1

Table A2: Bayesian Estimation Results from Basic Model: Posterior means

| Country | Posterior (Means) | | | | | |
|---|---|---|---|---|---|---|
| | $\rho_z^c$ | $\rho_g^c$ | $\sigma_z^c$ | $\sigma_g^c$ | $\alpha_z^c$ | $\alpha_X^c$ |
| Argentina | 0.5751 | 0.2774 | 0.0370 | 0.0190 | 0.0190 | 0.0157 |
| Belize | 0.4532 | 0.5530 | 0.0094 | 0.0301 | 0.0058 | 0.0043 |
| Bolivia | 0.6336 | 0.3433 | 0.0176 | 0.0238 | 0.0052 | 0.0080 |
| Brazil | 0.2672 | 0.5619 | 0.0093 | 0.0248 | 0.0165 | 0.0045 |
| Chile | 0.6647 | 0.5342 | 0.0185 | 0.0305 | 0.0234 | 0.0048 |
| Costa Rica | 0.7120 | 0.2835 | 0.0158 | 0.0128 | 0.0190 | 0.0015 |
| Dominican Republic | 0.7517 | 0.3894 | 0.0397 | 0.0190 | 0.0146 | 0.0025 |
| Ecuador | 0.6620 | 0.4509 | 0.0125 | 0.0210 | 0.0064 | 0.0051 |
| Guatemala | 0.4669 | 0.6373 | 0.0069 | 0.0112 | 0.0121 | 0.0001 |
| Guyana | 0.6988 | 0.3202 | 0.0228 | 0.0277 | 0.0092 | 0.0229 |
| Honduras | 0.5827 | 0.3248 | 0.0130 | 0.0142 | 0.0174 | -0.0010 |
| Mexico | 0.3328 | 0.3815 | 0.0094 | 0.0251 | 0.0176 | 0.0041 |
| Nicaragua | 0.6416 | 0.4959 | 0.0268 | 0.0485 | 0.0026 | 0.0106 |
| Panama | 0.7705 | 0.4015 | 0.0118 | 0.0313 | 0.0085 | 0.0152 |
| Paraguay | 0.5821 | 0.7096 | 0.0184 | 0.0194 | 0.0173 | 0.0070 |
| Peru | 0.8125 | 0.4263 | 0.0126 | 0.0329 | 0.0129 | 0.0214 |
| Trinidad and Tobago | 0.6563 | 0.6455 | 0.0140 | 0.0322 | 0.0113 | 0.0024 |
| Uruguay | 0.5996 | 0.4348 | 0.0096 | 0.0255 | 0.0151 | 0.0186 |
| Venezuela, RB | 0.6204 | 0.3278 | 0.0333 | 0.0211 | 0.0227 | 0.0074 |

Posteriors are a result of Markov chain of 1 million draws

Posterior means for $\rho_z^w$ and $\rho_g^w$ are 0.9414 and 0.5038 respectively

Table A3: Prior Distribution for Bayesian Estimation: Full Model

| | Uniform Prior Distributions | |
|---|---|---|
| Parameter | Min | Max |
| $\rho_z^c$ | 0.0001 | 0.99 |
| $\rho_g^c$ | 0.0001 | 0.99 |
| $\sigma_z^c$ | 0.0001 | 0.9 |
| $\sigma_g^c$ | 0.0001 | 0.9 |
| $\rho_z^w$ | 0.0001 | 0.99 |
| $\rho_g^w$ | 0.0001 | 0.99 |
| $\psi^c$ | 1.01 | 4 |
| $\eta^c$ | 0.0001 | 0.9999 |
| $\alpha_z^{VEN}$ | 0.0001 | 2 |
| $\alpha_X^{VEN}$ | 0.0001 | 2 |
| $\alpha_z^c$ | -2 | 2 |
| $\alpha_X^c$ | -2 | 2 |

$\sigma_z^w$ and $\sigma_g^w$ are normalized to 1

Table A4: Bayesian Estimation Results from Full Model: Posterior means

| Country | Posterior (Means) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $\rho_z^c$ | $\rho_g^c$ | $\sigma_z^c$ | $\sigma_g^c$ | $\psi^c$ | $\eta^c$ | $\alpha_z^c$ | $\alpha_X^c$ |
| 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 |

Posteriors are a result of Markov chain of 2 million draws

Posterior means for $\sigma_z^w$ and $\sigma_g^w$ are 0.8897 and 0.7555 respectively

# Online Appendix

## A Estimation Equations

### A.1 State-Space Form: The Basic Version

**Measurement Equation**

$$\Delta y_t = W + V \cdot \theta_t$$

where,

$$\Delta y_t = \left[\Delta y_t^1, \cdot, \Delta y_t^c, \cdot, \Delta y_t^{nc}\right]^{\mathrm{T}}$$

$$W = \left[\ln(g_{ss}^1) + \alpha_X^1 \ln(g_{ss}^w), \cdot, \ln(g_{ss}^c) + \alpha_X^c \ln(g_{ss}^w), \cdot, \ln(g_{ss}^{nc}) + \alpha_X^{nc} \ln(g_{ss}^w)\right]^{\mathrm{T}}$$

$$V = \begin{bmatrix} \alpha_z^1 & -\alpha_z^1 & \alpha_X^1 & 1 & -1 & 1 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \alpha_z^c & -\alpha_z^c & \alpha_X^c & 0 & 0 & 0 & \cdot & 1 & -1 & 1 & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \alpha_z^{nc} & -\alpha_z^{nc} & \alpha_X^{nc} & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 1 & -1 & 1 \end{bmatrix}$$

and

$$\theta_t = \Big[\ z_t^w \quad z_{t-1}^w \quad \ln(g_t^w/g_{ss}^w) \quad z_t^1 \quad z_{t-1}^1 \quad \ln(g_t^1/g_{ss}^1) \quad \cdot \quad z_t^c \quad z_{t-1}^c \quad \ln(g_t^c/g_{ss}^c) \quad \cdot$$
$$\cdot \quad z_t^{nc} \quad z_{t-1}^{nc} \quad \ln(g_t^{nc}/g_{ss}^{nc})\ \Big]^{\mathrm{T}}$$

The dimension of $\Delta y_t$ is $(nc \times 1)$. $W$ is also $(nc \times 1)$ and it is time invariant. V is $(nc \times (3 * nc + 3))$ and it is time invariant as well. The state variable vector, $\theta_t$, is $((3 * nc + 3) \times 1)$.

**Transition Equation**

The evolution of state vector (transition equation) can be represented as:

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

where $\lambda_t = \left[\epsilon_{z,t}^w, 0, \epsilon_{g,t}^w, \epsilon_{z,t}^1, 0, \epsilon_{g,t}^1, \cdot, \epsilon_{z,t}^c, 0, \epsilon_{g,t}^c, \cdot, \epsilon_{z,t}^{nc}, 0, \epsilon_{g,t}^{nc}\right]^{\mathrm{T}}$, $\epsilon_z^w \sim N(0, (\sigma_z^w)^2)$, $\epsilon_g^w \sim N(0, (\sigma_g^w)^2)$, $\epsilon_z^c \sim N(0, (\sigma_z^c)^2)$, $\epsilon_g^c \sim N(0, (\sigma_g^c)^2)$ and

$$
K = \begin{bmatrix}
\rho_z^w & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & \rho_g^w & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_z^1 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \rho_g^1 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & \rho_z^c & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & 1 & 0 & 0 & \cdot & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^c & \cdot & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & \rho_z^{nc} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^{nc}
\end{bmatrix}
$$

**Posteriors**

Given that all the prior distributions are assumed to be uniform, the posterior distributions show that they differ significantly from the prior distributions. Table OA1 in the appendix shows the means and standard deviations of all the estimated parameters. Among all the parameters related to a persistent level of shocks, the persistence of global shock to the transitory component of output is most precisely estimated. This precision is evident from the standard deviation of $\rho_z^w$ reported to be 0.04 in Table OA1. Some of the parameters related to the persistence level are not very precisely estimated. Table OA1 shows that the posterior distribution of the standard deviations is precisely estimated for all the countries. Though mean $\alpha$ values are positive for most of the countries, as shown in columns 7 and 8 of Table OA1, and the distributions of these $\alpha$ values are also precise, it is difficult to say whether the $\alpha$ values differ significantly from 0 for some of the countries.

## A.2 State-Space Form: The Full Version

The mechanism works through labor demand and the working-capital constraint. Through this channel, changes in real interest rate affect equilibrium quantity of labor. Since output is assumed to be produced using labor, output is also affected by interest rate changes.

In the full version, the output of country $c$ at given time $t$ (omitted from the equation for convenience) is given as:

$$Y^c = A^c(L^c)^{\alpha_L^c}$$

where $A^c = e^{z^c+\alpha_z^c z^w} X^c (X^w)^{\alpha_X^c}$ represents technology level.[22]

The technology, $A^c$, in full version is exactly the same as the output in basic version. Thus, the technology grows with shocks around a trend. The labor, as we know from our macro models as well as the data, is stationary. Even though labor is stationary, it fluctuates along with fluctuations in technology. Thus, labor here is assumed to be dependent on detrended level of technology which make it stationary but at the same time responsive to technology shocks.

Additionally, I assume that labor is inversely proportional to the world interest rate, which can occur because production is costly and firms in emerging markets tend to borrow in order to produce. When the interest rates rise, the borrowing cost increases, which causes a decrease in labor demand as well as the output. This relationship between labor and interest rate is microfounded at a later stage, when I discuss the model.

The two assumptions together give: $L_t^c = \kappa \tilde{A}_t^c/((1+r_t^*)^\eta)$, where $\kappa$ is a constant and $\tilde{A}$ is the detrended level of technology.[23] The output can, therefore, be rewritten as:

$$Y^c = e^{z^c+\alpha_z^c z^w} X^c (X^w)^{\alpha_X^c} (\kappa e^{z^c+\alpha_z^c z^w} g^c (g^w)^{\alpha_X^c}/(1+r^*))^{\alpha_L^c}$$

**Measurement Equation**

$$\Delta y_t = W_t + V \cdot \theta_t$$

where,

$$\Delta y_t = \left[\Delta y_t^1, \cdot, \Delta y_t^c, \cdot, \Delta y_t^{nc}\right]^{\mathrm{T}}$$

$$\begin{aligned} W_t = \big[&\ln(g_{ss}^1) + \alpha_X^1 \ln(g_{ss}^w) - (\psi^1 - 1)\eta^1 \Delta r_t^*, \cdot, \ln(g_{ss}^c) + \alpha_X^c \ln(g_{ss}^w) - (\psi^c - 1)\eta^c \Delta r_t^*, \cdot \\ &, \ln(g_{ss}^{nc}) + \alpha_X^{nc} \ln(g_{ss}^w) - (\psi^{nc} - 1)\eta^{nc} \Delta r_t^*\big]^{\mathrm{T}} \end{aligned}$$

$$\begin{aligned} \theta_t = \big[&z_t^w, z_{t-1}^w, \ln(g_t^w/g_{ss}^w), \ln(g_{t-1}^w/g_{ss}^w), z_t^1, z_{t-1}^1, \ln(g_t^1/g_{ss}^1), \ln(g_{t-1}^1/g_{ss}^1), \cdot, z_t^c, z_{t-1}^c, \\ &\ln(g_t^c/g_{ss}^c), \ln(g_{t-1}^c/g_{ss}^c), \cdot, z_t^{nc}, z_{t-1}^{nc}, \ln(g_t^{nc}/g_{ss}^{nc}), \ln(g_{t-1}^{nc}/g_{ss}^{nc})\big]^{\mathrm{T}} \end{aligned}$$

[22] I call $A_t^c$ as technology level and the corresponding shocks are shocks to technology but in reality, these shocks can be demand shocks or some other shocks. The purpose of the equation is to capture the shocks to output and in the full version, it is convenient to call the shocks as technology shocks.

[23] This functional form of labor is equivalent to $L_t^c = \kappa(\tilde{A}_t^c)^\mu/((1+r_t^*)^\eta)$ since it can be written as $L_t^c = (\kappa_1(\tilde{A}_t^c)/((1+r_t^*)^{\eta/\mu}))^\mu$. Once I substitue this in the output function, any scale effect of $\mu$ can be taken into account by a different value of $\alpha_L^c$.

and

$$V = \begin{bmatrix} \psi^1\alpha_z^1 & \cdot & \psi^c\alpha_z^c & \cdot & \psi^{nc}\alpha_z^{nc} \\ -\psi^1\alpha_z^1 & \cdot & -\psi^c\alpha_z^c & \cdot & -\psi^{nc}\alpha_z^{nc} \\ \psi^1\alpha_X^1 & \cdot & \psi^c\alpha_X^c & \cdot & \psi^{nc}\alpha_X^{nc} \\ -(\psi^1-1)\alpha_X^1 & \cdot & -(\psi^c-1)\alpha_X^c & \cdot & -(\psi^{nc}-1)\alpha_X^{nc} \\ \psi^1 & \cdot & 0 & \cdot & 0 \\ -\psi^1 & \cdot & 0 & \cdot & 0 \\ \psi^1 & \cdot & 0 & \cdot & 0 \\ -(\psi^1-1) & \cdot & 0 & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & \psi^c & \cdot & 0 \\ 0 & \cdot & -\psi^c & \cdot & 0 \\ 0 & \cdot & \psi^c & \cdot & 0 \\ 0 & \cdot & -(\psi^c-1) & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & 0 & \cdot & \psi^{nc} \\ 0 & \cdot & 0 & \cdot & -\psi^{nc} \\ 0 & \cdot & 0 & \cdot & \psi^{nc} \\ 0 & \cdot & 0 & \cdot & -(\psi^{nc}-1) \end{bmatrix}^T$$

The dimension of $\Delta y_t$ is $(nc \times 1)$ (where $nc$ is the total number of countries). $W_t$ is not time invariant now as it depends on changes in world interest rate. The dimension of $W_t$ is also $(nc \times 1)$. $V$ is $(nc \times (4 * nc + 4))$ and it is still time invariant as before. The state variable $\theta_t$ is $((4 * nc + 4) \times 1)$.

**Transition Equation**

The evolution of state vector (transition equation) is represented as:

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

where

$$K = \begin{bmatrix}
\rho_z^w & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_g^w & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_z^w & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \rho_g^w & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & \rho_z^w & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 1 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^w & 0 & \cdot & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 1 & 0 & \cdot & 0 & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & \rho_z^w & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & \rho_g^w & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 0 & 0 & \cdot & 0 & 0 & 1 & 0\cdot
\end{bmatrix}$$

and $\lambda_t = [\epsilon_{z,t}^w, 0, \epsilon_{g,t}^w, 0, \epsilon_{z,t}^1, 0, \epsilon_{g,t}^1, 0, \cdot, \epsilon_{z,t}^c, 0, \epsilon_{g,t}^c, 0, \cdot, \epsilon_{z,t}^{nc}, 0, \epsilon_{g,t}^{nc}, 0]^{\mathrm{T}}$, $\epsilon_z^w \sim N(0, (\sigma_z^w)^2)$, $\epsilon_g^w \sim N(0, (\sigma_g^w)^2)$, $\epsilon_z^c \sim N(0, (\sigma_z^c)^2)$ and $\epsilon_g^c \sim N(0, (\sigma_g^c)^2)$.

**Posteriors**

Table OA2 shows that the persistence parameters are much more precisely estimated in the full model than in the basic model. Small standard deviations for $\alpha$ values show that $\alpha$ is more precisely estimated than in the basic version, and the table also shows that $\alpha$ values are statistically different from 0 for many countries. Standard deviation values for $\psi^c$ and $\eta^c$ show that those values are also precisely estimated. The standard deviations are much smaller for $\psi^c$ than for $\eta^c$.

# B Empirical Analysis

The Kalman smoothed time series of shocks—country-specific shocks for every country and global shocks—obtained from the estimation part are used to perform some preliminary tests. Moreover, using a regression framework, I ask whether countries faced different shocks during clustered defaults vis-*à*-vis idiosyncratic defaults.

I start by examining the transitory and permanent shocks around idiosyncratic and clustered default episodes.[24] I then decompose these shocks into their global and country-specific components to investigate their individual contributions to idiosyncratic and clustered default events. In the next step, I perform a regression analysis to uncover whether global shocks play a substantial role in explaining clustered defaults. I begin with a logistic regression exercise and predict the probability of default events. I then test whether including global shocks as an explanatory variable increases the predicted probability of the default events.

In order to utilize the data on defaults by 92 countries and 146 default events from 1975 to 2014, I perform the Bayesian estimation on biggest possible subset of countries. I impose the condition that countries must have a continuous time series of output starting no later than 1960. This along with data availability of other regressors leaves 49 countries and 87 default episodes to analyze. To check robustness, and to work on an even larger set of countries, I also perform HP-filtering on the output data which requires output from 1975 and not 1960. This results in 58 countries and 99 defaults episodes to be analyzed.

## B.1 Data

In the empirical section, the paper uses the Kalman-smoothed time series of output shocks, which comes from the estimation section. The paper also uses some data on defaulting countries and some global variables to evaluate their explanatory power for the default decision of the country.

For the empirical analysis, to capture the output shocks, I use the Kalman-smoothed time series of country-specific and global components of the output process for every country. This time series comes directly from the estimation section, and it 49 defaulting countries and 87 defaults for the period of 1975-2014. I test the robustness of the results by using HP-filtered components of GDP, which provide a larger set of countries.[25] This expanded set of countries also covers the sovereign defaults between 1975 and 2014. The data on these default episodes come from Uribe and Schmitt-Grohé (2017). As summarized in Table OA3,

[24]The time series of all the four components of output that we use has a nice property. Since the only observable in the estimation is the output growth of countries, the estimation process is completely independent of the default data. Additionally, adding developed countries that have never defaulted to the estimation process ensures that the estimated global shocks are not contaminated by the presence of default events. Thus, adding these additional developed countries eliminates the reverse causality problem. A negative shock to some global component of output will not be a result of the output decline of a set of countries in response to default.

[25]The global shocks are proxied by using HP-filtered cycle and trend components of GDP for the US.

this dataset contains a set of 92 countries that chose to default 146 times between 1975 and 2014. The greatest share of these defaults comes from two regions: (1) Africa and the Middle East, where 42 countries led to 65 defaults, and (2) Latin America and the Caribbean, where 28 countries defaulted a total of 51 times. The dataset contains not only the years of default but also the number of years[26] subsequent to the default episode during which the countries remained in default status.[27] Additionally, the paper uses country-specific data on the total external debt to GDP ratio of countries. I use the data on net foreign assets of the borrowers as a fraction of GDP from the full version of Lane and Milesi-Ferretti (2007) to proxy for total external-debt to GDP ratio. Another proxy that I use is the data on government debt as a fraction of GDP from Abbas et al. (2010). Finally, spot crude oil price data, another global variable, are also retrieved from FRED. I adjust the oil price for inflation using consumer price index data for all urban consumers, also retrieved from FRED.

## B.2 Global and Country-specific Shocks around Default Episodes

I use aggregate transitory and permanent shocks, along with their global and country-specific components, around different default episodes. In this manner, I aim to distinguish whether a representative clustered default episode faced different shocks, in terms of nature and severity, than a representative idiosyncratic default episode. I use the median values of shocks across default episodes, clustered or idiosyncratic or both type, to obtain the representative default of respective category. The results remain robust to using mean values.

The basic version of the output process of a country, $c$, has already been given as:

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

[26]The data contain start and end dates of default. For example, Peru had one default with a start date of 1978 and an end date of 1978, and Argentina had a default with a start date of 1982 and an end date of 1993. I use the date of start of default as the default date and calculate the number of years that the country remained in default for every default episode. The number of years for the Peruvian default of 1978, for example, is calculated as 1, and the number of years for the Argentinean default of 1982 is calculated as 12.

[27]The definition of a country in default status is as follows, from Uribe and Schmitt-Grohé (2017), who in turn follow Standard and Poor's specification: *Standard and Poor's defines default as the failure to meet a principal or interest payment on the due date (or within a specified grace period) contained in the original terms of a debt issue (Beers and Chambers, 2006). This definition includes not only situations in which the sovereign simply refuses to pay interest or principal, but also situations in which it forces an exchange of old debt for new debt with less-favorable terms than the original issue or it converts debt into a different currency of less than equivalent face value. A country is considered to have emerged from default when it resumes payments of interest and principal including arrears. In cases of debt renegotiation and restructuring, the country is assumed to rejoin the markets when the rating agency concludes that no further near-term resolution of creditors' claims is likely.*

Using this output specification in a multicountry setting, the Bayesian estimation provided the parameters that govern global shock processes—$z^w$, $\ln(g^w)$—and country-specific shock processes—$z^c$, $\log(g^c/g^c_{ss})$. The estimation also provides the parameter through which global shocks affect the output of country $c$: $\alpha^c_z$ and $\alpha^c_X$. Thus, I construct the aggregate transitory and permanent shocks—$z^c + \alpha^c_z z^w$, $\ln(g^c/g^c_{ss}) + \alpha^c_X \ln(g^w)$—for the output of every country. I then decompose these aggregate transitory and permanent shocks into global and country-specific components to study their movements near the default episodes.

The first row of Figure OA5 shows median values for the aggregate transitory component of the GDP and growth in the aggregate permanent component of the GDP near default episodes. The three lines in each figure show median values across all default episodes, across clustered default episodes and across idiosyncratic default episodes. The figure suggests that during clustered defaults, even though the countries were doing much better 1 year before the crisis and 2 years before the crisis, they underwent a steep reduction in output as they approached the year of default. This drop is much more severe in the case of the transitory component of the GDP. For idiosyncratic defaults, half of the time, the countries were doing poorly even 2 years before the default, and they gradually did worse as they approached the default year. The next two rows decompose the permanent and transitory shocks into global and idiosyncratic components.

Figure OA5 further suggests that the large negative transitory shock that many borrowers observe during clustered default episodes is driven mainly by the global shock to the transitory component of output rather than by idiosyncratic shock. In contrast, the permanent shock, which is slightly more pronounced in the clustered default episodes, comes mainly from country-specific shocks.

Another point to note in Figure OA5 is that the decline in the transitory component of the GDP is much more severe than the actual magnitude of the transitory component, even in the year of default. Growth in the permanent component, on the other hand, is negatively affected for most of the defaulters.

The results for permanent and transitory shocks presented in Figure OA5 remain robust to HP-filtering the output series of individual countries to obtain the cycle and the trend growth. [28]

The last global variable I review is the world real interest rate. Since the period 1981-1983 is a period of higher-than-usual interest rates as well as a period of clustered defaults, Figure OA6 shows that the clustered defaults were accompanied by higher risk-free interest

[28] Since the HP filter cannot provide a global shock from country outputs, we use cyclical and trend shocks to world output as a proxy for global shock. For idiosyncratic shock, we use cyclical and trend components for every country individually.

rates, while idiosyncratic defaults occurred at a median risk free rate of approximately 4%.

## B.3 Empirical Specifications

A preliminary observation of country-specific and global shocks shows that countries involved in clustered defaults faced negative global transitory shocks to output as well as a hike in the world interest rate. In this subsection, I incorporate country-specific and global shocks into a regression framework to address the problem in a formal setting. I predict the probability of default for all the observed default events using two specifications: one with only country-specific explanatory variables and the other with both country-specific and global explanatory variables. Predicting the default probability of default events and comparing them across the two specifications informs us about the marginal role played by global variables in influencing sovereign defaults. The empirical exercise shows that clustered default episodes can be explained significantly better when the specification includes global variables. Idiosyncratic defaults, on the other hand, are not influenced by the presence of global variables in the specification, and the predicted probability of default remains the same across both specifications.

Since the canonical work on sovereign default attributes defaults to the high indebtedness of the borrower or to the negative output shock to the borrowing countries, it is natural to assume the same for idiosyncratic defaults. Clustered defaults, however, due to the nature of being concentrated around a small window, suggest a role of worsening global fundamentals. Thus, I test whether global shocks play a different role in clustered defaults than in idiosyncratic defaults. Since the default decision is a 0/1 variable, I use a logistic regression framework, similar to that of Kaminsky and Vega-Garcia (2016), to explain default decisions.

The logistic regression framework attributes the default status of a country to a set of factors including negative output shocks to countries. Negative output shocks to a borrowing country might keep the borrowing country in default status. This suggestion gives rise to a probable reverse causality concern. Not only low output in the country might lead the borrower to default and to remain in default status for a long time, but also, a default in the borrowing country might cause its output to remain low for the foreseeable future.[29] Thus, to get ride of reverse causality issue, it is reasonable to eliminate data for the borrower for a few years after the country's default. I remove data subsequent to a default for all years in which the borrower remains in default status and has difficulty accessing world financial

[29] The output can remain low after default for several reasons: reduced borrowing due to restricted access to financial markets, trade restrictions, increased unemployment due to postdefault devaluation policies , etc.

markets.[30]

The two regression specifications are as follows:

**Specification 1:**

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

**Specification 2:**

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

In both specifications, the default dummy, $D_{c,t}$, is the dependent variable. It takes a value of 1 in the year the country defaulted or is in default status and 0 otherwise. Since I remove data points in which the country is in default status after the country has defaulted because of reverse causality concerns, I have $D_{c,t} = 1$ only in the period of default. Both specifications include country fixed effects to account for unobserved country-specific differences. In terms of explanatory variables, both specifications have country-specific variables, $X_{c,t}$. Only the second specification has global variables, $X_{w,t}$, which is the difference between two specifications.

As most of the literature emphasizes, output shocks to borrowers are one of the most important criteria that explain sovereign defaults. To capture these output shocks, I use the same components of output that I obtained from the estimation exercise: country-specific and global shocks to transitory and permanent components of output.

In addition to the transitory and permanent components of country-specific output shocks, the next country-specific explanatory variable used here is the borrower's net foreign asset position as a percentage of GDP.[31] This ratio of net foreign assets to GDP measures the indebtedness of the borrower. For global explanatory variables, the first one that I use is real interest at the disposal of investors. I construct the data on the world real interest rates by using the rate on 5-year treasury constant maturity and adding a market risk spread to it. This spread is constructed by using Moody's seasoned BAA-rated corporate bonds and Moody's seasoned AAA-rated corporate bonds. I further adjust the interest rate for inflation by using expectations for one-year-ahead annual average inflation measured by the GDP price index. The next global variables are the transitory and permanent components of global shocks to output. Finally, I use inflation-adjusted oil prices to control for the investment surge hypothesis of defaults. The hypothesis, largely related to the Latin American defaults of 1982, suggests that a decrease in oil prices can cause defaults. The

[30] This data is available from Uribe and Schmitt-Grohé (2017).

[31] The series on net foreign assets as a percentage of GDP is available only to 2011; thus, the paper uses the series on government debt as a fraction of GDP for robustness checks. The series on government debt is available for recent years and is highly correlated with the series on net foreign assets as a fraction of GDP (correlation coefficient of -0.84).

mechanism starts with a rise in oil prices that causes a surge in investment by oil-rich countries in emerging economies. This leads to overindebtedness, which results in default when oil prices plummet and investments dry up. Since this channel is expected to work through the debt level of a country, which the specification has already controlled for, it is unclear whether controlling for oil prices will matter. Oil price fluctuations can also lead to global shocks in output through the supply channel. Thus, global output shocks, both transitory and permanent, that are already added as explanatory variables, might capture the effect of oil price fluctuations in themselves.Hence, it again becomes unclear whether controlling for oil prices matter.

Before I move on to the results and compare the two specifications, I check whether the regression coefficients concur with common beliefs in the literature about the effects of different explanatory variables on a default decision. First, negative output shocks lead to defaults. Second, high indebtedness or a low new foreign asset position as a percentage of GDP leads to default. Third, high world real interest rates lead investors to withdraw money from borrowing countries, making it harder for the borrower to obtain new loans and service existing debt. This difficulty eventually leads the borrower to default. Finally, plummeting oil prices cause investments to dry up in developing countries, which eventually results in default.

Returning to the specifications, the two regression specifications suggest two different hypotheses. The first specification suggests that a country's decision to default depends, for the most part, on the borrowing country itself. A priori, we can expect that adverse output shocks to the borrowing country and too much debt as a percentage of GDP for the borrowing country can lead the country into default. The second specification also takes global variables into account. These global variables are proxies for shocks to global fundamentals that affect all borrowers together. In this specification, therefore, we expect worsening global fundamentals to cause default. Thus, the specification means that the default decisions depend not only on borrower-specific variables but also global variables.

Each regression specification and the corresponding hypothesis seem to fit one category of defaults better than the other. The first specification, which attributes defaults only to country-specific explanatory variables, seems to fit idiosyncratic defaults better. Since these defaults occur in isolation compared to clustered defaults, in which default by a country is accompanied by defaults in multiple other countries, it is plausible that global shocks do not make a significant difference in leading countries to idiosyncratic defaults. For clustered default episodes, in contrast, global fundamentals usually face worsen at approximately the same time that countries decide to default. Thus, it seems appropriate to assume that clustered default episodes are a much better fit for the specification and the hypothesis that include global shocks as explanatory variables.

Since each specification and the corresponding hypothesis fit one category of default better than the other, we reformulate the hypotheses according to the default category. For idiosyncratic default episodes, we hypothesize that moving from specification 1 to specification 2 does not make a great difference in predicting idiosyncratic defaults, on average. In other words, adding global shocks to a specification that already has country-specific shocks does not make a significant difference in predicting idiosyncratic defaults compared to a specification with only country-specific shocks. For clustered defaults, we hypothesize that specification 2 significantly improves the predictive power of clustered defaults in comparison to specification 1.

To test the reformulated hypotheses, we perform regression for both the specifications. Once we obtain the regression coefficients, we predict the probability of default for each of the specification. We then examine the probability of default for the 87 default events in our sample. If the hypothesis is true, we expect the specification 1 to be better—or both specifications to be almost the same—for the idiosyncratic default events in our sample. Additionally, specification 2 must yield significantly higher default probabilities for the clustered default events in our sample. Mathematically,

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

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

## B.4 Results

As emphasized in the literature, the results confirm that the debt level in a country as a percentage of GDP and country-specific shocks to the output of the borrowing economy are both good predictors of default. Additionally, real interest rate shocks and global shocks to the transitory component of the GDP are also good predictors of default events. For idiosyncratic defaults, the results show that the predicted probability of default events conditional on default is almost the same for both specifications. For clustered defaults, however, the predicted probability of default conditional on default events is more than twice as high in specification 2 as in specification 1. Thus, global shocks make a great difference in leading countries to default in the case of clustered default events.

### B.4.1 Specification with Country-Specific Variables

Motivated by the set of stylized facts discussed in section B.2, I choose a 2-year change in the country-specific and global shocks to the transitory component of output as explanatory variables. The results are reported in Table OA8. I also show that the results are robust to choosing the level of country-specific and global shocks to the transitory component of output rather than 2-year changes. The results with levels instead of changes are reported in Table OA5 in the appendix. Table OA8 shows that although all three country-specific explanatory variables have the expected signs, only the debt level and the country-specific shocks to the permanent component of the output are statistically significant in predicting the default decision of the borrowing country.

Columns 2 and 4 of Table OA8 report the regression coefficients. Since the empirical specification uses logistic regression, the coefficient estimates have a lesser quantitative appeal beyond the signs. For this reason, I also report the marginal effects of changing an explanatory variable on the probability of default in columns 3 and 5 of Table OA8. For example, Column 3 shows that 1 standard deviation decrease in net foreign asset as a fraction of output increases the probability of default by 0.09. Similarly, 1 standard deviation decrease in the growth rate from its average increases the probability of default by 0.13. A decrease in the 2-year difference of the country-specific shock to the transitory component of output decreases the probability of default, but the magnitude of this change is not significantly different from 0.

### B.4.2 Specification with Country-specific and Global Variables

Column 4 of Table OA8 shows the results of specification 2. As in specification 1, the coefficients related to all the country-specific variables remain very similar in terms of magnitude and effect on the default decision of the country. Among global variables, only the real interest rate in the US and the 2-year change in the transitory component of real output have a significant effect on the probability of default.

Column 5 of Table OA8 shows that a 1 standard deviation increase in the US interest rate causes the default probability to increase by almost 0.10. This finding is in line with the belief that when credit becomes expensive, countries find it more difficult to roll over the existing debt, and they tend to default more often. It also supports the commonly held belief that increased risk-free rates have a substantial negative impact on default decisions. Negative global shock to the transitory component of the output also increases the default probability, as expected. A 1 standard deviation decrease in $\Delta z^w_{t,t-2}$ causes the default probability to increase by 0.06. The sign on the coefficient of global permanent growth shock to output is surprising, even if it is statistically indistinguishable from 0. This finding is also evident from the bottom-left panel of Figure OA5. Clearly, during and near the default episodes, the fluctuations in the global component of permanent growth are nonexistent compared to other output shocks. The coefficient on oil prices, though not statistically significant, confirms our expectation that an oil price decrease leads to decreased lending in emerging countries. The decreased lending causes difficulties in repayment of the interest and the principal on existing debt, which lead to more frequent defaults. For oil-exporting developing economies, a decrease in oil prices leads to a decrease in export revenues and output which can also lead to default.

Considering the changes in probability when we change an explanatory variable by 1 standard deviation, whether we can interpret the change in probability by directly multiplying the marginal effect and the standard deviation together might be a concern because of the shape of the logit function. It shows very small changes in probability with increases in the explanatory variable, both at low and high values of the explanatory variable. This concern is addressed in Figure OA3 in the appendix. This figure shows that our estimates in column 5 of Table OA8 are close estimates of the actual marginal changes.

With summary statistics of the explanatory variables in Table OA4 and the marginal effects of these explanatory variables in Figure OA3 in the appendix, we can return to examine the contributions of different global shocks in leading countries to clustered defaults vis-à-vis idiosyncratic defaults. As shown in Figure OA6, the median real interest rate during a default is higher by almost 2.5% for clustered default episodes than for for idiosyncratic defaults. This finding shows that, all other variables remaining the same, real interest rate alone can account for an increase in the probability of default of 0.12. Figure OA5 shows that a 2-year change in country-specific shock to the transitory component of output is -0.05 for clustered default episodes and close to 0 for idiosyncratic episodes. Thus, ceteris paribus, global shocks increase the probability of default by 0.15 during clustered default episodes compared to idiosyncratic default episodes. Both of these observations suggest a substantial role for global shocks when it comes to clustered defaults. The same global shocks, on the other hand, do not seem to play a major role in increasing the probability of default for idiosyncratic default episodes. In the next section, I test this hypothesis more formally.

#### B.4.3 Comparing Specifications: Clustered and Idiosyncratic Defaults

Given the predicted probability of default from both specifications, this paper compares the two specifications across clustered and idiosyncratic defaults. Figure OA7 shows the predicted probabilities for all the default events. The y-axis shows the predicted probabilities from specification 1, and the x-axis measures the same from specification 2. Additionally, there is a 45-degree line to determine whether the predicted probabilities are the same in both specifications or whether they are systematically higher in one specification than in the other. A default episode on the right side of the 45-degree line means that specification 2 beats specification 1 at predicting that particular default, while opposite means that specification 1 wins. The figure also attaches different markers to idiosyncratic and clustered defaults.

In an ideal scenario, since the predicted probabilities are conditional on the respective country defaulting in the data, all these predicted values should be close to 1. Figure OA7 shows that this is clearly not the case, as the predicted probabilities are substantially lower than 1. This finding signifies the inability of the explanatory variables to predict default, which is also evident from the low pseudo-$R^2$ values in Table OA8. Even though the values of the predicted probabilities are low, Figure OA7 shows that clustered defaults lie systemically towards the right of the 45-degree line, while idiosyncratic defaults events appear to be evenly distributed on both sides of the 45-degree line. This finding shows that both specifications do equally well in predicting idiosyncratic defaults; hence, global variables play virtually no role in predicting idiosyncratic defaults. In contrast, adding global variables increases the probability of default for most of the defaults that occurred during the 1982 cluster.

Table OA9 presents the results of Figure OA7 more formally. It shows that on average, the predicted probability of default for idiosyncratic defaults is 0.063 when we use specification 1. Including global variables along with country-specific variables to predict idiosyncratic defaults does not make much of a difference. The average predicted probability of default in specification 2 is 0.056. The predicted probabilities of clustered defaults differ greatly based on the specification used. On average, the predicted probability of clustered default is 0.115 in specification 1. This average is higher than the one for idiosyncratic defaults with either specification. This finding informs us that country-specific fundamentals were also poor during the clustered default episode of 1979-1983. With Specification 2, the average predicted probability of clustered default events jumps to 0.285. The difference of the mean t-statistic is negative and significant at 0.1%. An increase of close to 150% results just from adding global variables to the specification. Thus, even though country fundamentals were poor during the clustered default period, global fundamentals were much worse. This finding shows that including global variables in the specification makes a great difference in explaining the probability of default for clustered default episodes but makes no difference in explaining idiosyncratic default episodes. This signals a role of worsening global fundamentals in leading multiple countries to default during the clustered default period of 1979-1983.

The results in Figure OA7 and Table OA9 are robust to alternative specification in which we use the levels of country-specific and global shock to the transitory component of output instead of their 2-year changes, as shown in Figure OA4 and Table OA6 in the appendix.

The results are also robust to using government debt data instead of net foreign assets and to using HP-filtered data on the output of countries instead of the Kalman-smoothed data from the estimation exercise. However, these results are not attached in the appendix to avoid repetition.

The final issue of concern is the predicted probabilities of default conditional on non-default. First, since the default probabilities conditional on countries defaulting in a non-clustered period are already low, the default probabilities conditional on nondefault in the same period must be even lower. Second, in the clustered period, the probabilities of default conditional on countries defaulting is high. Conditional on countries not defaulting, the probability of default should not be high. It should not be the case that worsening global fundamentals predicted high probabilities of default even in cases when countries did not default.

Table OA10 shows that in nonclustered periods, the predicted probability of default conditional on no default is almost half of the probabilities conditional on default in the same period. This finding shows that on average, in relatively calmer times, the predicted probability of default for nondefault cases is lower in magnitude. To address the concern that poor global fundamentals in the clustered period might make the predicted default probabilities sky-high even conditional on nondefault cases, I focus on row 2 of Table OA10. The table shows that the predicted probabilities conditional on no default are very low compared to the predicted probabilities conditional on default during the clustered default period. Table OA7 in the appendix shows that both results are robust to change in the explanatory variables.

# C Model Equations

## C.1 Basic Version of The Model: Equations

### Households

In the basic version, the household gets utility only from consumption of the final good

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

where $\gamma$ represents the Arrow-Pratt measure of relative risk aversion

Every period households gets exogenous endowment in the form of output and transfer from the government. The household budget constraint is therefore given as:

$$C_t = Y_t + T_t \tag{12}$$

Since both output and transfers are given, households consumption level is also given and there is no optimization problem to solve for the household. The government decides the level of transfer in order to maximize household utility. The equations of the basic version of the model are kept in a similar as the full model. Alternatively, we can allow household to borrow from rest of the world and make debt, default and consumption decisions. In terms of the model equations and the solution, this alternative way is exactly the same as the current version of the of the baseline model.

**Government**

The aim of benevolent social planner or the government is to maximize the utility of the households. Therefore, the government's problem remains the same as in the full version of the model.

The amount borrowed, net of repayments, is again the transfer when government decides not to default:

$$T_t = q_t d_{t+1} - d_t \tag{13}$$

When the government decides to default, there is no additional borrowing and government transfer is 0.

The the continuation payoff i.e. value function when the agent doesn't default and continues to repay the debt, is given as:

$$V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \max_{c_t, d_{t+1}} [u(c_t) + \beta E_{y,r}[V^G(d_{t+1}; z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*)] \tag{14}$$

subject to the household budget constraint and the government transfer condition. Here $V^G$ represents the value function when the agent enters the period with good financial standing $(f = 0)$.

The continuation payoff in bad standing is given as:

$$\begin{aligned} V^B(z_t, z_t^w, X_t, X_t^w, r_t^*) = u(c_t^A) + \beta E_{y,r}\{\lambda V^G[(0; z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*) \\ + (1-\lambda) V^B(z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*)\} \end{aligned} \tag{15}$$

subject to the household budget constraint and that the transfer to households is now 0. In this case, the function $\phi$, that governs output loss in default, will also be non-zero. The function $\phi$ and thus, the output loss in default depends on individual technology shocks.

The continuation payoff when agent starts a period in good standing:

$$V^G(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \max\{V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*), V^B(z_t, z_t^w, X_t, X_t^w, r_t^*)\} \tag{16}$$

The default rule is therefore be given as:

$$F(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) = \begin{cases} 1 & \text{if } V^B(z_t, z_t^w, X_t, X_t^w, r_t^*) > V^C(d_t; z_t, z_t^w, X_t, X_t^w, r_t^*) \\ 0 & \text{otherwise} \end{cases} \tag{17}$$

**Lender**

The last piece of the model is to explain the lender side. I assume a large number of risk neutral lenders. Risk free return is therefore adjusted for the probability of default to get rate of return on debt.

$$(1+r_t)\times Prob_{y,r}(V^C(d_{t+1}; z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*) > V^B(z_{t+1}, z_{t+1}^w, X_{t+1}, X_{t+1}^w, r_{t+1}^*)) = 1+r_t^*$$

Given that the price of debt, $q_t = 1/(1+r_t)$, we have

$$q_t(d_{t+1}; z_t, z_t^w, X_t, X_t^w, r_t^*) = \frac{Prob_{y,r}(V_{t+1}^C > V_{t+1}^B)}{1+r_t^*} \tag{18}$$

## C.2 Full Model: Autarky and Borrowing Equilibria

**Autarkic Equilibrium**

If the government enters the period in autarky, it does not have an optimization problem to solve. It makes no transfer to households, $T_t = 0$, and it has no debt or default choice to make. Alternatively, if the government enters the period in good standing but finds that the utility from defaulting is higher than the utility from borrowing and repayment, then it defaults. Again, the government does not have any choice variables once it decides to default. The transfers are, by default, $T_t = 0$, and no debt choice is possible. Thus, in autarky, only firms and households will make equilibrium choices.

The first thing to note is that firms face an output cost of default during autarky. Thus, the output produced decreases depending on the state of the economy. Sine the output cost is convex in nature, the output loss in autarky will be higher when the economy is doing relatively better (relatively greater shocks to different components of the technology level in the economy). Firms' optimality conditions will therefore be given by:

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

which is the same condition that captures the effect of the working-capital constraint on the cost of hiring an additional worker. The profit for the firm will be:

$$\Pi_t^{f,Aut} = (1-\phi_t(\cdot)) \cdot A_t(L_t^{Aut})^{\alpha_L} - w_t^{Aut}L_t^{Aut} - \eta r_t^* w_t^{Aut}L_t^{Aut}$$

where $\phi_t(\cdot) = \phi(z_t, z_t^w, g_t, g_t^w)$ is a function of states.

Households solve their first order conditions and supply labor such that:

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

Solving household and firm first order conditions will give closed-form solutions to the equilibrium quantity of labor and wage level in autarky as a function of state variables and parameters. These values are then used to obtain the values of equilibrium output and profit that households receive. These profits through the household budget constraint provide the value of household consumption in autarky.

$$C_t^{Aut} = (1-\phi^{Aut}) \cdot A_t(L_t^{Aut})^{\alpha_L} - \eta r_t^* w_t^{Aut}L_t^{Aut}$$

**Equilibrium with borrowing**

Equilibrium with borrowing is the equilibrium in which the government is able to choose a debt level, $d_{t+1}$, in the current period. This can occur in two ways: is the government enters a period with good standing or if it enters the period in bad standing but is allowed to re-enter the market[32] and finds it optimal to continue with the repayment of debt in either case. In the former case, the government enters the period with a debt, $d_t$, to be repaid, while in the latter case, $d_t = 0$.

The first order conditions of the firm and the household provide us with a closed-form solution for the equilibrium quantity of labor:

$$L_t = \left(\frac{\alpha_L A_t}{\Gamma_{t-1}(1+\eta r_t^*)}\right)^{\frac{1}{\omega-\alpha_L}}$$

which can be used to obtain the equilibrium wage rate from the household first order condition. Given the value of the wage rate, equilibrium quantity of labor, and an initial debt

[32] An event that occurs with probability $\lambda$ after entering the period in bad standing.

level $d_t$, the government chooses a new debt level, $d_{t+1}$, to maximize its continuation utility

$$V^C(d_t; z_t, z_t^w, g_t, g_t^w, r_t^*) = \max_{C_t, d_{t+1}} \{u(C_t, L_t) + \beta E_y[V^G(d_{t+1}; z_{t+1}, z_{t+1}^w, g_{t+1}, g_{t+1}^w, r_{t+1}^*)]\}$$

subject to:

$$C_t = A_t L_t^{\alpha_L} - \eta r_t^* \Gamma_{t-1} L_t^{\omega} + q_t(d_{t+1}; z_t, z_t^w, X_t, X_t^w, r_t^*) \cdot d_{t+1} - d_t$$

$$L_t = \left( \frac{\alpha_L A_t}{\Gamma_{t-1}(1 + \eta r_t^*)} \right)^{\frac{1}{\omega - \alpha_L}}$$

$$q_t(d_{t+1}; z_t, z_t^w, X_t, X_t^w, r_t^*) = \frac{Prob_y(V_{t+1}^C > V_{t+1}^B)}{1 + r_t^*}$$

where $V_{t+1}^B$ is the value function in autarky which can be solved using equations 8, 9 and the autarky equilibrium.

## C.3 Equations in Detrended Form

All the equations and time $t$ variables are detrended by $\Gamma_{t-1}^c \equiv X_{t-1}^c (X_{t-1}^w)^{\alpha_X^c} \cdot \mu_g^c (\mu_g^w)^{\alpha_X^c}$ and a detrended variable $\nu$ after detrending becomes $\tilde{\nu}_t = \frac{\nu_t}{\Gamma_{t-1}}$. Thus the detrended output is given as:

$$\tilde{Y}_t = e^{z_t + \alpha_z z_t^w} g_t (g_t^w)^{\alpha_X} / (\mu_g (\mu_g^w)^{\alpha_X})$$

The budget constraint of the household when not in default is given as:

$$c_t = y_t + q_t d_{t+1} - d_t$$

$$\implies \frac{c_t}{\Gamma_{t-1}} = \frac{y_t}{\Gamma_{t-1}} + \frac{q_t d_{t+1}}{\Gamma_{t-1}} - \frac{d_t}{\Gamma_{t-1}}$$

$$\implies \tilde{c}_t = \tilde{y}_t + \frac{\Gamma_t}{\Gamma_{t-1}} \frac{q_t d_{t+1}}{\Gamma_t} - \tilde{d}_t$$

$$\implies \tilde{c}_t = \tilde{y}_t + g_t (g_t^w)^{\alpha_X} \cdot q_t \tilde{d}_{t+1} - \tilde{d}_t$$

In a similar fashion, we can detrend the utility function and hence the value functions too. The only difference is that we detrend them by $(\Gamma_{t-1})^{1-\gamma}$ instead of $\Gamma_{t-1}$. This is because of the peculiar form of utility function used.[33] The detrended utility function can thus be

[33] which is why we use $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$ instead of $u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$

written as:

$$\tilde{u}(\tilde{c_t}) \equiv \frac{u(c_t)}{(\Gamma_{t-1})^{1-\gamma}} = \frac{\tilde{c_t}^{1-\gamma}}{1-\gamma}$$

The value functions can also be detrended in the same way. The continuation value is given as:

$$v^c(y_t, d_t) = \max_{d_{t+1}} \{u(y_t + q_t d_{t+1} - d_t) + \beta \cdot E\left[v^g(y_{t+1}, d_{t+1})\right]\}$$

$$\implies \frac{v^c(y_t, d_t)}{(\Gamma_{t-1})^{1-\gamma}} = \max_{\tilde{d}_{t+1}} \left\{ \tilde{u}(\tilde{y_t} + g_t (g_t^w)^{\alpha_X} \cdot q_t \tilde{d}_{t+1} - \tilde{d}_t) + \beta \cdot \frac{(\Gamma_t)^{1-\gamma}}{(\Gamma_{t-1})^{1-\gamma}} \frac{E\left[v^g(y_{t+1}, d_{t+1})\right]}{(\Gamma_t)^{1-\gamma}} \right\}$$

$$\implies \tilde{v^c}(\tilde{y_t}, \tilde{d_t}) = \max_{\tilde{d}_{t+1}} \left\{ \tilde{u}(\tilde{y_t} + g_t (g_t^w)^{\alpha_X} \cdot q_t \tilde{d}_{t+1} - \tilde{d}_t) + \beta \cdot (g_t (g_t^w)^{\alpha_X})^{1-\gamma} \cdot E\left[\tilde{v^g}(\tilde{y}_{t+1}, \tilde{d}_{t+1})\right] \right\}$$

The value function when the country defaults or is in bad standing is given by:

$$v^b(y_t) = u\left(y \cdot (1 - \phi(z_t, z_t^w, g_t, g_t^w))\right) + \beta \cdot E\left[\lambda v^g(y_{t+1}, 0) + (1-\lambda) v^b(y_{t+1})\right]$$

$$\implies \tilde{v^b}(\tilde{y_t}) = \tilde{u}\left(\tilde{y_t} \cdot (1 - \phi(z_t, z_t^w, g_t, g_t^w))\right) + \beta \cdot (g_t (g_t^w)^{\alpha_X})^{1-\gamma} \cdot E\left[\lambda \tilde{v^g}(\tilde{y}_{t+1}, 0) + (1-\lambda) \tilde{v^b}(\tilde{y}_{t+1})\right]$$

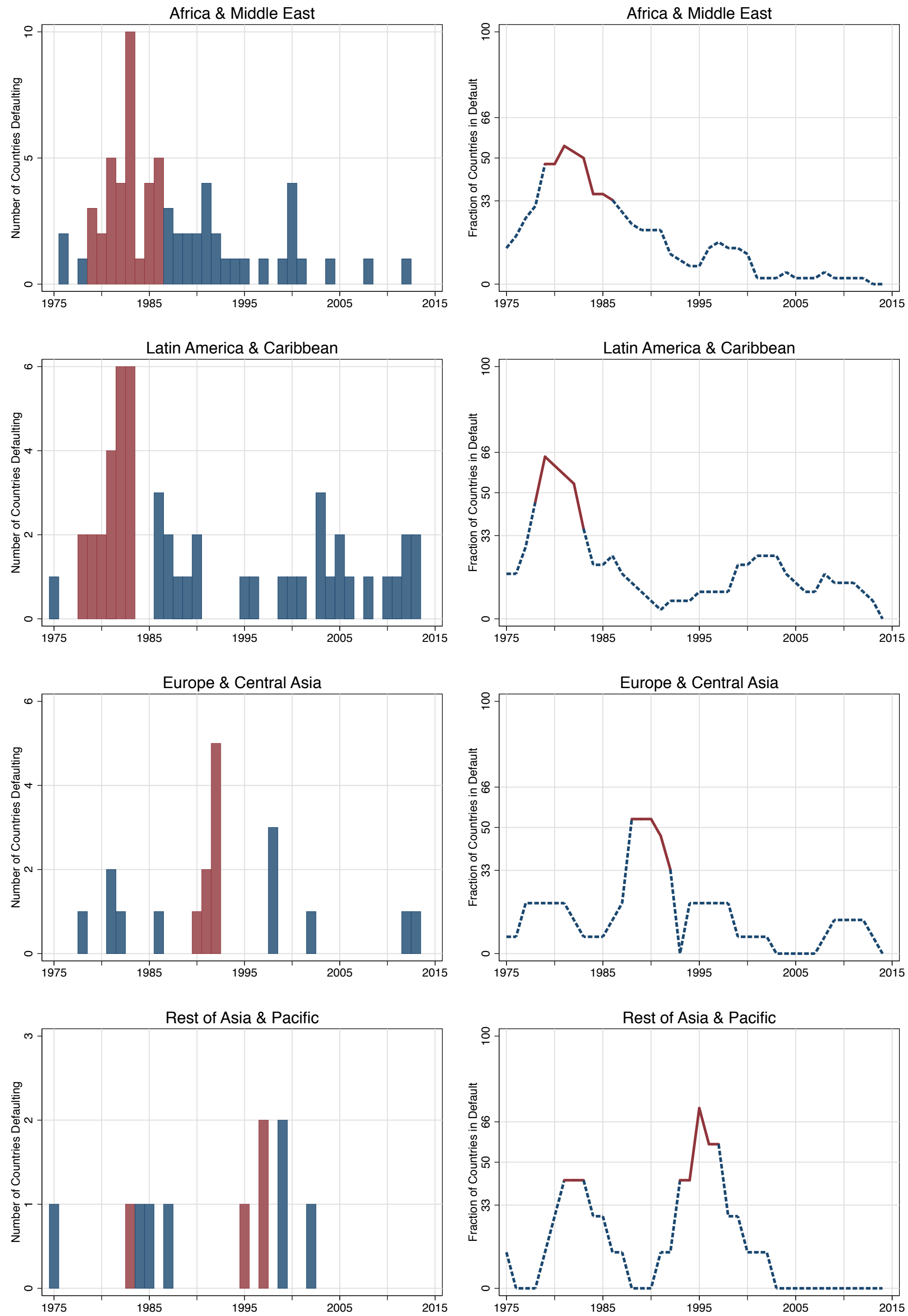
Detrended version of value function in good standing is:

$$v^g(y_t, d_t) = \max\left\{v^b(y_t), v^c(y_t, d_t)\right\}$$

$$\implies \tilde{v^g}(\tilde{y_t}, \tilde{d_t}) = \max\left\{\tilde{v^b}(\tilde{y_t}), \tilde{v^c}(\tilde{y_t}, \tilde{d_t})\right\}$$

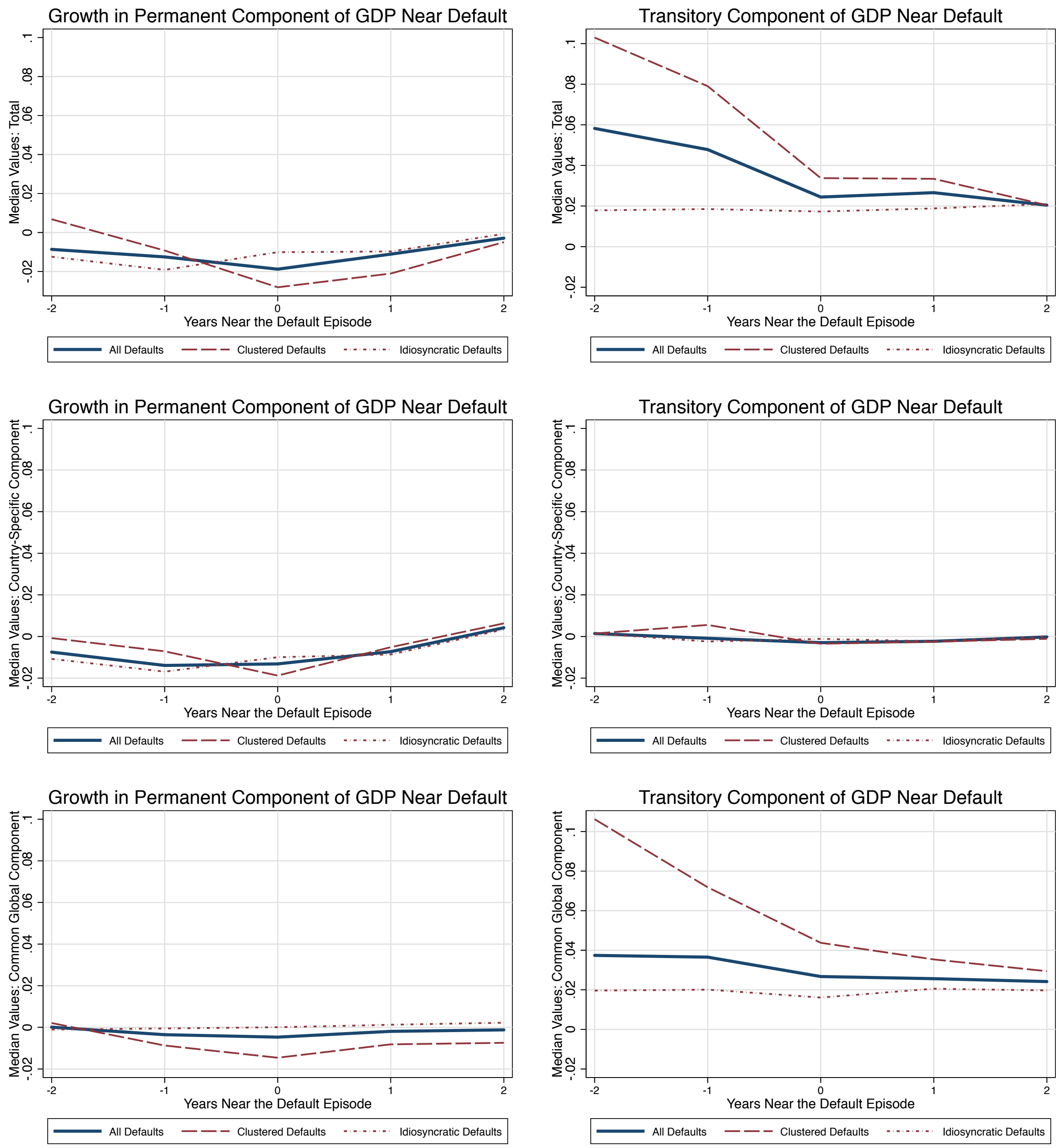
# D Figures and Tables

Figure OA1: Countries defaulting in a 5-year rolling window by Region




The top panel shows number of countries in default in every year from 1975-2014 at the region level. The bottom panel shows fraction of countries defaulting in a 5-year rolling window starting every year at the region level. Maroon line highlights the period of clustered default while navy line highlights idiosyncratic defaults.

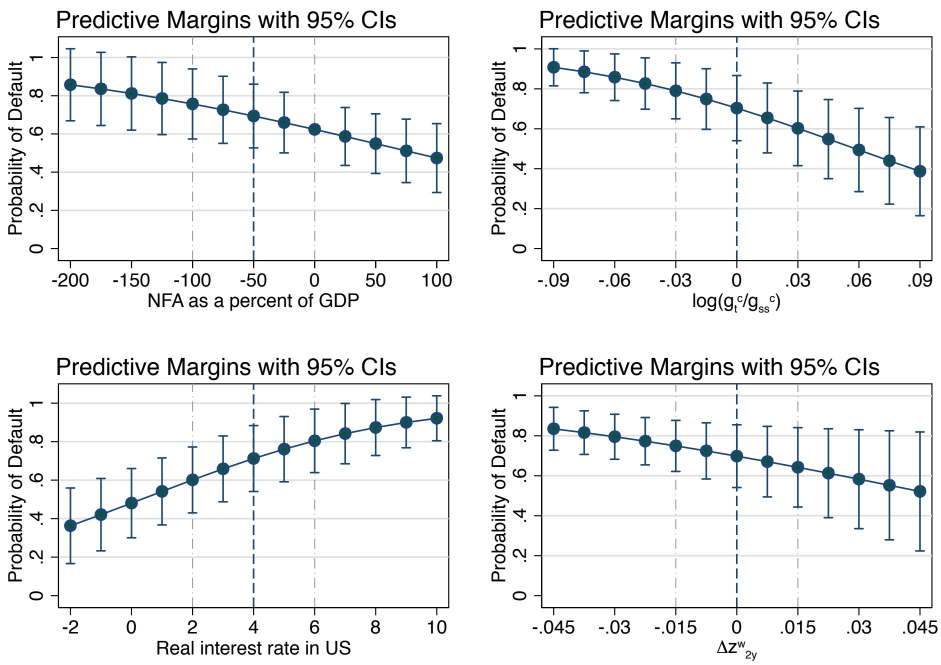
Figure OA2: Transitory and Permanent Components of Output Near Default




Note: (1) 0 depicts the crisis year. -1 and -2 depict 1 and 2 years before the crisis while 1 and 2 depict 1 and 2 years after the crisis. (2) The diagram is based on components of output process obtained from estimation using data from 49 defaulting countries and 10 developed countries.

The left panels plot growth rate in the permanent component of GDP. It starts with the total growth rate of permanent component—$\log(g_t^c/g_{ss}^c) + \alpha_X^c \log(g_t^w/g_{ss}^w)$—in the first row and then decomposes its country-specific and global parts—$\log(g_t^c/g_{ss}^c)$ and $\alpha_X^c \log(g_t^w/g_{ss}^w)$—respectively. The right panels plot the transitory component of GDP. It starts with the total transitory component—$z_t^c + \alpha_z^c z_t^w$—in the first row and then decomposes its country-specific and global parts—$z_t^c$ and $\alpha_z^c z_t^w$—respectively.

Figure OA3: Change in Probability with changes in one explanatory




The figure depicts marginal change in probability of default if one explanatory variable changes (keeping all other explanatory variables fixed). The mean value of explanatory variables are highlighted with the vertical dashed line. The dash-dot line represents one standard deviations for respective explanatory variables.

Figure OA4: Predicted probabilities: Specifications 1 vs Specifications 2

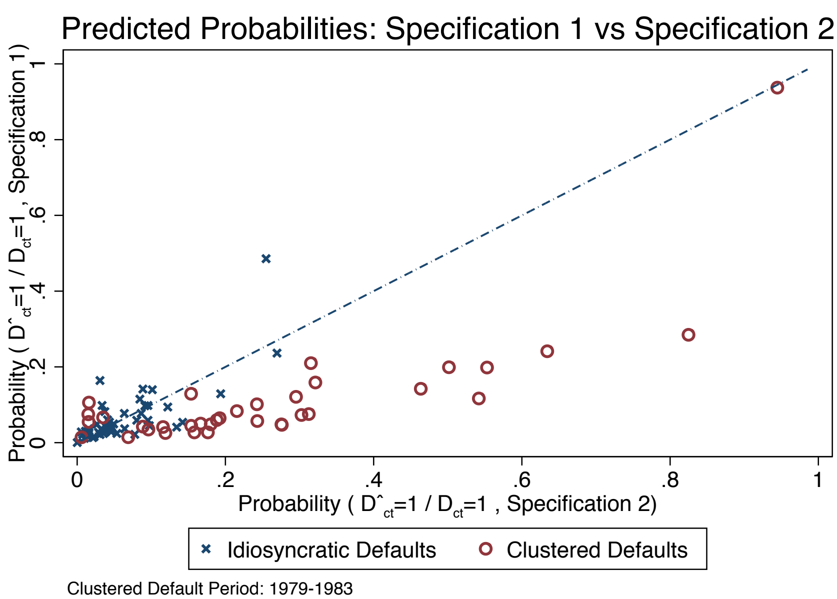
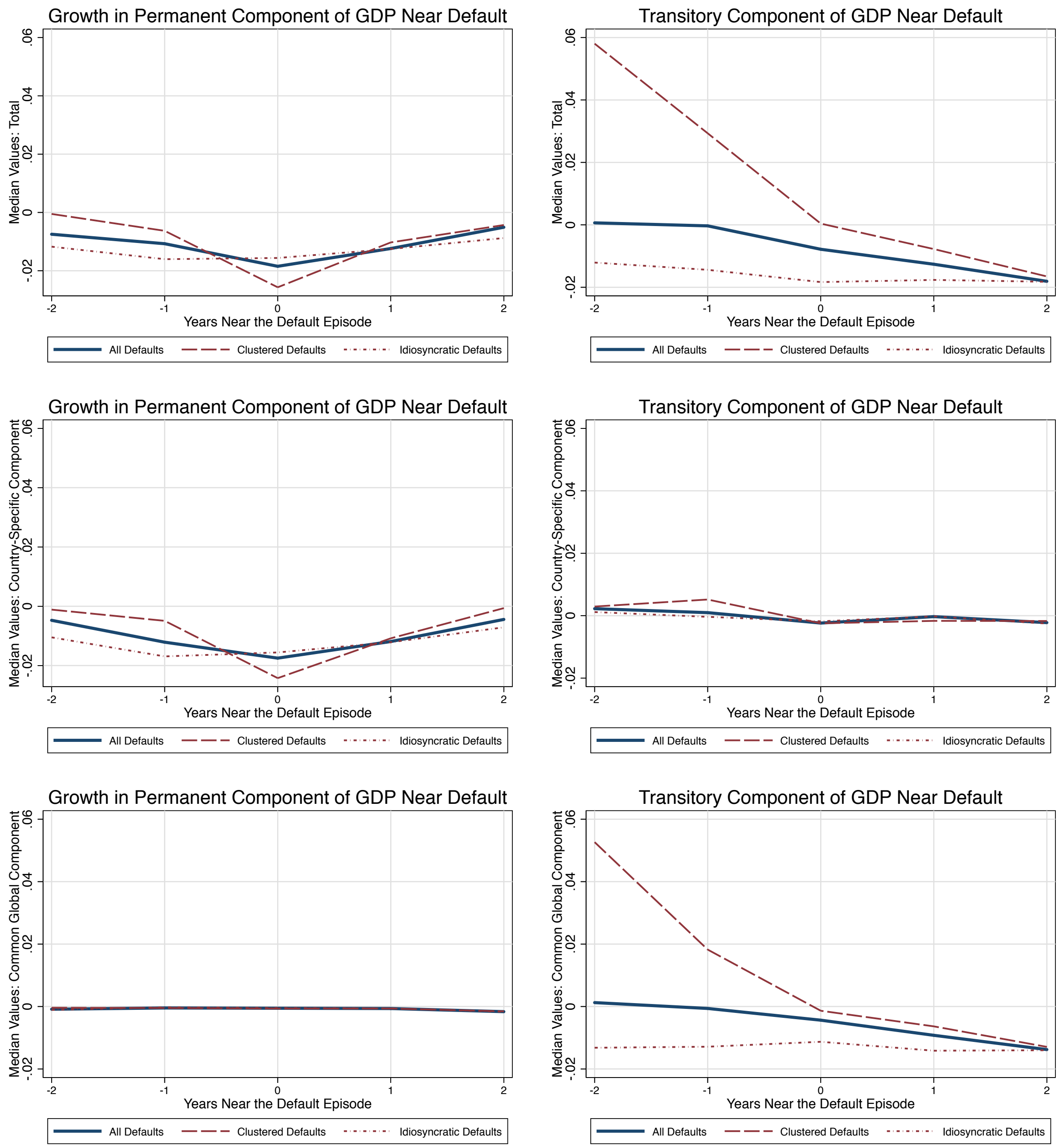


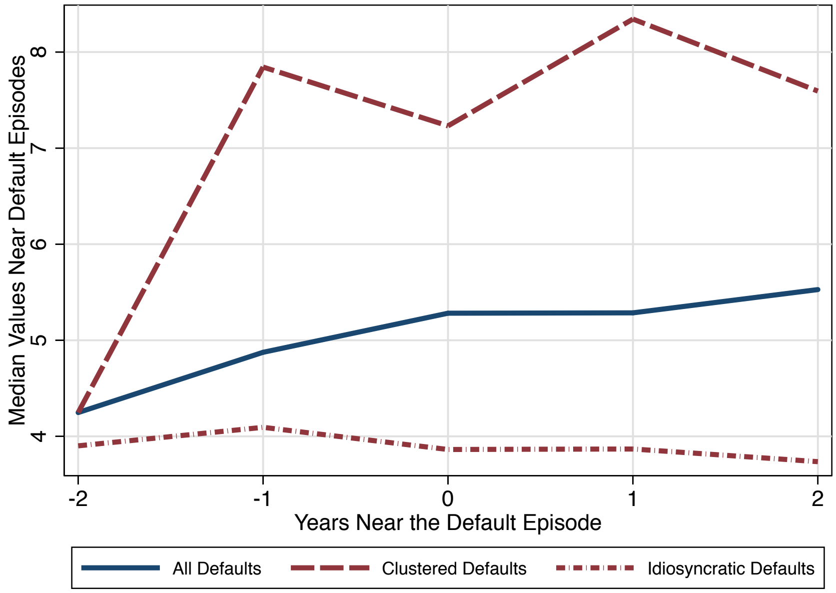
Figure OA5: Transitory and permanent components of output near default




Notes: (1) 0 depicts the crisis year. -1 and -2 depict 1 and 2 years before the crisis, while 1 and 2 depict 1 and 2 years after the crisis. (2) The diagram is based on components of the output process obtained from estimation using data from 19 defaulting countries and 5 developed countries.

The left panels plot growth rate in the permanent component of GDP. It starts with the total growth rate of the permanent component—$\log(g_t^c/g_{ss}^c) + \alpha_X^c \log(g_t^w/g_{ss}^w)$—in the first row and then decomposes its country-specific and global components—$\log(g_t^c/g_{ss}^c)$ and $\alpha_X^c \log(g_t^w/g_{ss}^w)$—,respectively. The right panels plot the transitory component of GDP. It starts with the total transitory component—$z_t^c + \alpha_z^c z_t^w$—in the first row and then decomposes its country-specific and global components—$z_t^c$ and $\alpha_z^c z_t^w$—respectively.

Figure OA6: World interest rate near default




Note: 0 depicts the crisis year. -1 and -2 depict 1 and 2 years before the crisis while 1 and 2 depict 1 and 2 years after the crisis.

Figure OA7: Predicted probabilities of default using specification 1 and specification 2

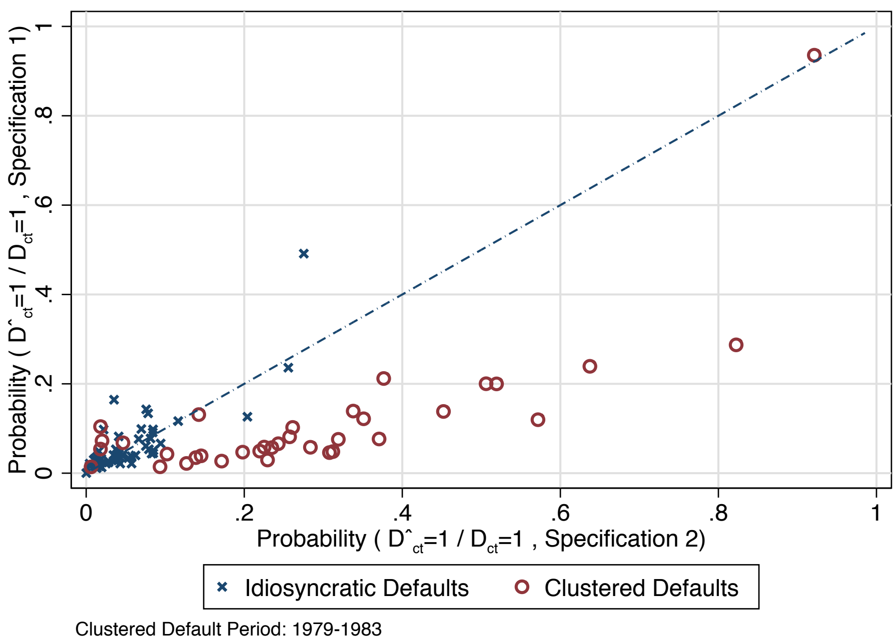
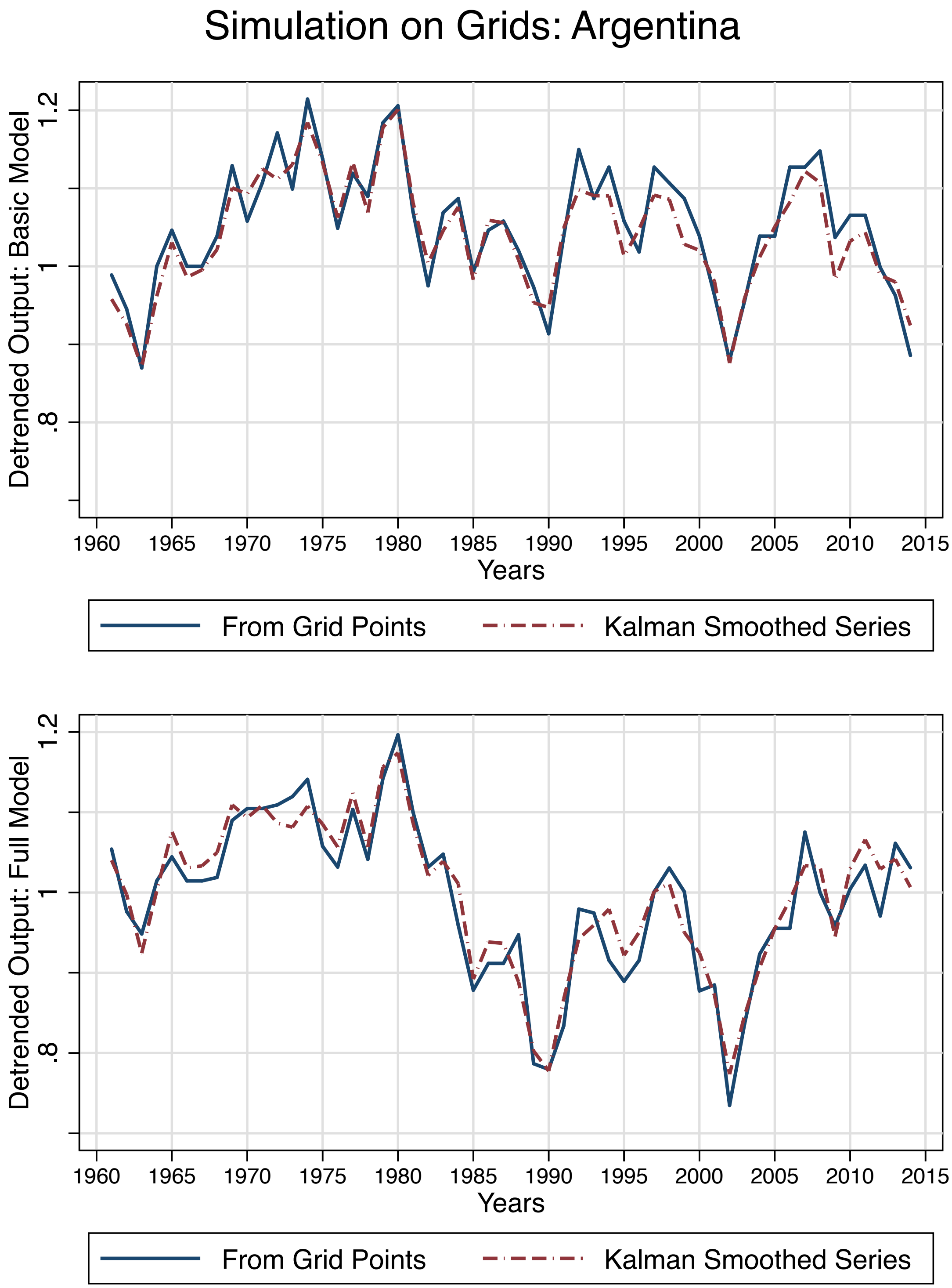
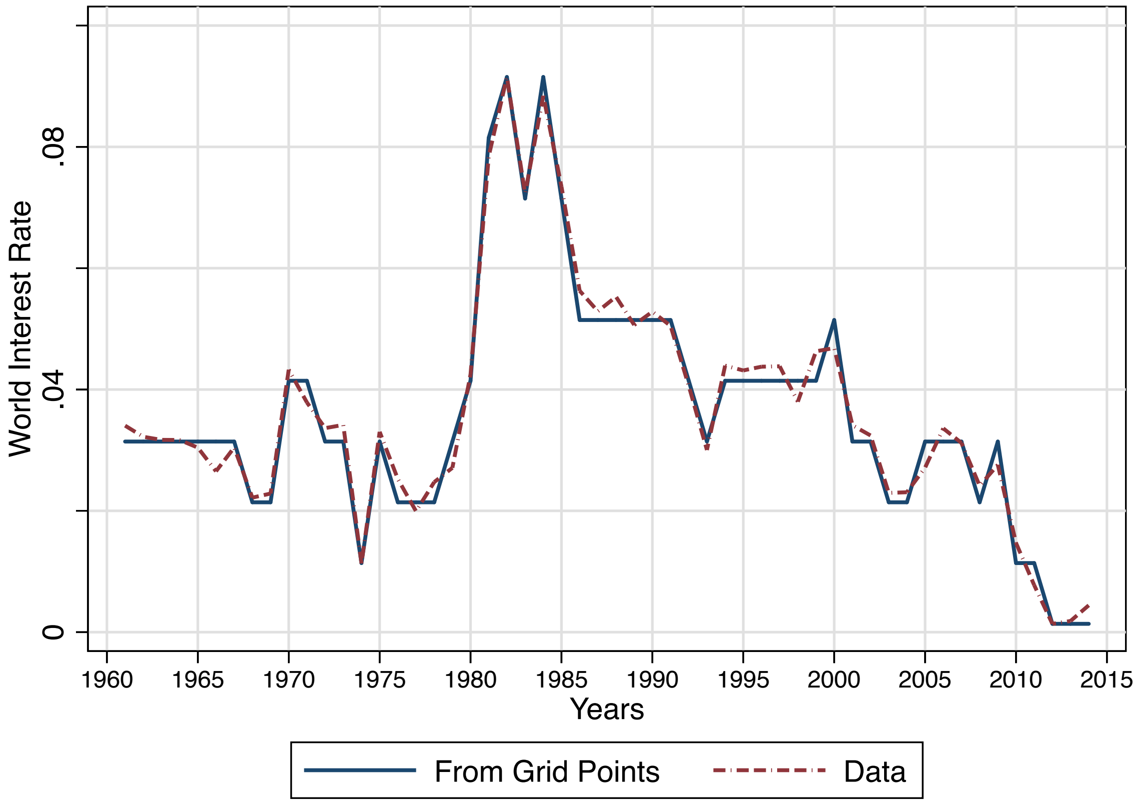


Figure OA8: Simulation of Latent state variables on the Grid




The top panel shows the detrended output simulated using the grid points and the detrended output calculated from the series of four Kalman smoothed components of output. The middle panel shows the same two series of detrended output for the full model.

Figure OA9: Simulation of interest rate on grid vs the data




The figure shows the movement of interest rate on a grid of 10 points used in the model and for simulation. It also shows the movement of interest rate in the data.

Figure OA10: Decomposition of shocks to detrended output of Belize and Bolivia

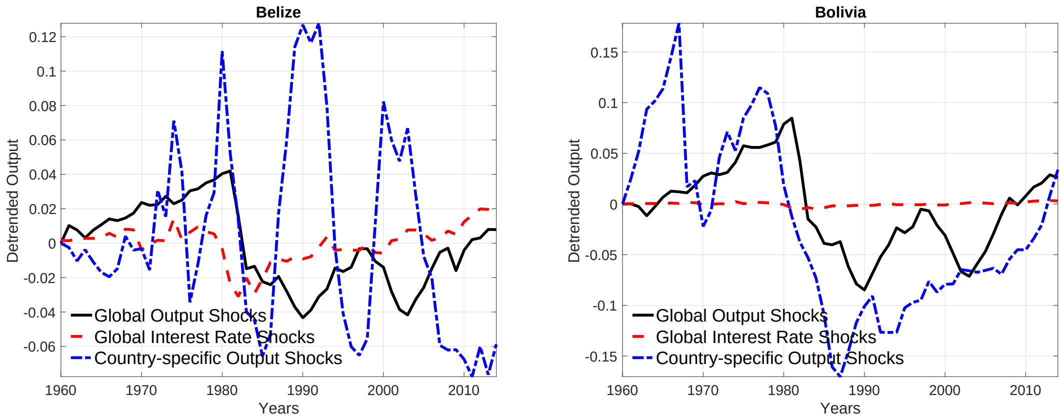


Figure OA11: Decomposition of shocks to detrended output of Brazil and Chile

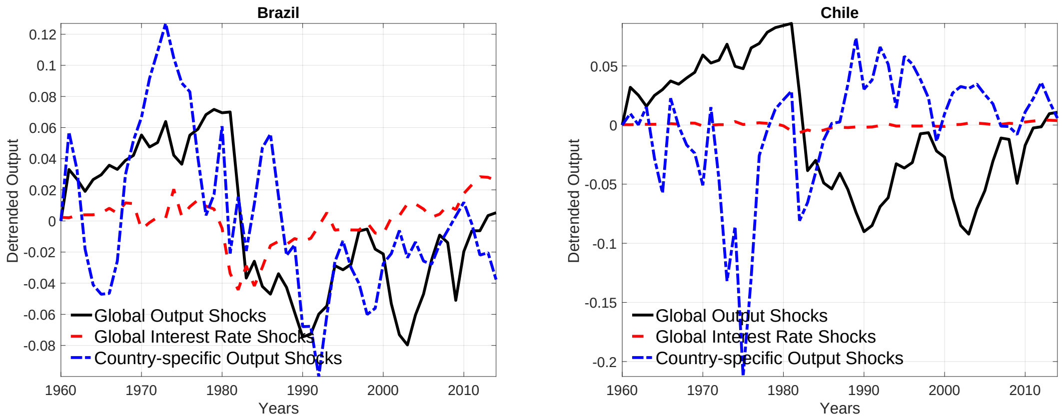



Figure OA12: Decomposition of shocks to detrended output of Costa Rica and Dominican Republic

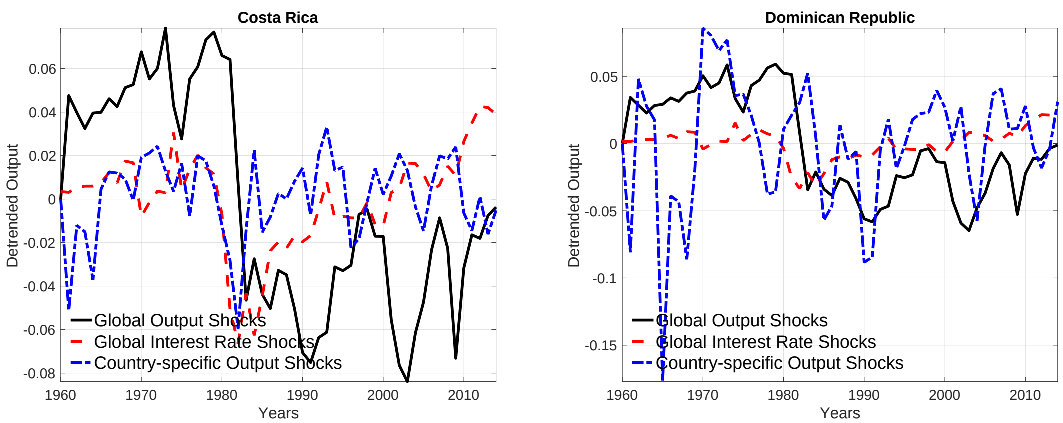



Figure OA13: Decomposition of shocks to detrended output of Ecuador and Guatemala

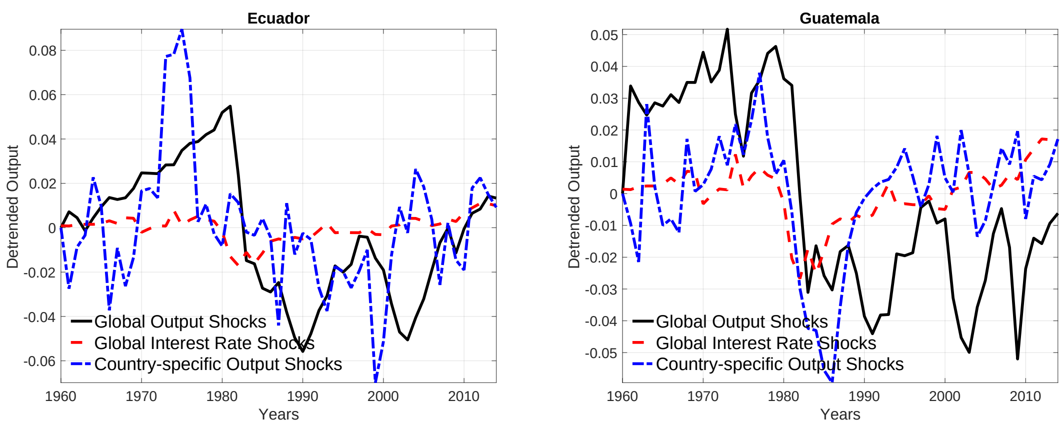


Figure OA14: Decomposition of shocks to detrended output of Guyana and Honduras

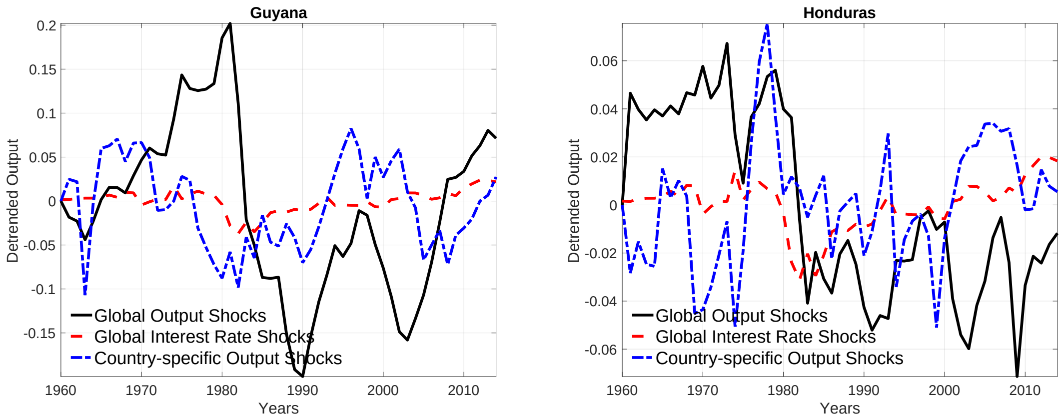



Figure OA15: Decomposition of shocks to detrended output of Mexico and Nicaragua

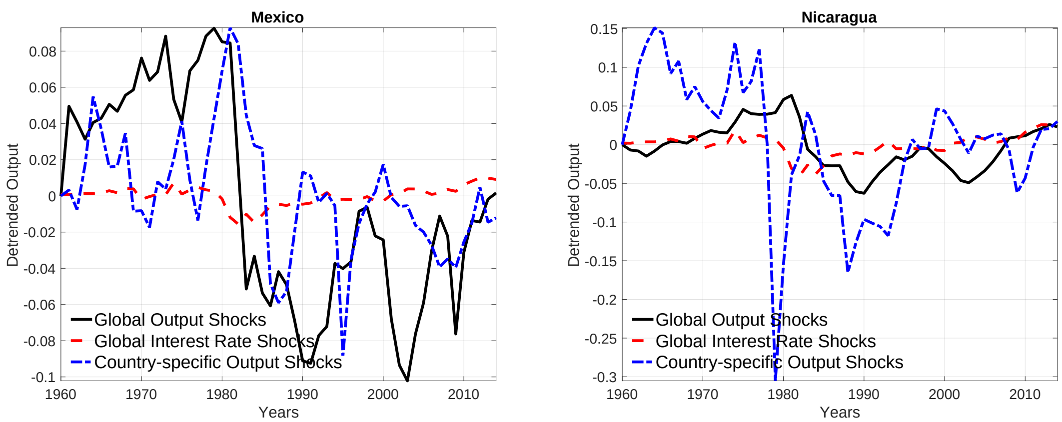



Figure OA16: Decomposition of shocks to detrended output of Panama and Paraguay

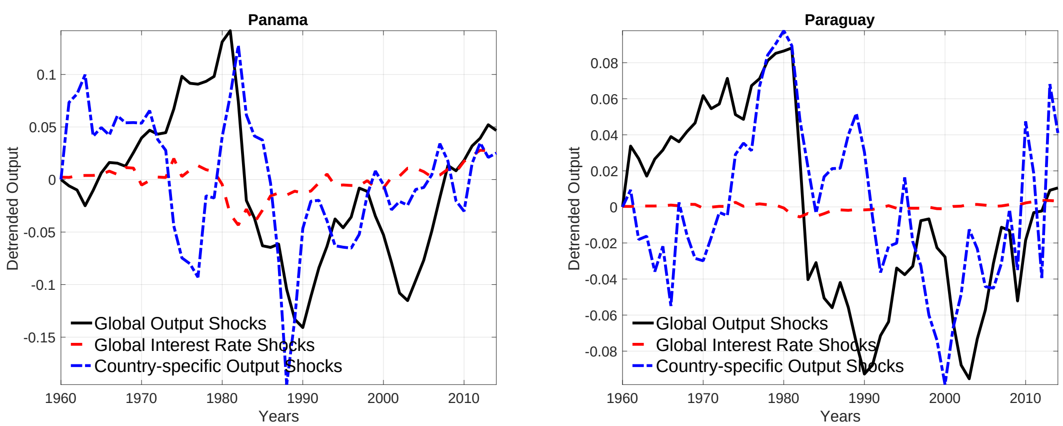


Figure OA17: Decomposition of shocks to detrended output of Peru and Trinidad & Tobago

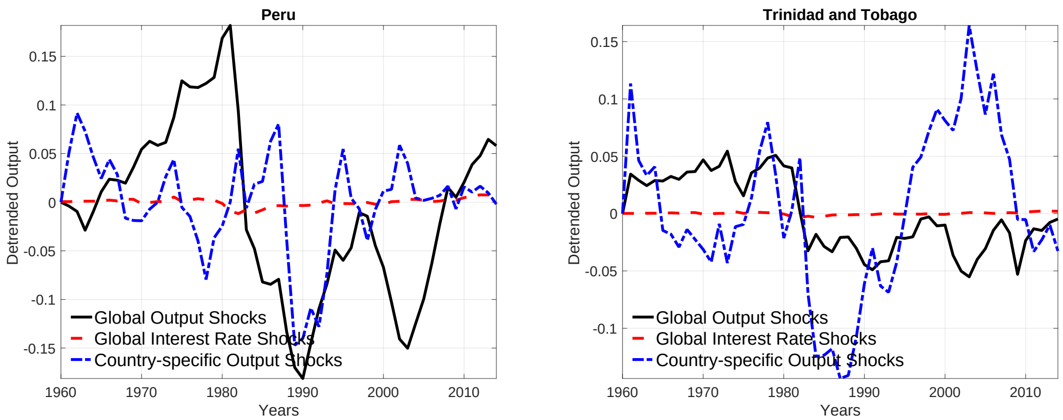



Figure OA18: Decomposition of shocks to detrended output of Uruguay and Venezuela, RB

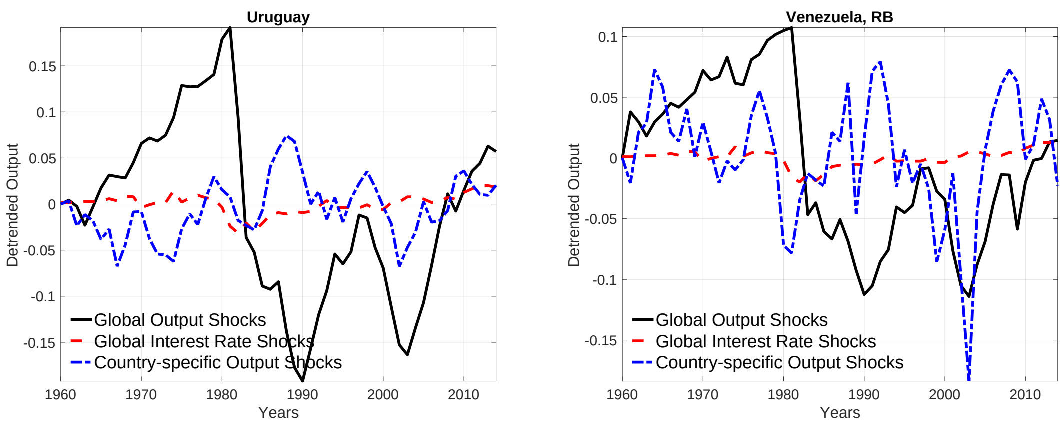


Table OA1: Bayesian Estimation Results from Basic Model: Posterior means

| Country | Statistic | Posterior (Mean & Standard Deviation) | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\rho_z^c$ | $\rho_g^c$ | $\sigma_z^c$ | $\sigma_g^c$ | $\alpha_z^c$ | $\alpha_X^c$ |
| Argentina | Mean | 0.5751 | 0.2774 | 0.0370 | 0.0190 | 0.0190 | 0.0157 |
| | Std. Dev. | 0.2075 | 0.2019 | 0.0117 | 0.0151 | 0.0207 | 0.0234 |
| Belize | Mean | 0.4532 | 0.5530 | 0.0094 | 0.0301 | 0.0058 | 0.0043 |
| | Std. Dev. | 0.2310 | 0.1441 | 0.0058 | 0.0047 | 0.0100 | 0.0104 |
| Bolivia | Mean | 0.6336 | 0.3433 | 0.0176 | 0.0238 | 0.0052 | 0.0080 |
| | Std. Dev. | 0.2917 | 0.2002 | 0.0091 | 0.0091 | 0.0110 | 0.0106 |
| Brazil | Mean | 0.2672 | 0.5619 | 0.0093 | 0.0248 | 0.0165 | 0.0045 |
| | Std. Dev. | 0.1914 | 0.1560 | 0.0049 | 0.0050 | 0.0123 | 0.0188 |
| Chile | Mean | 0.6647 | 0.5342 | 0.0185 | 0.0305 | 0.0234 | 0.0048 |
| | Std. Dev. | 0.2495 | 0.1635 | 0.0092 | 0.0083 | 0.0164 | 0.0229 |
| Costa Rica | Mean | 0.7120 | 0.2835 | 0.0158 | 0.0128 | 0.0190 | 0.0015 |
| | Std. Dev. | 0.1802 | 0.1802 | 0.0060 | 0.0072 | 0.0127 | 0.0162 |
| Dominican Republic | Mean | 0.7517 | 0.3894 | 0.0397 | 0.0190 | 0.0146 | 0.0025 |
| | Std. Dev. | 0.1498 | 0.2268 | 0.0117 | 0.0152 | 0.0129 | 0.0154 |
| Ecuador | Mean | 0.6620 | 0.4509 | 0.0125 | 0.0210 | 0.0064 | 0.0051 |
| | Std. Dev. | 0.2388 | 0.1922 | 0.0067 | 0.0063 | 0.0082 | 0.0091 |
| Guatemala | Mean | 0.4669 | 0.6373 | 0.0069 | 0.0112 | 0.0121 | 0.0001 |
| | Std. Dev. | 0.3095 | 0.1878 | 0.0030 | 0.0031 | 0.0088 | 0.0117 |
| Guyana | Mean | 0.6988 | 0.3202 | 0.0228 | 0.0277 | 0.0092 | 0.0229 |
| | Std. Dev. | 0.2267 | 0.1896 | 0.0111 | 0.0115 | 0.0258 | 0.0209 |
| Honduras | Mean | 0.5827 | 0.3248 | 0.0130 | 0.0142 | 0.0174 | -0.0010 |
| | Std. Dev. | 0.2886 | 0.1823 | 0.0067 | 0.0067 | 0.0129 | 0.0141 |
| Mexico | Mean | 0.3328 | 0.3815 | 0.0094 | 0.0251 | 0.0176 | 0.0041 |
| | Std. Dev. | 0.2627 | 0.1451 | 0.0058 | 0.0049 | 0.0121 | 0.0183 |
| Nicaragua | Mean | 0.6416 | 0.4959 | 0.0268 | 0.0485 | 0.0026 | 0.0106 |
| | Std. Dev. | 0.2062 | 0.2308 | 0.0161 | 0.0145 | 0.0191 | 0.0175 |
| Panama | Mean | 0.7705 | 0.4015 | 0.0118 | 0.0313 | 0.0085 | 0.0152 |
| | Std. Dev. | 0.1549 | 0.1549 | 0.0082 | 0.0067 | 0.0182 | 0.0177 |
| Paraguay | Mean | 0.5821 | 0.7096 | 0.0184 | 0.0194 | 0.0173 | 0.0070 |
| | Std. Dev. | 0.2761 | 0.1758 | 0.0059 | 0.0068 | 0.0125 | 0.0194 |
| Peru | Mean | 0.8125 | 0.4263 | 0.0126 | 0.0329 | 0.0129 | 0.0214 |
| | Std. Dev. | 0.1149 | 0.1530 | 0.0089 | 0.0068 | 0.0245 | 0.0235 |
| Trinidad and Tobago | Mean | 0.6563 | 0.6455 | 0.0140 | 0.0322 | 0.0113 | 0.0024 |
| | Std. Dev. | 0.2137 | 0.1413 | 0.0075 | 0.0070 | 0.0117 | 0.0157 |
| Uruguay | Mean | 0.5996 | 0.4348 | 0.0096 | 0.0255 | 0.0151 | 0.0186 |
| | Std. Dev. | 0.2519 | 0.1715 | 0.0068 | 0.0062 | 0.0201 | 0.0207 |
| Venezuela, RB | Mean | 0.6204 | 0.3278 | 0.0333 | 0.0211 | 0.0227 | 0.0074 |
| | Std. Dev. | 0.2247 | 0.2298 | 0.0121 | 0.0148 | 0.0123 | 0.0213 |

| World | Statistic | $\rho_z^w$ | $\rho_g^w$ |
|---|---|---|---|
| | Mean | 0.9414 | 0.5038 |
| | Std. Dev. | 0.0433 | 0.1599 |

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.

Table OA2: Bayesian Estimation Results from Full Model: Posterior means

| Country | Statistic | Posterior (Mean & Standard Deviation) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $\rho_z^c$ | $\rho_g^c$ | $\sigma_z^c$ | $\sigma_g^c$ | $\psi^c$ | $\eta^c$ | $\alpha_z^c$ | $\alpha_X^c$ |
| Argentina | Mean | 0.2813 | 0.6431 | 0.0134 | 0.0141 | 2.0832 | 0.3924 | 0.0196 | 0.0029 |
| | Std. Dev. | 0.2314 | 0.0743 | 0.0064 | 0.0076 | 0.0769 | 0.0895 | 0.0055 | 0.0057 |
| Belize | Mean | 0.4934 | 0.7748 | 0.0028 | 0.0138 | 2.5386 | 0.3669 | 0.0041 | 0.0017 |
| | Std. Dev. | 0.0906 | 0.0757 | 0.002 | 0.0017 | 0.1036 | 0.148 | 0.0033 | 0.0033 |
| Bolivia | Mean | 0.9477 | 0.2448 | 0.0136 | 0.0036 | 2.3502 | 0.0713 | 0.0086 | -0.0003 |
| | Std. Dev. | 0.041 | 0.1542 | 0.002 | 0.0026 | 0.1037 | 0.0506 | 0.0033 | 0.0032 |
| Brazil | Mean | 0.2023 | 0.8617 | 0.0025 | 0.0122 | 2.2738 | 0.6329 | 0.0078 | 0.0065 |
| | Std. Dev. | 0.1091 | 0.0538 | 0.0017 | 0.0016 | 0.1897 | 0.1084 | 0.0034 | 0.0033 |
| Chile | Mean | 0.9267 | 0.6321 | 0.011 | 0.021 | 1.7075 | 0.1645 | 0.0126 | 0.0082 |
| | Std. Dev. | 0.0446 | 0.1088 | 0.0067 | 0.0054 | 0.0786 | 0.0873 | 0.0065 | 0.0062 |
| Costa Rica | Mean | 0.2902 | 0.5339 | 0.0039 | 0.0069 | 2.3393 | 0.9032 | 0.0073 | 0.0092 |
| | Std. Dev. | 0.1159 | 0.1386 | 0.0023 | 0.0024 | 0.1737 | 0.0572 | 0.0028 | 0.0026 |
| Dominican Republic | Mean | 0.3735 | 0.543 | 0.0135 | 0.0235 | 1.7342 | 0.8289 | 0.0078 | 0.0089 |
| | Std. Dev. | 0.0965 | 0.0731 | 0.0069 | 0.0058 | 0.1156 | 0.0916 | 0.0068 | 0.0054 |
| Ecuador | Mean | 0.4392 | 0.7825 | 0.0084 | 0.0142 | 1.4405 | 0.7039 | 0.0092 | 0.002 |
| | Std. Dev. | 0.0925 | 0.0928 | 0.004 | 0.0034 | 0.1037 | 0.0857 | 0.0047 | 0.0044 |
| Guatemala | Mean | 0.7671 | 0.7034 | 0.0025 | 0.0083 | 1.7201 | 0.6772 | 0.0054 | 0.009 |
| | Std. Dev. | 0.0806 | 0.0687 | 0.0016 | 0.0013 | 0.1368 | 0.1588 | 0.0031 | 0.0029 |
| Guyana | Mean | 0.3798 | 0.6713 | 0.0037 | 0.0125 | 2.9785 | 0.3414 | 0.0159 | -0.0035 |
| | Std. Dev. | 0.1044 | 0.1285 | 0.0024 | 0.002 | 0.1592 | 0.0869 | 0.0037 | 0.0044 |
| Honduras | Mean | 0.4223 | 0.6674 | 0.0043 | 0.0096 | 2.0775 | 0.5282 | 0.005 | 0.0103 |
| | Std. Dev. | 0.1067 | 0.0843 | 0.0022 | 0.0019 | 0.0552 | 0.1607 | 0.0035 | 0.0033 |
| Mexico | Mean | 0.7295 | 0.7787 | 0.0057 | 0.0104 | 2.0862 | 0.2603 | 0.0105 | 0.0107 |
| | Std. Dev. | 0.0982 | 0.0648 | 0.0033 | 0.003 | 0.0863 | 0.0706 | 0.004 | 0.0041 |
| Nicaragua | Mean | 0.9303 | 0.7011 | 0.0152 | 0.0254 | 2.0281 | 0.7145 | 0.0073 | -0.0019 |
| | Std. Dev. | 0.0465 | 0.0787 | 0.0094 | 0.0082 | 0.1693 | 0.1683 | 0.0078 | 0.007 |
| Panama | Mean | 0.5375 | 0.8314 | 0.0039 | 0.0141 | 2.5912 | 0.4966 | 0.0129 | -0.0016 |
| | Std. Dev. | 0.1635 | 0.075 | 0.0032 | 0.0026 | 0.2035 | 0.1027 | 0.0043 | 0.0039 |
| Paraguay | Mean | 0.5385 | 0.6997 | 0.0047 | 0.0162 | 1.8303 | 0.122 | 0.0121 | 0.0081 |
| | Std. Dev. | 0.1257 | 0.1002 | 0.003 | 0.0028 | 0.1154 | 0.0895 | 0.0048 | 0.0046 |
| Peru | Mean | 0.4378 | 0.7591 | 0.0051 | 0.0205 | 1.8 | 0.268 | 0.0239 | -0.002 |
| | Std. Dev. | 0.1151 | 0.0907 | 0.0037 | 0.0029 | 0.1233 | 0.0781 | 0.0068 | 0.0062 |
| Trinidad and Tobago | Mean | 0.1823 | 0.8532 | 0.004 | 0.0177 | 1.9957 | 0.0632 | 0.0054 | 0.0079 |
| | Std. Dev. | 0.1085 | 0.049 | 0.0027 | 0.0022 | 0.0816 | 0.0516 | 0.0047 | 0.0045 |
| Uruguay | Mean | 0.9247 | 0.7466 | 0.0088 | 0.0117 | 1.7514 | 0.7631 | 0.0261 | 0.0001 |
| | Std. Dev. | 0.0489 | 0.107 | 0.0049 | 0.0051 | 0.0682 | 0.1214 | 0.0054 | 0.0065 |
| Venezuela, RB | Mean | 0.8535 | 0.5335 | 0.0174 | 0.0105 | 2.0829 | 0.3363 | 0.0129 | 0.008 |
| | Std. Dev. | 0.0943 | 0.1222 | 0.0062 | 0.0077 | 0.1941 | 0.1569 | 0.0054 | 0.0043 |
| World | Statistic | $\rho_z^w$ | $\rho_g^w$ | | | | | | |
| | Mean | 0.8897 | 0.7555 | | | | | | |
| | Std. Dev. | 0.0845 | 0.0957 | | | | | | |

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.

Table OA3: Summary Stats: Default Episodes

| | No. of Countries Defaulting | No. of Defaults |
|---|---|---|
| World | 92 | 146 |
| Africa & Middle East | 42 | 65 |
| Latin America & Caribbean | 28 | 51 |
| Europe & Central Asia | 15 | 19 |
| Rest of Asia & Pacific | 7 | 11 |

Table OA4: Summary Stats: Explanatory Variables

| | Mean | Std. Dev. |
|---|---|---|
| **Country-Specific Variables** | | |
| (NFA as a % of GDP)$_t^c$ | -50.160 | 51.8705 |
| $\log(g_t^c/g_{ss}^c)$ | 0.001 | 0.0310 |
| $z_t^c$ | -0.001 | 0.0397 |
| $\Delta z_{t,t-2}^c$ | 0.001 | 0.0387 |
| **Global Variables** | | |
| (Real interest rate in US)$_t$ | 3.898 | 1.9481 |
| $\log(g_t^w/g_{ss}^w)$ | -0.003 | 0.0056 |
| $z_t^w$ | -0.001 | 0.0238 |
| $\Delta z_{t,t-2}^w$ | -0.000 | 0.0158 |
| (Inflation Adjusted Oil Prices)$_t$ | 64.560 | 27.8581 |
| Observations | 1220 | |

Table OA5: 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)$_t^c$ | -0.00768$^{***}$ | -0.0876 | -0.00678$^{**}$ | -0.0449 |
| $\log(g_t^c/g_{ss}^c)$ | -19.49$^{***}$ | -0.1331 | -19.88$^{***}$ | -0.0787 |
| $z_t^c$ | -2.554 | -0.0223 | -2.911 | -0.0147 |
| **Global Variables** | | | | |
| (Real interest rate in US)$_t$ | | | 0.364$^{***}$ | 0.0905 |
| $\log(g_t^w/g_{ss}^w)$ | | | 25.20 | 0.0180 |
| $z_t^w$ | | | -14.82$^{*}$ | -0.0450 |
| (Inflation Adjusted Oil Prices)$_t$ | | | 0.00301 | 0.0107 |
| Country Fixed Effects | Yes | | Yes | |
| $N$ | 1220 | | 1220 | |
| pseudo $R^2$ | 0.101 | | 0.215 | |

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Table OA6: 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 | .0634 | 0.0604 | 0.4418 |
| Clustered Default | 35 | 0.1148 | 0.2631 | -6.1837 |

Table OA7: 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 | 0.0274 | 8.0879 |
| Clustered Default Period | 165 | 0.0353 | 0.0555 | -4.0970 |

Table OA8: 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 | |

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

Table OA9: 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 OA10: 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 |