Clustered Sovereign Defaults*

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Abstract

Clustered sovereign defaults, where multiple countries default in a relatively short period of time, are a recurring phenomenon, yet there is a lack of quantitative models designed to study them. This paper builds a quantitative framework to study clustered defaults, and investigates the nature of shocks and the mechanism through which these shocks lead countries to clustered defaults. The paper begins with a joint estimation of structural parameters that drive the output process of 24 countries and a process for the world interest rate. The postulated output process includes transitory and permanent global components, as well as transitory and permanent country-specific components. The paper then builds a sovereign default model augmented with financial frictions at the firm level. 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 1982. The two main findings of the paper are: (1) the primary driver of clustered defaults is global shock to the transitory component of output; and (2) contrary to what is commonly believed, the Volcker interest rate hike was not a decisive factor for the 1982 developing country debt crisis.

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

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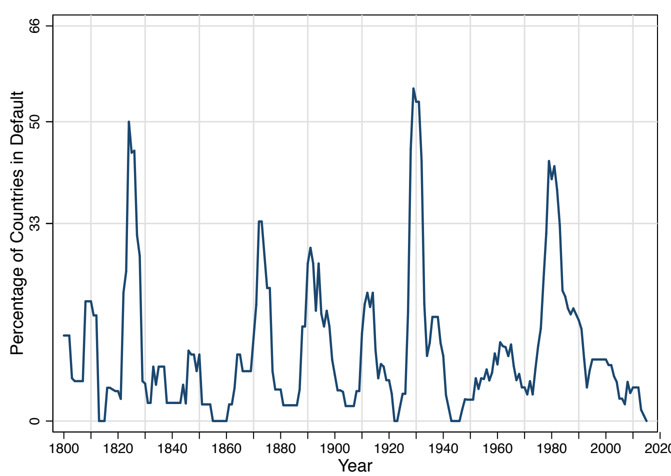
1 Introduction

Historical data on sovereign defaults tell us that *clustered* defaults, where multiple countries default in a relatively short period of time, is a recurring phenomenon. Figure 1 illustrates that the late 1820s, early 1870s, early 1930s and early 1980s were all eras when a large number of countries defaulted in a 5-year period.[1] Despite the frequent recurrence of clustered defaults, only a handful of papers examine historical data to analyze the occurrence of clustered defaults.[2] More importantly, these papers suggest that global shocks played a central role in causing clustered defaults. However, to understand clustered defaults, it is important not only to accommodate the possibility of global shocks but also to identify both their nature and the extent to which they impact countries differentially. Once the global shocks are disentangled from country-specific shocks and a model is developed to study clustered defaults, the framework can be customized for future use by policymakers—whether global policymakers who might be interested in formulating bailout policies or policymakers in large economies who might be contemplating changes to the interest rate. This paper, therefore, builds a quantitative framework that caters very specifically the need to understand clustered defaults. The framework starts by disentangling different global and country-specific shocks that countries face and then builds a quantitative model to understand the mechanism through which these shocks can lead countries to default.

Figure 1: Percentage of defaulting countries in a rolling 5-year window



Note: Author's Calculations. Data Source: Reinhart et al. (2016). World level data. Number of defaulters increase over time–14 in 1800, 29 in 1825, 36 in 1850, 36 in 1875, 39 in 1900, 44 in 1925, 56 in 1950, 96 in 1975, and 107 in 2000. 278 overall defaults from 1800 to 2015.

[1]There are six peaks between 1800 and 2015 but if I impose the requirement of calling episodes with more than one-third countries defaulting as clustered defaults, I am left with four clustered defaults.

[2]Reinhart and Rogoff (2011b), Bordo and Murshid (2000), Kaminsky and Vega-Garcia (2016) etc.

The necessity of having a separate framework arises from the fact that most of the previous studies on sovereign default focus on *idiosyncratic* defaults; and examine countries in isolation. As a byproduct, shocks are considered country-specific and there is no role for global shocks in default decisions. Thus, a default where output decreases by 9% due to country-specific shocks and 1% due to global shocks would be treated the same way as a default where output decreases by 9% due to global shocks and 1% due to country-specific shocks because, in aggregate, the output decreased by 10% in both cases. This is precisely why the formal setup of idiosyncratic defaults does not suit clustered defaults. This paper addresses the need of having a setup through a quantitative framework that can analyze clustered defaults and situations like above, likewise.

The quantitative framework that I develop in this paper is based on the traditional model of Eaton and Gersovitz (1981); Arellano (2008); and Aguiar and Gopinath (2006), and enables this paper to answer 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 shocks—matter? Third, can the quantitative framework generate the 1982 default cluster, as observed in the data?

To answer these questions, the paper is built in three parts. The first part addresses the identification of various global and country-specific shock processes. The second part uses the shock processes identified in the first part to show a significant contribution of global shocks—global shocks to transitory component of the output and shocks to the world interest rate—in leading countries toward clustered defaults. The third part develops a quantitative model of sovereign default to capture the mechanism through which these shocks lead countries to clustered defaults. The results from the model confirm the empirical finding that global transitory shocks contribute the most to generating clustered defaults. Next, I show that the quantitative model *does* predict a cluster during 1982, which is in line with the data in terms of both timing and magnitude. Finally, in regard to generating a cluster, the model *does* show that fluctuations in interest rate might lead to clustered defaults, but, contradicting a widely held notion, the model also plays down the impact of the Volcker interest rate hike in causing the clustered default of 1982.

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. 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.

In the second part, the time series of smoothed-out global and country-specific shocks are used to perform preliminary tests in the style of Kaminsky and Vega-Garcia (2016). The empirical tests highlight that global variables are essential in predicting clustered defaults but not in predicting idiosyncratic ones.

The third part builds on the setup of Arellano (2008) and Aguiar and Gopinath (2006) by making three important changes in order to accommodate all five shocks from the estimation part in a sovereign default model. First, it allows for two global and two country-specific shocks to the output process. Second, the output is now produced using labor. Third, and most important, it incorporates the labor market and a financial friction in the form of working-capital constraint on the firm side. The inclusion of working-capital constraint in the model enables world interest rate, the fifth shock, to influence default decisions through two channels. I call the first channel the *debt-pricing channel* and the second channel the *endogenous output channel*.[3]

The two channels provide a novel way to capture the effect of interest rate movements on default decisions. In first channel, an increase in interest rate also raises the risk 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 intraperiod 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.

The rest of the model remains the same and features incomplete markets (due to the presence of single-period non-state-contingent debt) and risk-neutral foreign lenders. When I simulate the model for every country on the time series of all the shock processes, the model generates the clustered default of 1982. This proves to be a joint validation of the model and the estimated driving forces. Moreover, I find that the transitory global shock was most important in generating the clustered default of 1982. This counterintuitive result contradicts

[3]The shocks to output or technology affect the output of the country both exogenously and endogenously (through the labor market), but changes in interest rate work only through the endogenous channel (via the labor market).

the finding of Aguiar and Gopinath (2006), who attribute defaults to permanent rather than temporary shocks. The mechanism that drives this result depends on two features: the convex output costs of default and the high persistence of global temporary shocks. The convex output cost assumption[4] makes transitory shocks more important than permanent shocks in leading countries to default; while high persistence of global transitory shocks makes global transitory shocks more important than the country-specific transitory shocks.

The intuition for how convex costs influence the result lies in the different nature of transitory and permanent shocks. After a negative transitory shock, the output decreases today but improves later. Thus, the cost of default tomorrow is much higher than the cost of default today. This difference makes countries prefer default after a negative transitory shock. Since lenders endogenize this situation, the level of debt that countries can hold after a negative transitory shock is much lower than the average level. This problem makes the debt distribution spread out enoromously in the presence of only transitory shocks. Thus, after a few positive shocks to output, borrowing countries increase their debt holdings so much that a negative shock at that point leads to default because the deleveraging required to avoid default is too great. This channel is even more pronounced when a transitory shock is persistent because the debt distribution becomes even more spread out. For negative permanent shocks, in contrast, the output decreases and goes down even more tomorrow. The cost of default is therefore greater today, and the countries prefer to delay default. Since lenders endogenize this situation, the countries are offered a higher level of debt, and the debt distribution is concentrated around the mean. Thus, when a country faces a negative shock after a profusion of positive shocks, the required deleveraging is still small. This situation makes countries prefer deleveraging over default after permanent shocks.

Finally, even after incorporating both the channels through which interest rate can have an effect on default decisions, the full version of the model shows that the Volcker interest-rate hike was not a decisive factor for the clustered default of 1982.

The remainder is structured as follows. Section 2 discusses the related literature and the contribution of this paper to the literature. Section 3 covers the data used in the paper and defines idiosyncratic and clustered defaults. Section 4 discusses the estimation process of global and country-specific shocks. Section 5 performs the empirical exercise. Section 6 builds the model of clustered sovereign default. Section 7 concludes.

[4]The output cost assumption, although ad hoc, is similar to the one used by Chatterjee and Eyigungor (2012) and Uribe and Schmitt-Grohé (2017). More recently, Hébert and Schreger (2017) estimate the output cost of default for the Argentinean default of 2001, and the results support the assumption. In certain other 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.

2 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), who develop quantitative frameworks for the analysis of the debt and default decisions of countries. 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. The introduction of stochastic world interest rate and its two channels enable this paper to study the effect of interest rate changes on defaults. This paper, therefore, becomes the first in sovereign default literature to quantitatively study the impact of Volcker interest-rate hike on the emerging market debt crisis of 1982.

This paper introduces two global output shocks and real interest rate changes in the output specification of every country and in the specification of world interest rate. This modification makes the output of all the countries dependent on global shocks and requires a joint estimation of the parameters. Using the Bayesian method, I estimate the distribution of 196 parameters with data on the output of 24 countries and world interest rate. An estimation of this type and scale has previously not been used in the sovereign default literature. In other fields, there are some studies—Kose et al. (2003), Kose et al. (2008), Miyamoto and Nguyen (2017)—that use a similar dynamic factor method approach to disentangle different global and country-specific shocks.

The full version of the estimation includes not only the global and country-specific shocks but also the endogenous effect of world interest rate changes on the output of different countries using a reduced form. This mechanism that captures the effect of interest rate changes in the US on the output of emerging countries is microfounded in the model section of the paper. This paper makes a methodological contribution to the literature that estimates the effect of monetary shocks in the US on the rest of the world. Georgiadis (2016) and Dedola et al. (2017) use VAR methodology to estimate the same effect, 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 using the Bayesian method to capture the effect of interest rate changes. The sensitivity of output to interest rate changes estimated in this paper falls in the same range as those in the aforementioned papers, validating both the model and the estimation procedure.

To capture the effect of changes in world interest rate shocks through a model, this paper uses working-capital constraints, which is not a common approach in the sovereign default literature. The form of working-capital constraints used in this paper is borrowed from the small open economy setting of 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, but in a different setting and to answer different questions.

This paper uses a multicountry setup to study clustered defaults. Recent papers such as Arellano et al. (2017) and Park (2014) also use multicountry setup to study the risk contagion between countries. In both papers, the default premiums of the countries are linked because the lenders are common and risk-averse. Thus, an idiosyncratic shock to a particular country can propagate to other countries causing risk premiums to co-move. There are a number of differences between this paper and the contagion papers that I have mentioned. First, the contagion papers focus mainly on the recent European debt crisis, in which only Greece defaulted, whereas this paper focuses on clustered defaults in which large number of countries defaulted in the past. Second, the success of the model used in papers on contagion is measured by matching the co-movement of spreads, whereas in this paper, I match the default events in 19 countries over a period of 40 years. Lastly, the channel through which countries affect each other in the contagion papers is the presence of risk-averse lenders, whereas in this paper, the lenders are assumed to be risk-neutral. Shocks that lead multiple countries to default propagate either through output decline or through increased world interest rate. Borri and Verdelhan (2011) features correlated shocks between the borrowing countries and the lending countries along with risk aversion on the lender side. My paper does not assume correlated shocks between borrowers and the lenders, as Borri and Verdelhan (2011) does. I examine global shocks, which affect different borrowers differently, whereas lenders remain risk neutral.

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 also used in 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. Since these mechanisms work through the presence of multiple equilibria, or sunspots, they are also plausible mechanisms for generating 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 will capture all of them. The only requirement is that the slowdowns in output happen for multiple countries and they must be captured as global output shocks in my estimation procedure.

Lastly, this paper also contributes to the empirical literature on clustered defaults. Most notable papers that focus on clustered sovereign defaults are Bordo and Murshid (2000) and Reinhart and Rogoff (2011a). Bordo and Murshid (2000) examines the possibility of contagion in crisis episodes over three different eras. By comparing the extent of co-movements across markets before and after the onset of a crisis, they find little evidence of the contagion phenomena in more recent crises of Asia and Latin America. Reinhart and Rogoff (2011a) document the clustering effect of crises, calling them serial defaults, using data from more than two centuries. Kaminsky and Vega-Garcia (2016) remains one of the few papers to perform a detailed empirical investigation of the possibility of global shocks—panics to financial centers—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. Furthermore, they consider the international collapse of liquidity and the growth slowdown in the financial centers to be responsible for clustered defaults. The default definitions as well as the preliminary empirical setup used in this paper follow Kaminsky and Vega-Garcia (2016) but my paper uses a dataset of 92 countries and 146 sovereign defaults between 1975 and 2014. Contradicting the results of Kaminsky and Vega-Garcia (2016), the empirical setup shows that global transitory shocks rather than permanent ones were mainly responsible for the clustered default of 1982.

3 Clustered and Idiosyncratic Sovereign Defaults

3.1 Data

The paper is divided into three main sections: the estimation section, the empirical section and the model section. I start with the estimation section, in which data on country-specific output growth and the world interest rate are used. 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. In the model section, the calibration of different parameters requires country-specific data.

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. I use data on the real GDP of all borrowers along with some developed countries[5] that did not default in the sample period. I construct the data on the world real interest rate by using the 5-year treasury constant maturity rate and adding a market risk spread. This spread is constructed by using Moody's seasoned BAA-rated corporate bonds and Moody's seasoned AAA-rated corporate bonds. All three 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.

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.[6] 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 1, 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[7] subsequent to the default episode during which the countries remained in default status.[8] 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

[5]France, Italy, Japan, United Kingdom, and United States–the biggest countries at the start of the data period.

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

[7]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.

[8]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.*

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.

Table 1: 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

In the model section, I use the same GDP data and the world real interest rate data that I use during the estimation exercise. To calibrate the model, I use data on default frequency from Reinhart and Rogoff (2011b). When those data are 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). The data on net foreign assets as a fraction of GDP are the same as those used in the empirical section. The data on average years in default come from Reinhart and Rogoff (2011b). If they are unavailable, I again use the data from Uribe and Schmitt-Grohé (2017).

3.2 Definition

Clustered defaults are those default episodes that occur during periods when a great number of countries are defaulting on their external debt obligations. To capture the clustered defaults, this paper follows the same definition as that proposed by Kaminsky and Vega-Garcia (2016). The first step in their approach 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 in every year from 1975 to 2010.[9] For every such window, I count the number of countries that defaulted in the 5-year window.[10] 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

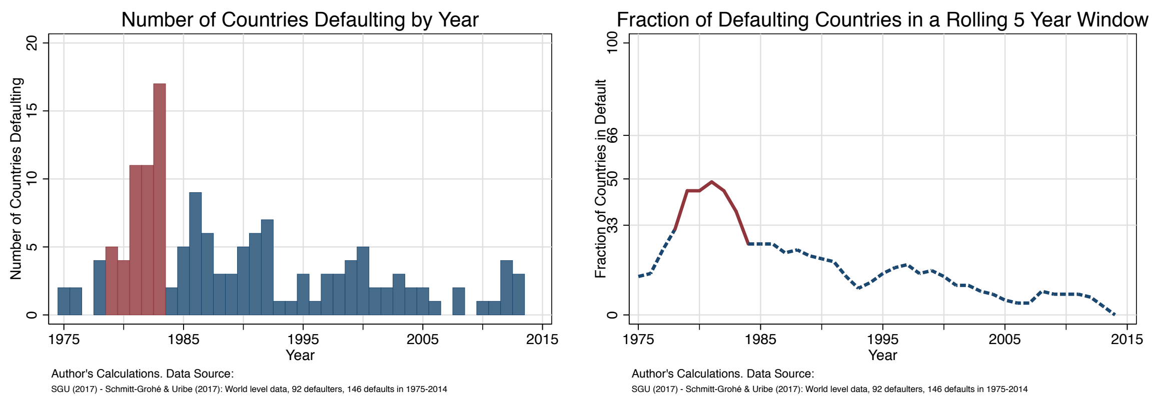
[9] Since the data on default goes from 1975 to 2014, the last rolling window containing 5 years is 2010.

[10] 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.

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".[11] All the remaining defaults are "idiosyncratic defaults".

3.3 Categorizing Defaults as Clustered or Idiosyncratic

Figure 2: Countries defaulting in a 5-year rolling window



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.

Given the definition of clustered and idiosyncratic default episodes 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 2 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 2 shows that out of 146 defaults, 48 fall in the category of clustered defaults by this definition. Automatically, the remaining 98 defaults become idiosyncratic defaults.

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

[11] 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.

Table 2: 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

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.

Figure A1 in the appendix shows the years of clustered defaults for regional classification. The summary of the same data is presented in Table 2. Thirty-four 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% to 45% of all defaults between 1975 and 2014 were clustered.

This paper, henceforth, considers the world-level classification for the analysis 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.

4 Estimating Global and Country-Specific Shocks

The output of every country is assumed to have two country-specific and two global components. I postulate the time-varying processes for these components of output and then estimate the parameters governing these processes and those of the output function using the Bayesian method.

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 produced using labor. I then make some identification assumptions to estimate the parameters in this full version. The purpose of this full version is to capture the effect of changes in world interest rate shocks on the output of emerging economies.

4.1 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.

As the name suggests, global shocks affect the output of all the countries. The way these global shocks affect different countries is different; therefore, the way the global shocks enter the output process of different countries is also different. Thus, the same global shock can affect, for example, Argentina completely differently than it affects Mexico.

The presence of global shocks in the output process of all the countries makes it necessary to observe the output processes of all the countries jointly in order to estimate the parameters governing the output, the country-specific shock processes and the global shock processes.

I start by writing down the output of country c, at given time t (omitted from the equation for convenience) 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.[12] 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. In the log specification of output, the global components—z^w and $\ln(X^w)$—enter with a multiplicative factor of α_z^c and α_X^c, respectively. 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, trade of goods or services, etc. If this interaction is negligible, then the values of both αs is close to zero. In contrast, if the interaction is sizable, we find that both αs have a nonzero value. In terms of natural logarithms, the equation can be written as:

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

Both the transitory components—z^c and z^w—are assumed to follow an $AR(1)$ process with persistence ρ_z^c, ρ_z^w and standard deviation σ_z^c, σ_z^w respectively. The long-run mean of both the transitory components is assumed to be 0.

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

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

[12] The detrended version of output will therefore be $\tilde{Y^c} = Y^c/(X_{-1}^c \times \mu_g^c \times (X_{-1}^w)^{\alpha_X^c} \times (\mu_g^w)^{\alpha_X^c}) = e^{z^c + \alpha_z^c z^w} g^c (g^w)^{\alpha_X^c} / \mu_g^c$, where $g^c = X^c / X_{-1}^c$, $g^w = X^w / X_{-1}^w$ and $\mu_g^w = 1$.

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 ρ_g^c, ρ_g^w; standard deviation σ_g^c, σ_g^w; and long-run means of g_{ss}^c and g_{ss}^w.

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

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

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

When the output growth rate for the countries is treated as observable, the output equation for country c can be rewritten as:

$$y_t^c - y_{t-1}^c = z_t^c - z_{t-1}^c + \alpha_z^c(z_t^w - z_{t-1}^w) + \ln(g_t^c) + \alpha_X^c \ln(g_t^w)$$

This 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, $\ln(g_t^c/g_{ss}^c)$.

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

As the equation suggests, 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 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 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 Δy_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, θ_t, is $((3 * nc + 3)$

$\times 1$). The evolution of the state vector (transition equation) can be represented as:

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

Section B.1 of 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 as observable, thus obtaining a total of 19 countries. If I estimate the latent states using this set of 19 countries, my estimates of global state variables may be biased due to the presence of only defaulting countries. To avoid this bias, I add 5 developed countries—France, Japan, Italy, the United Kingdom, and the United States—taking the total number of countries to 24.

Since the output process of every country comprises four components, I have (i) two country-specific shock processes—z^c and $\ln(g^c)$—for every country, (ii) two global shock processes—z^w and $\ln(g^w)$—and (iii) two coefficients corresponding to the global shocks—α_z^c and α_X^c—for every country. For every component, I estimate the persistence and the variance of the process. With the data on 24 countries, I thus have 96 parameters related to country-specific shocks (ρ_z^c, ρ_g^c, σ_z^c and σ_g^c for every c). Moving on to global shocks, I normalize the standard deviation of the world shocks to 1 without loss in generality because α_z^c and α_X^c can account for any scale effect arising from a different value of standard deviation.[13] Once the standard deviation of the world shocks is normalized to 1, the direction and the volatility of the effect of world shocks on a specific country will be governed by country-specific factors: α_z^c, α_X^c. Thus, there are 48 more parameters that govern the effect of global transitory and permanent components on the output of individual countries. Finally, 2 persistence parameters remain: for global transitory and permanent shock processes. Together there are 146 parameters to estimate.

The average growth rate of countries, μ_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: I restrict α_z^c and α_X^c to be positive because a particular time series, z^w and $\ln(g^w)$, and the corresponding multiplicative parameter values, α_z^c and α_X^c, generate a particular

[13] Both z^w and $\ln(g^w)$ appear along with the α_z^c and α_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 σ_w^z as well as σ_w^g to 1.

time series of global shocks to every country's output. If there are no restrictions on α, a time series that is negative of z^w and $\ln(g^w)$ along with the opposite signs of α_z^c and α_X^c will also generate the same contribution to every country's output. To eliminate this multiplicity, I assume that for Venezuela, $\alpha_z^{VEN} > 0$ and $\alpha_X^{VEN} > 0$.

The paper uses the Bayesian method to estimate the parameters pertaining to the output process of all the countries. I start by using the output growth data on 24 countries from 1961 to 2014. I assume a uniform prior for all the parameters and apply the Kalman filter to calculate the likelihood given the past data. The calculated likelihood along with the prior produces the posterior likelihood. The Metropolis-Hastings algorithm and the sequence of posterior likelihoods yield an approximate posterior distribution of all the parameters.

The prior distributions are shown in Table A5 in the appendix. All the persistence levels, country-specific as well as global, are assumed to have the same uniform prior distribution. The standard deviations of global shocks are normalized to 1, but all the country-specific standard deviations also have the same prior distribution. The prior for the α values for Venezuela is between 0.0001 and 2, but all other α values have a uniform prior between -2 and 2. With a Markov chain of 1 million draws, the posterior means of ρ_z^w and ρ_g^w are estimated to be 0.94 and 0.50. The posterior means for the remaining parameters are shown in Table 3. Among the 4 output shocks, global shock to the transitory component with a persistence of 0.94 is the most persistent shock.

Given that all the prior distributions are assumed to be uniform, the posterior distributions show that they differ significantly from the prior distributions.[14] Table A7 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 ρ_z^w reported to be 0.04 in Table A7. Some of the parameters related to the persistence level are not very precisely estimated. Table A7 shows that the posterior distribution of the standard deviations is precisely estimated for all the countries. Though mean α values are positive for most of the countries, as shown in columns 7 and 8 of Table A7, and the distributions of these α values are also precise, it is difficult to say whether the α values differ significantly from 0 for some of the countries.

I use mean values from the posterior estimates of all the parameters and use the Kalman smoothing algorithm to smooth out all the latent shocks that different countries face. Figure A5 in the appendix shows the time series of the global transitory and permanent components of output. The top panel shows a large negative transitory shock in the early 1980s and then a small negative transitory shock around the great recession. The bottom panel shows multiple

[14]Posterior distributions are not shown here. Only Mean and standard deviations are reported.

Table 3: Bayesian Estimation Results from Basic Model: Posterior means

Country	Posterior (Means)					
	ρ_z^c	ρ_g^c	σ_z^c	σ_g^c	α_z^c	α_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

Posterior means for ρ_z^w and ρ_g^w are 0.9414 and 0.5038 respectively
The countries included in the estimation process are 24. 19 defaulting countries from Latin America & Caribbean and 5 non-defaulting developed countries. Parameter estimates are reported only for 19 Latin America & Caribbean countries.

permanent shocks, but those with the greatest impact are observed during the early 1980s and just before the 1990s. Both time series are scaled to the parameters of Argentina. Thus, the time series show that during the early 1980s, Argentina faced a negative transitory shock that took detrended GDP to 9% below 1 in 4 years, and the negative permanent shock that took it to 7% below 1 in 3 years.

The time series obtained using the Kalman smoothing algorithm is used for the empirical exercise performed in the next section. The time series is also used in the model section when I simulate the optimal debt and default decision for all the countries.

4.2 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 changes in the world interest rate on output but can also be microfounded in a general equilibrium framework. This is done in Section 6.1 when I discuss the model of sovereign default. 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.[15]

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 κ is a constant and $\tilde{A}$ is the detrended level of technology.[16] The output can, therefore, be rewritten as:

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

Taking logs, I can write the output growth in the full version as:[17]

[15]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.

[16]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 μ can be taken into account by a different value of α_L^c.

[17]This equation of output growth looks exactly like the one that we get from the model which is solved in a general equilibrium framework. The interpretation of coefficients in this equation are slightly different than the ones obtained from the model because the later is based on the parameters of the model.

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

where $\psi^c = 1 + \alpha_L^c$.

The 4 basic sources of shocks remain the same in the full version as in the basic version—z_t^c, z_t^w, $\ln(g_t^c)$, and $\ln(g_t^w)$—although the interpretation of these shocks changes a little. In the basic version, all four processes are components of the output process. In the full version, they are components of technology (henceforth TFP). Thus, the four components of TFP follow the same process as their counterpart in the basic version. The parameters governing these processes also remain exactly the same.

An additional source of change in output growth is the stochastic world interest rate. The equation above shows that a 1% increase in 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 Δy_t is $(nc \times 1)$ (where nc is the total number of countries). W_t is not currently time invariant, 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 θ_t is $((4 * nc + 4) \times 1)$. The evolution of the state vector (transition equation) is represented as:

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

Section B.2 in the 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, ψ^c and η^c must be estimated for all the countries, which brings the total number of parameters to 194.

Table 4: Bayesian Estimation Results from Full Model: Posterior means

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

Posterior means for σ_z^w and σ_g^w are 0.8897 and 0.7555 respectively

The countries included in the estimation process are 24. 19 defaulting countries from Latin America & Caribbean and 5 non-defaulting developed countries. Parameter estimates are reported only for 19 Latin America & Caribbean countries.

The 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 A6 in the appendix. The priors are again uniform and are the same as in the basic model. For ψ and η, I use the equation from the model. In the model, ψ depends on the labor share as well as the Frisch elasticity of labor supply; thus, I assume a uniform prior from 1.01 to 4.[18] In the model, η is a fraction of the wage bill needed in advance. I use a uniform prior between 0.0001 and 0.9999 for η.

Table 4 reports the mean of posterior distribution from a Markov chain of 2 million draws. Table A8 in the appendix reports both the mean and the standard deviation. Table 4 shows that the global shocks to both transitory and permanent components of TFP are very persistent, $\rho_z^w = 0.89$ and $\rho_g^w = 0.76$. Some negative values of α_X^c show that global shock led some countries to see increased growth when other countries experienced a growth slowdown. The values of ψ^c are close to 2 rather than the prior mean of 2.5. Values of ψ^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 means $\omega = 1.4$ which is close to what other papers use in the macroeconomics literature.[19] Values of η^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%.

Table A8 shows that the persistence parameters are much more precisely estimated in the full model than in the basic model. Small standard deviations for α values show that α is more precisely estimated than in the basic version, and the table also shows that α values are statistically different from 0 for many countries. Standard deviation values for ψ^c and η^c show that those values are also precisely estimated. The standard deviations are much smaller for ψ^c than for η^c.

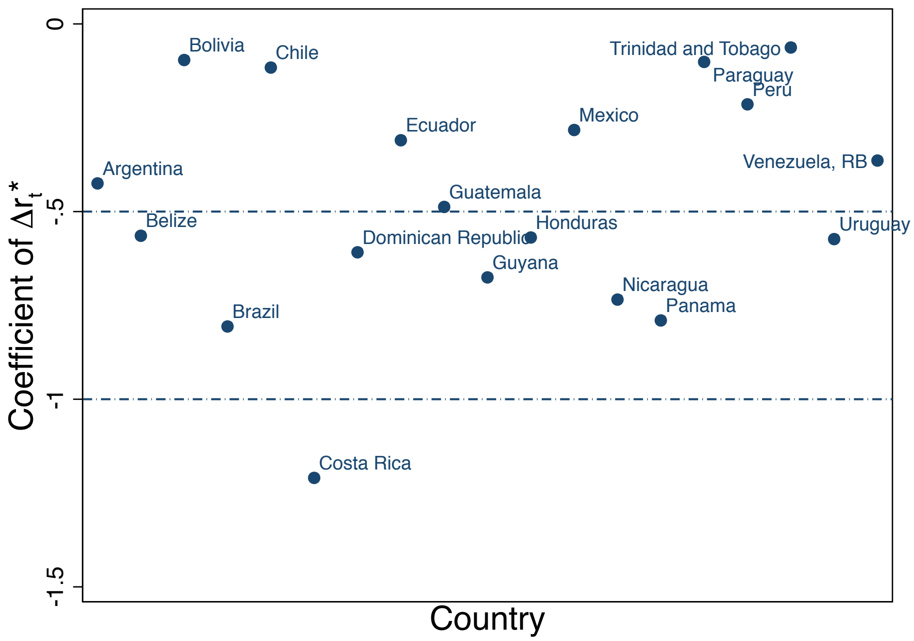
Given the values of ψ^c and η^c, I calculate the value of $-(\psi^c - 1) \cdot \eta^c$, which is the coefficient of Δr^* in the output growth equation of the full version. This value shows the change in output that a borrower experiences if the world interest rate changes by 1%. Figure 3 shows the magnitude 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.

Using the mean values from the posterior estimates of all the parameters, I use the Kalman smoothing algorithm to smooth-out the latent global shocks and the country-specific shocks

[18]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 calculate ω to vary from 1.2 to 6 given that I allow the Frisch elasticity to vary from 0.2 to 5. Additionally, α_L is labor share, which is considered close to 0.7, and I assume it to vary from 0.3 to 0.9. Thus, the value of $\psi = \omega/(\omega - \alpha_L)$ varies from 1.0526 to 4, which is a subset of the interval of my prior on ψ.

[19]Mendoza (1991), for example, uses $\omega = 1.455$, which gives a Frisch elasticity value of 2.2.

Figure 3: Coefficient of Δr^* from output growth equation: $-(\psi^c - 1) \cdot \eta^c$



that different countries face, exactly as in the basic version. Figure A6 in the appendix shows the time series of the global transitory and permanent components of output. The top panel shows a large negative transitory shock that began in the early 1980s and reached a minimum in 1990. Another large negative transitory shock occurred in the early 2000s. The bottom panel shows multiple permanent shocks, but those with the greatest impact are observed during the 1975s and 1980s and at the onset of the great recession. In the basic version, it was the transitory shock to output that hit during the great recession, but here, it is the permanent global shock. As before, both time series are scaled to the parameters of Argentina.

The time series obtained using the Kalman smoothing algorithm is used in the model section when I simulate the optimal debt and default decision for all the countries.

5 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.[20] 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.

5.1 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:

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

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, $\log(g^c/g_{ss}^c)$. The estimation also provides the parameter through which

[20] 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.

global shocks affect the output of country c: α_z^c and α_X^c. Thus, I construct the aggregate transitory and permanent shocks—$z^c + \alpha_z^c z^w$, $\ln(g^c/g_{ss}^c) + \alpha_X^c \ln(g^w)$—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 4 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 4 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.

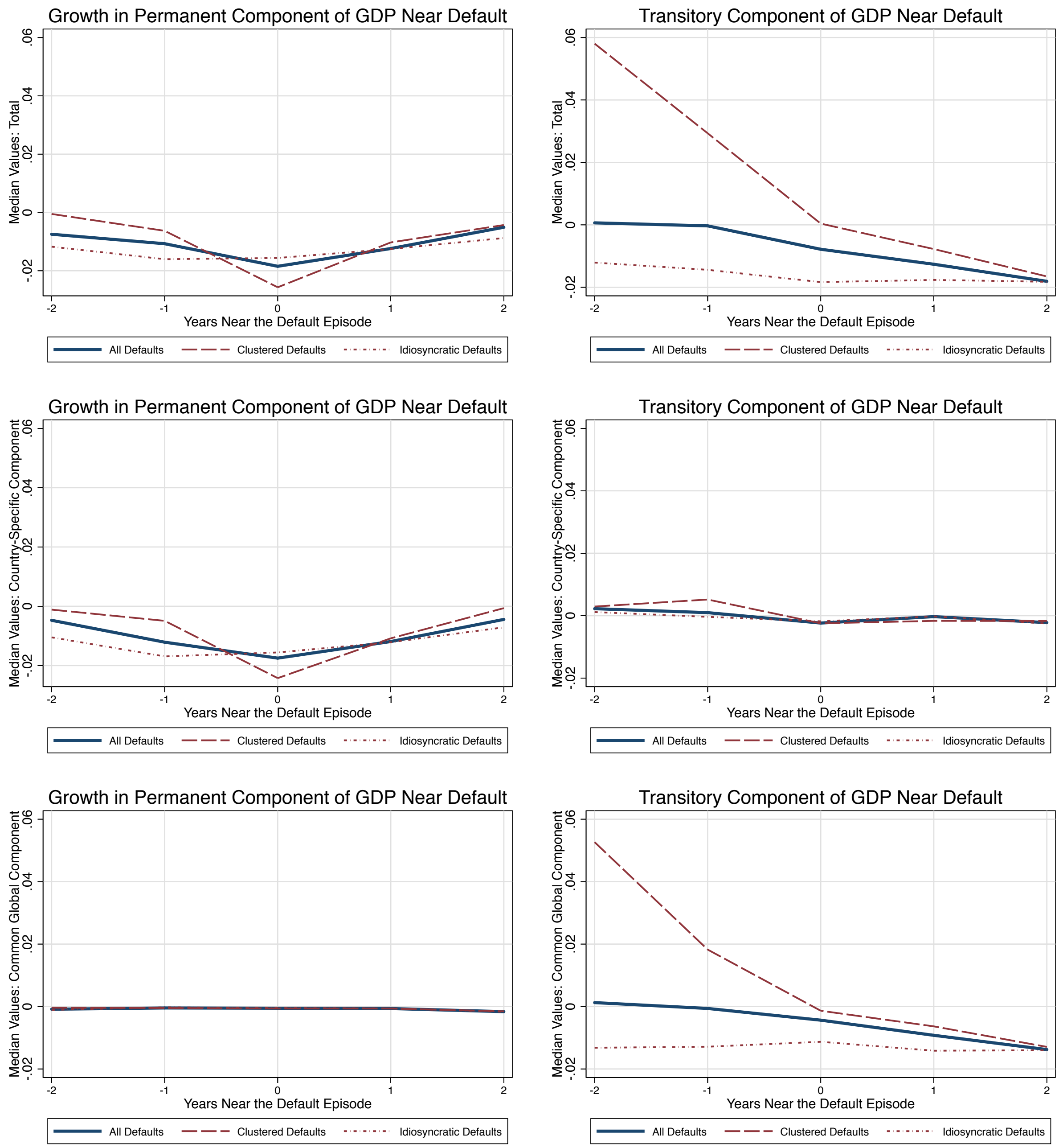
Another point to note in Figure 4 is that the decline in the transitory component of the GDP is much more severe than the actual magnitude of the transitory component, even in the year of default. Growth in the permanent component, on the other hand, is negatively affected for most of the defaulters.

The results for permanent and transitory shocks presented in Figure 4 remain robust to HP-filtering the output series of individual countries to obtain the cycle and the trend growth. [21]

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 5 shows that the clustered defaults were accompanied by higher risk-free interest rates, while idiosyncratic defaults occurred at a median risk free rate of approximately 4%.

[21] 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.

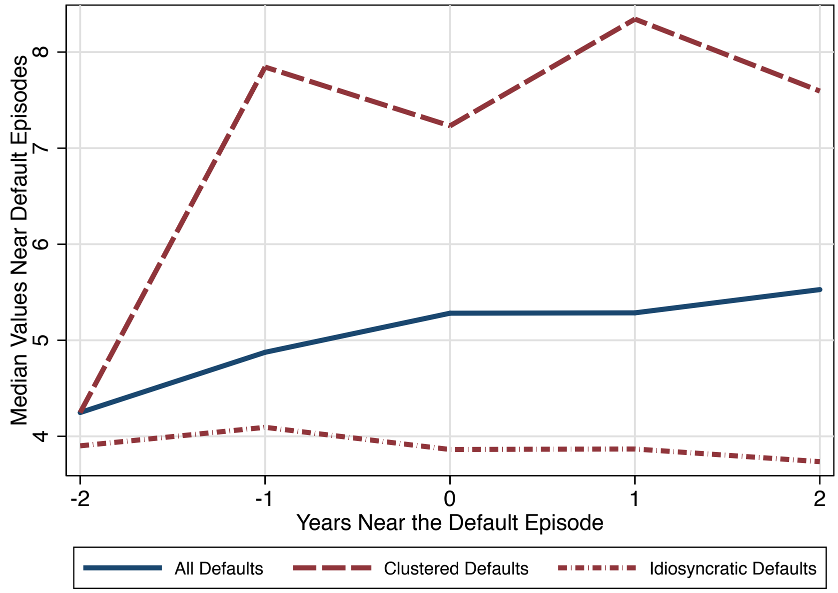
Figure 4: Transitory and permanent components of output near default



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 5: 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.

5.2 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.[22] 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 markets.[23]

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

[22]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.

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

asset position as a percentage of GDP.[24] 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 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

[24]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).

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,

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

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

5.3 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.

5.3.1 Specification with Country-Specific Variables

Table 5: 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	

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

Motivated by the set of stylized facts discussed in section 5.1, 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 5. 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 A2 in the appendix. Table 5 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 5 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 5. 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.

5.3.2 Specification with Country-specific and Global Variables

Column 4 of Table 5 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 5 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 4. 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 A3 in the appendix. This figure shows that our estimates in column 5 of Table 5 are close estimates of the actual marginal changes.

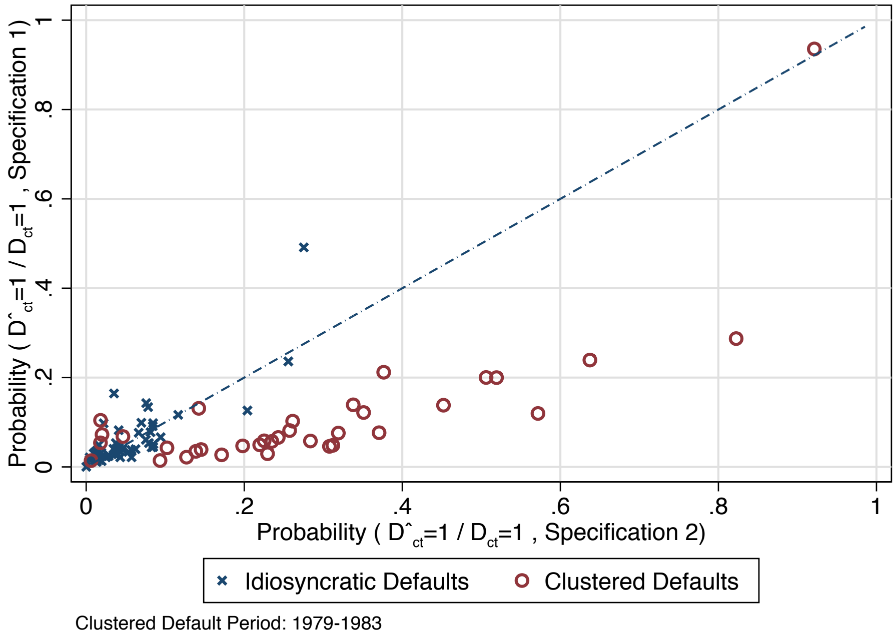
With summary statistics of the explanatory variables in Table A1 and the marginal effects of these explanatory variables in Figure A3 in the appendix, we can return to examine the contributions of different global shocks in leading countries to clustered defaults vis-à-vis idiosyncratic defaults. As shown in Figure 5, 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 4 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.

5.3.3 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 6 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 6 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,

Figure 6: Predicted probabilities of default using specification 1 and specification 2



which is also evident from the low pseudo-R^2 values in Table 5. Even though the values of the predicted probabilities are low, Figure 6 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 6 presents the results of Figure 6 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.

Table 6: 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

The results in Figure 6 and Table 6 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 A4 and Table A3 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 7: 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

Table 7 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 7. 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 A4 in the appendix shows that both results are robust to change in the explanatory variables.

6 Model

The empirical section highlights two important facts: (1) Global variables are mainly responsible for leading countries to default during clustered default episodes but play no role during idiosyncratic defaults, and (2) among global shocks, it is the shocks to the transitory component of the output and the shocks to interest rate that seem to drive clustered defaults. In this section, the paper 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 causal impact of these global shocks on default decision through the lens of a sovereign default model.

The model is built on a standard Eaton-Gersovitz framework. I start with a basic version of the model in which the output has country-specific transitory and permanent components as well as global transitory and permanent components. At the begining of the basic version, the world interest rate is assumed to be constant in order to assess the relative impacts of different output shocks on default decisions. I then make the world interest rate stochastic so that changes in the interest rate can influence default decisions through changes in the price of debt. This change enables the model to assess the contribution of world interest rate shocks, through the *debt-pricing channel* relative to the contribution of output shocks. Finally, I build an full version of the model that incorporates financial frictions in the form of working-capital constraints at the firm level. The presence of financial frictions enables changes in the world interest rate to affect the default decision through endogenous changes in the output of the borrowing countries. The full version assesses the contribution of world interest rate shocks, through the *debt-pricing channel* and the *endogenous output channel*, relative to the contribution of output shocks.

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[25] was not a determinant factor of the 1982 developing country debt crisis.

6.1 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 Aguiar and Gopinath (2006)and Arellano (2008). The model features incomplete markets due to the presence of single-period non-state-contingent debt that countries use to borrow. In the absence of a commitment device, the countries can optimally chose to default on the outstanding debt in certain periods.

The framework of the model is built on the assumption of exogenous but stochastic output realizations. I begin with the same assumption as 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 to a high degree, I explain the full version of the model here and present equations related to the basic version in Section C.1 in the 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. Neither households nor firms are 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 from foreign lenders, and they do not default on these loans.[26] The government, however has no commitment device and is free to default if defaulting is optimal. Foreign lenders are assumed to be risk neutral.

[25]The Volcker interest rate hike, in nominal terms, was large. Even after adjusting for inflation i.e. in real terms, interest rates increased a lot. This increase can partly be observed at the start of the 1980s from Figure A8 in the appendix.

[26]The rate on these loans is the rate on US treasury plus the spread between BAA-rated Moody's 5 year bonds and AAA-rated Moody's 5 year bonds. This rate captures the increase in risk aversion among the investors that is not coming from country risk. This rate is then discounted by expected inflation data from the survey of professional forecasters. This rate might not reflect the rate at which the firms in the borrowing country get loans at but as long as the changes in these rates are consistent or even proportional, results remain the same.

Households

The household gains utility from consuming the final good and gains 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 γ represents the Arrow-Pratt measure of relative risk aversion, $1/(\omega - 1)$ is the Frisch elasticity of labor supply and Γ 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 by the labor term to make it grow over time.

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 borrows, 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. Households make consumption and labor supply decision in every period t. Since households are not directly involved in borrowing and holding debt, they make no intertemporal decisions. 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 producer that demands labor to produce output in every time period t.[27] To hire labor and produce output, firms need working-capital in advance. The working-capital requirement forces firms to have a fraction of total labor wage payments in advance. To finance working-capital, firms obtain intraperiod loans from foreign lenders.[28] 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 begining 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 α_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 ϕ is a function of technology shocks and takes a value of 0 in normal times. When a country defaults, the country suffers a dip in TFP, and the function ϕ governs this decrease in TFP.

Like households, firms do not borrow via the single-period debt from foreign lenders. Additionally, assuming no role for capital accumulation dynamics spares us 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

[27] We abstain from dealing with capital, but an assumption of constant capital stock also works. The reason is to abstain from capital accumulation dynamics.

[28] Alternatively, we can include banks in the model and assume that firms obtain these intraperiod loans form home-country banks, and the banks have some endowment.

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 for an extra worker but also pays the interest on the intraperiod loan that it needed in order to hire an extra worker. This intraperiod loan is a fraction of the wage of that additional labor; hence, the total interest on that intraperiod loan is $\eta r_t^* w_t$. This is the extra term in the firm first order condition.

Government

The aim of a benevolent social planner or the government is to maximize the utility of households. Unlike households and firms, 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 proceeds from the borrowing to households as a lump-sum transfer. Additionally, the government repays the outstanding debt.

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 λ 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 be repaid in the next period. 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, most papers in the literature use recursive dynamic programming 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 λ 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:

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

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 ($F_t = 0$), it has 0 debt to repay and cannot incur any new debt. Additionally, the agent faces an exogenous decrease in TFP that reduces its output and hence consumption 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 λ.

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

subject to the household and firm equilibrium conditions and with a transfer to households of 0. In this case, the function ϕ, which governs output loss in default, will also be nonzero. The function ϕ, and thus the output loss in default, depends on individual technology shocks.

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.

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

The default rule is therefore given as:

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

Lender

The last piece of the model is the lender side. I assume a large number of risk-neutral lenders. 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 good, 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 Π^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.

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[29] 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 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.

6.1.1 Model Calibration

The calibration is performed separately for every version of the model. There are three 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. I begin with the basic version of the model with a constant interest rate; continue to

[29] An event that occurs with probability λ after entering the period in bad standing.

the basic version, where the interest rate fluctuates; and finally continue to the full version of the model.

The parameters in the model are related to the coefficient of relative risk aversion (γ), the world interest rate (r^*), the average yearly growth rate of the country (μ_g^c), the probability of rejoining the financial markets after default (λ), and impatience (β). Additionally, for the basic version, I use the following loss function specification:[30]

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

which provides us with two more parameters (a_1, a_2). Since the expression in the ϕ_t function is same as the output of the country, total output net of output loss is effectively: $y - y \cdot \max\{a_1 + a_2 \cdot y\}$. This is similar to the quadratic output loss specification used in Chatterjee and Eyigungor (2012). The full version of the model will have an output loss function which looks a bit more complicated that the one used in the basic version. This is due to the presence of the interest rate shocks that effect output of the country. Nonetheless, total output net of output loss in the full version will also boil down to the same expression. Hence, I have the same two parameters (a_1, a_2) in the full version of the model.

Table 8: Calibrated Parameter Values

	Parameter Value	Example	Comments
γ	2	Standard	
r^*	3.67% pa	Standard	Average value from 1960 to 2014
μ_g^c	C-specific	1.025 for Arg	
λ	C-specific	0.095 for Arg	Matched 10.5 years in default on an average in 200 years
β	C-specific	0.83 for Arg	~ 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 β, a_1, and a_2 correspond to the first version of the baseline model

The coefficient of relative risk aversion, γ, follows the existing literature. For example, Mendoza (1991), Arellano (2008) etc. assume γ to be equal to 2.

Since a unit of time in the model is a year instead of a quarter, the world interest rate, r$*$, is calibrated to the average value between 1960 to 2014. This provides $r^* = 3.67\%$.

Steady state growth rate is different for different countries. Thus, to calibrate μ_g^c, I take the average yearly growth rate from the data spanning 1960 to 2014 for all the countries. For

[30] 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.

example, $g^{ss}_{Arg} = \mu^{ss}_{Arg} = 1.025$ 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, λ, I use data from Reinhart and Rogoff (2011b) 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, β, 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.

6.1.2 Grid Size

I solve the model using finite state-space method. I, therefore, begin by detrending all the variables and 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: $\{z^c_t, z^w_t, g^c_t, g^w_t\}$. In the full version of the model, I also have $\{r^*_t\}$. The debt level, $\{d_t\}$, is an endogenous state variable.

I use 7 grid points for each of the output shocks taking 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 when I simulate the time series of the Kalman smoothed state variables to feed into the model. I, therefore, analyze the grid points that I use to approximate the movements of the state variables and examine whether these grids can simulate the estimated global state variables. Figure A7 in the appendix shows the detrended output for the basic model and for the full model. Each panel shows a version obtained from the Kalman smoothing algorithm as well as a version which is simulated through $7 \times 7 \times 7 \times 7$ grid points. It can be observed that the version simulated through the grid points matches the original Kalman smoothed version very well. Thus, the number of grid on output match the movement of detrended output very closely.

Simulation of state variables also requires simulating the interest rate through the grid points. For this purpose, I match the interest rate simulated through grid points and the actual movement of interest rate in the data to test if 10 grid points are sufficient to match the movements. Figure A8 shows that 10 grid points are sufficient to simulate the interest rate movements and this matches closely with the actual movements in data.

6.1.3 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 parameters α_z^c and α_X^c for every country. Given these grids and transition probability matrices for the global shocks, the model is solved on country-by-country basis. For calibrating the parameters of the model, the moments are matched for one country at a time. The remaining algorithm for model solution remains similar to one available online from Uribe and Schmitt-Grohé (2017).

One more addition in the model, and hence the algorithm, is the introduction of firms and thus, labor. This addition doesn't come at a very big cost because equilibrium quantity of labor can be solved analytically, both when country wants to default and when it does not. Therefore, labor, with and without default costs, can be calculated based on the 5 exogenous state variables—4 output shocks and interest rate. This gives a closed form solution for output as well as consumption based on the values of all 6 state variables, the sixth being initial debt level. Thus, current utility can be calculated using the utility function and it can then be used to calculate the flow utilities. Once the flow utility is calculated, the remaining part of the algorithm becomes similar to the standard algorithm available from Uribe and Schmitt-Grohé (2017).

Once the model is solved, simulation is relatively straight forward as the time series of global and country-specific shocks are already available for every country from Section 4. The time series for these output shocks as well as the interest rate are available from 1960 to 2014. I assume the initial debt in 1960 to be 0.[31] Given the endogenous state—debt level in 1960—and the exogenous states—four output shocks and the interest rate—every country chooses the default decision for 1961. Additionally, if the country chooses not to default in 1961, the country chooses the debt level. If the country choose to default in 1961, the initial debt level in 1961 automatically goes to 0. Thus, the optimal debt and default decision in 1961 proves a value for endogenous state variable in 1961, d_{1961}. Repeating this process till

[31]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 2 or 3 years after the start of the period. Countries increase or decrease the debt level very quickly.

2014, I get the time series of default decision for all the countries. Aggregating across all the countries, I plot the percentage of countries defaulting in a rolling 5-year window for every year from 1960 to 2010.

6.2 Model Performance

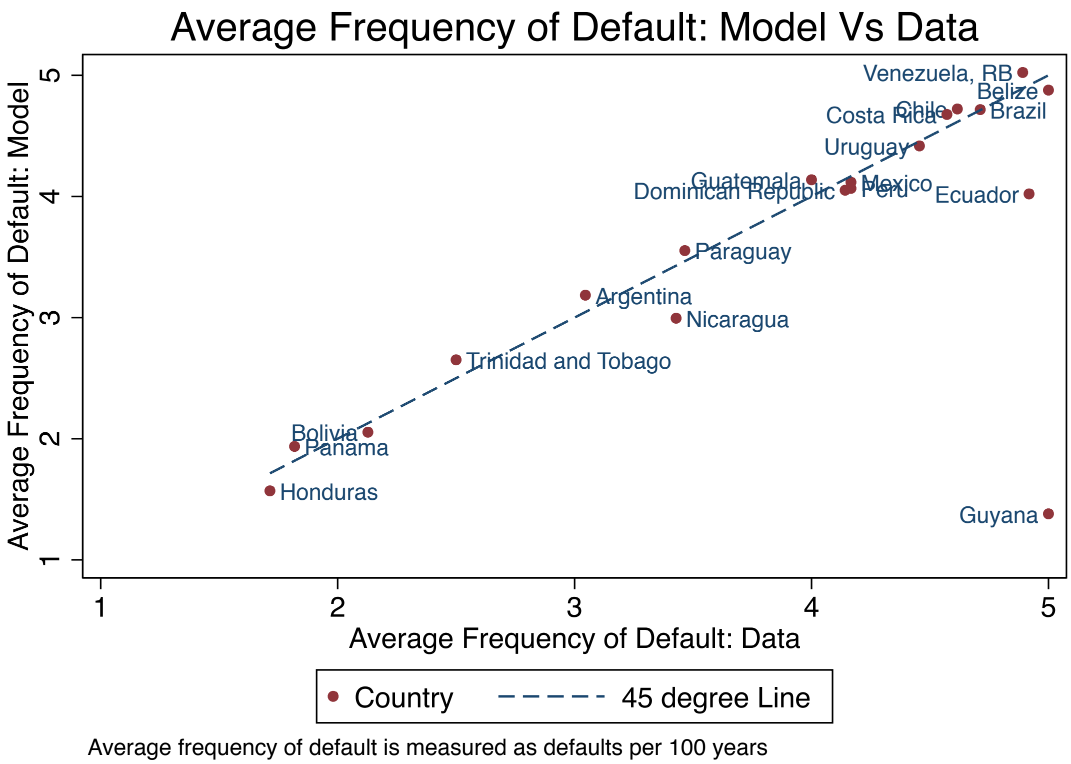
Before exploring the simulation of optimal debt and default decisions for different countries, I start by evaluating the performance of the model based on a set of moments in the data and their counterpart from the model. Some of these moments were targeted while calibrating the parameters of the model; hence, these moments are expected to have a good match in the model and as they are in the data. Some additional moments—mean and standard deviations of risk spread; correlation between spread and output; correlation between trade balance to output ratio and spread—were not targeted by the model, and comparing these moments from the data and the model gives us more information about the performance of the model. I find that the model does extremely well in matching most of the moments from the data. This result shows that apart from matching the clustered default, that I show later, the model exhibits remarkable performance in multiple other dimensions too.

Figure 7 shows the moments generated by the model and the moments observed in the data.[32] While performing the calibration, I chose the parameters related to discount rate, β, and the output loss function, a_1 and a_2, differently for every country to match the average default frequency per 100 years and the average debt level as a percentage of output in the country. Since I target these moments, Figure 7 shows that the match of the model-generated moment and the moment from the data is very good except in the case of Guyana. The data show that Guyana, on average during non-default periods, held a negative net foreign asset amount equivalent to 144% of its output after accounting for 90% of the average haircut level. This high level of debt coupled with a default rate of 5 times per 100 years is hard to match. The model attempts to go as high as possible in terms of average debt as a percentage of output. Thus, Guyana holds a debt of approximately 60% of its output, but there is a sacrifice in terms of default frequency, which drcreases to 1.4 defaults per 100 years.

The next two figures, Figure 8 and Figure 9, show the moments that were not targeted by the model. Both the figures present moments related to country spread. These moments, mean and standard deviation, require data on spreads that comes from J.P. Morgan EMBI database. The database contains the global stripped spreads for only 10 of the 19 countries included in the paper. Thus, the moments are matched only for these 10 countries.

[32] Figure 7 and the subsequent figures compare moments from basic version of the model with data.

Figure 7: Targeted moments: default frequency and average debt in nondefault periods



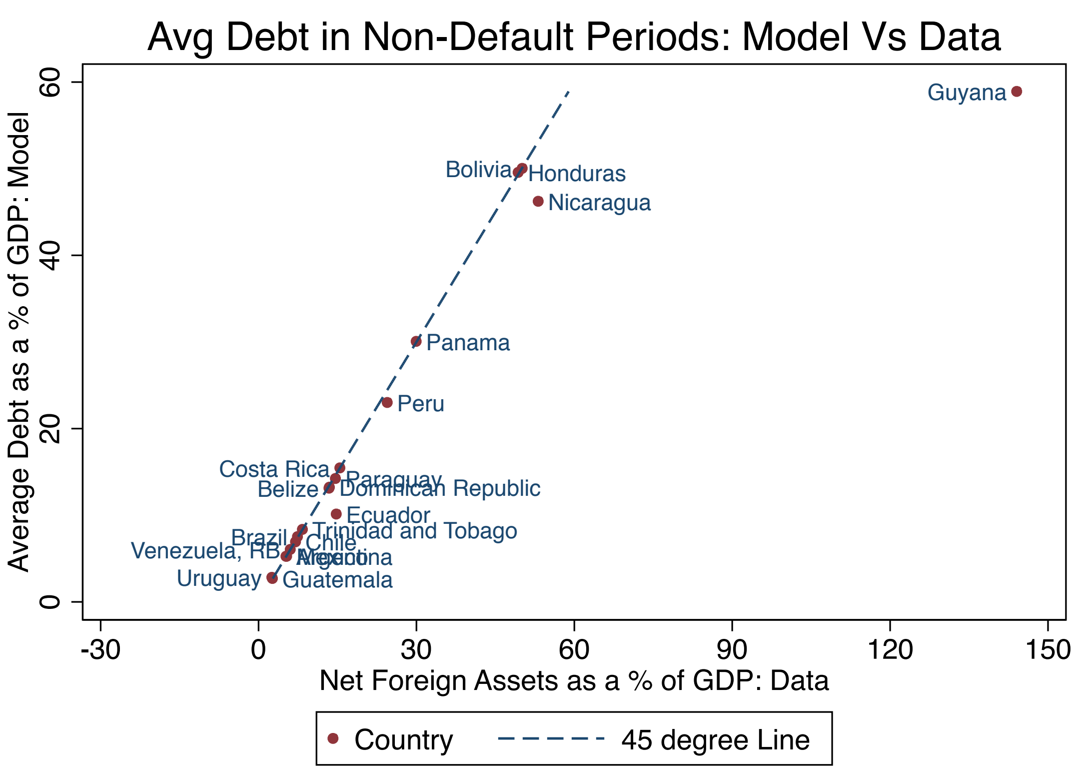
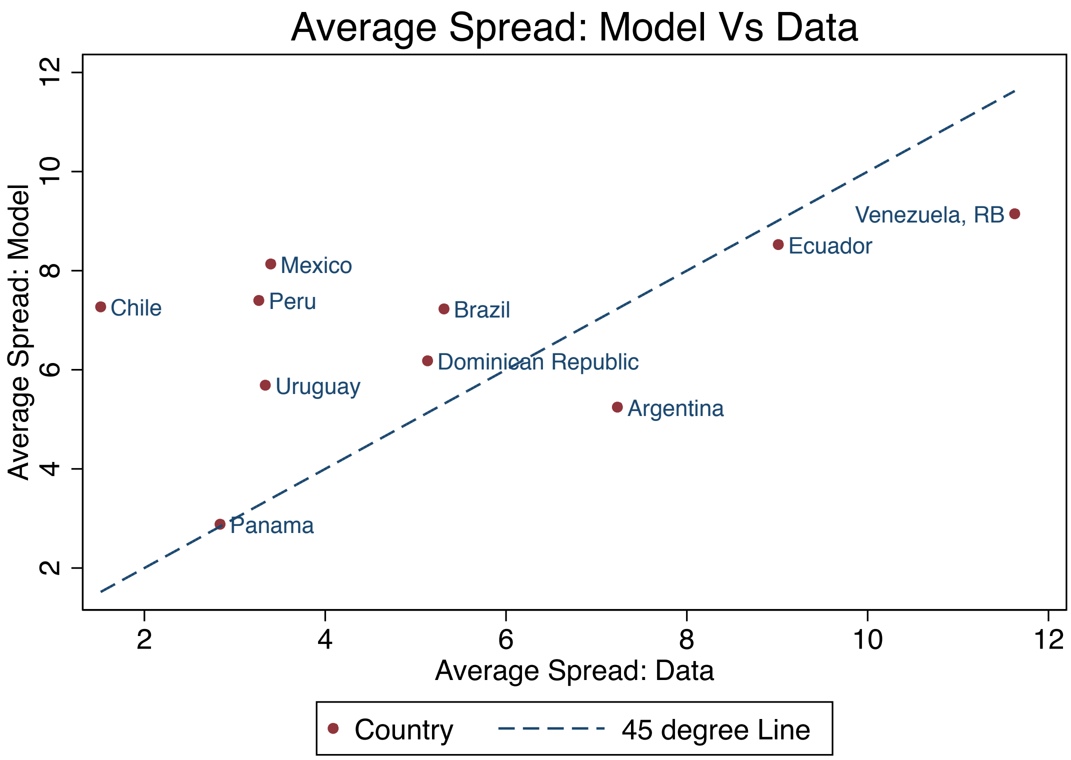


Figure 8: Nontargeted moments: first and second moments of spread



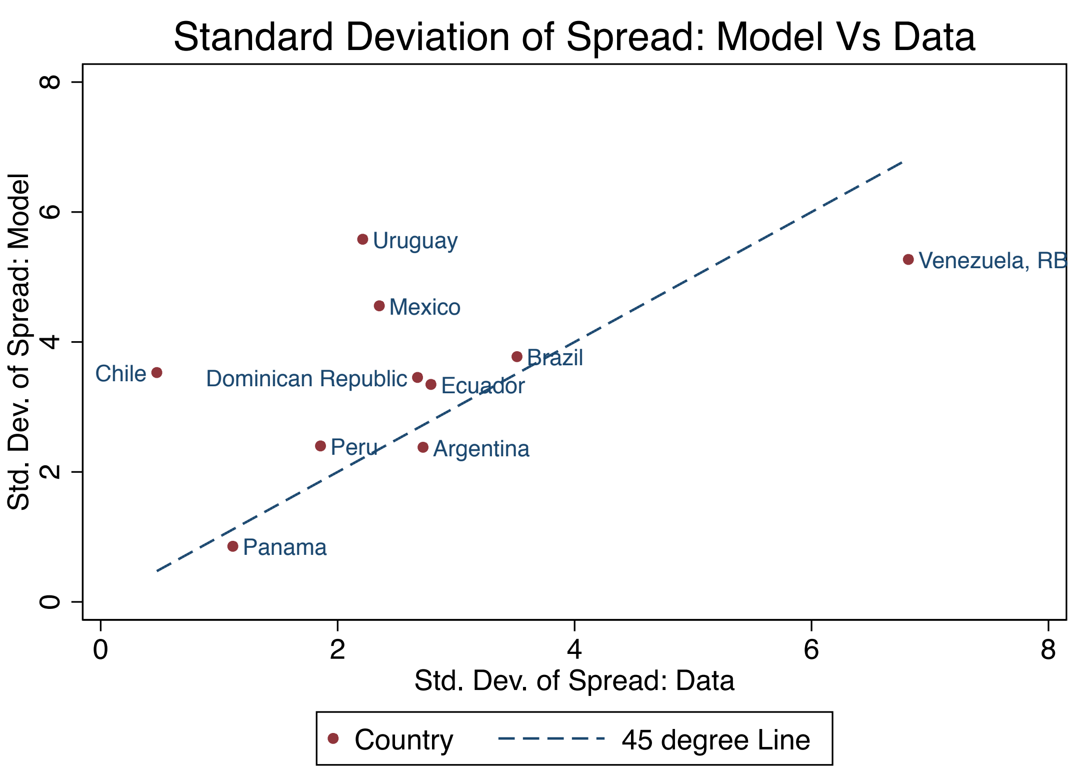


Figure 9: Nontargeted moments: correlations with spread

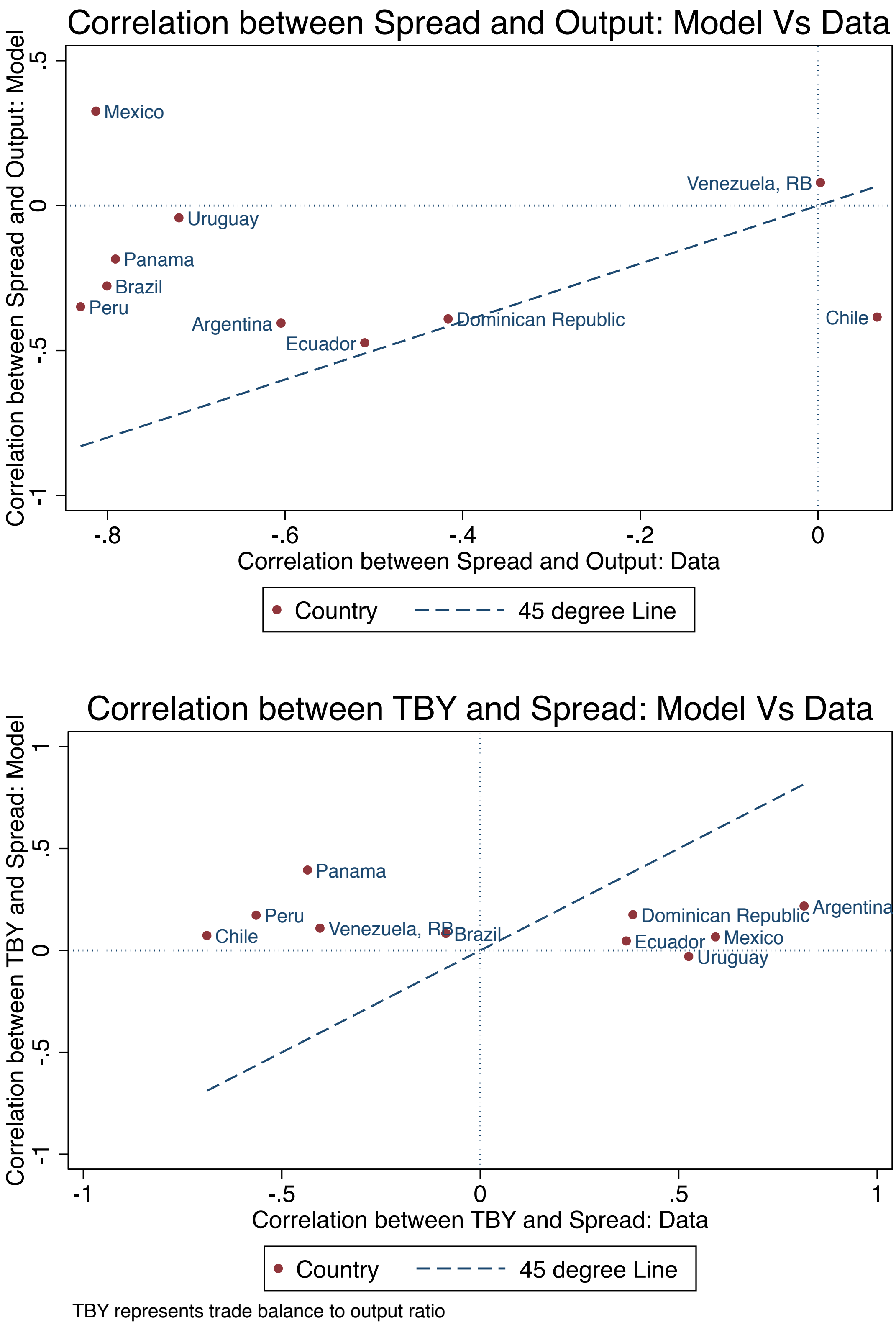


Figure 8 displays the means and standard deviations of the spreads. The top panel shows the average spread in nondefault episodes. The points that correspond to different countries are not as close to the 45-degree line as they were in the case of targeted moments. Most of the countries, except Chile, Mexico and Peru, are still in the neighborhood of the 45-degree line. The standard deviation of spreads in nondefault 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 nontargeted moments pertain to the correlation of spreads. Figure 9 shows that the model does well to explain the countercyclicality of the country premium, but the model does not do very well in terms of predicting the correlation between trade balance to output ratio and spread. Some of the countries show positive correlation between trade-balance to output ratio and spread, while some portray negative correlation in the data. The model, on the other hand, displays a small and positive correlation between trade balance to output ratio and spread.

6.3 Simulating the Defaults

For every country, the model provides the optimal decision—the level of debt that the country chooses and whether the country wants to default—for any value of the state variables (four output shocks, the interest rate shock and an initial level of debt). Thus, feeding the model with actual time series of output shocks, estimated in Section 4, and interest rate shocks from 1960 to 2014, I obtain the default decision for every country and every year from 1960 to 2014. Aggregating these default decisions across all the countries from 1960 to 2010, I show the percentage of countries defaulting in a 5-year window for every year. Switching different shocks on and off and comparing the model predicted defaults with the data, the paper finds two important results. The first results is that primary driver of clustered defaults is global shock to the transitory component of output. The second result plays down the importance of the Volcker interest-rate hike in causing the 1982 developing country debt crisis.

I use three version of the model 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. I begin with the basic version of the model with constant interest rate. Proceed to the basic version where interest rate fluctuates and then finally to the full version of the model.

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, that cause fluctuations in the price of debt, 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 delineate if the interest rate fluctuations influence the default decision more than the output shocks.

6.3.1 Baseline Model with Constant World Interest Rate

The time series of output shocks begins in 1960. The world interest rate is kept constant at 3.66%, and the initial level of debt in 1960 is assumed to be 0.[33] For all the subsequent periods, countries choose whether it is optimal for them to default. This default choice is then aggregated across countries and I match the percentage of countries defaulting in the model with its counterpart from the data.

Figure 10: Aggregated default decisions of all countries: model with both country-specific shocks and global shocks vs data

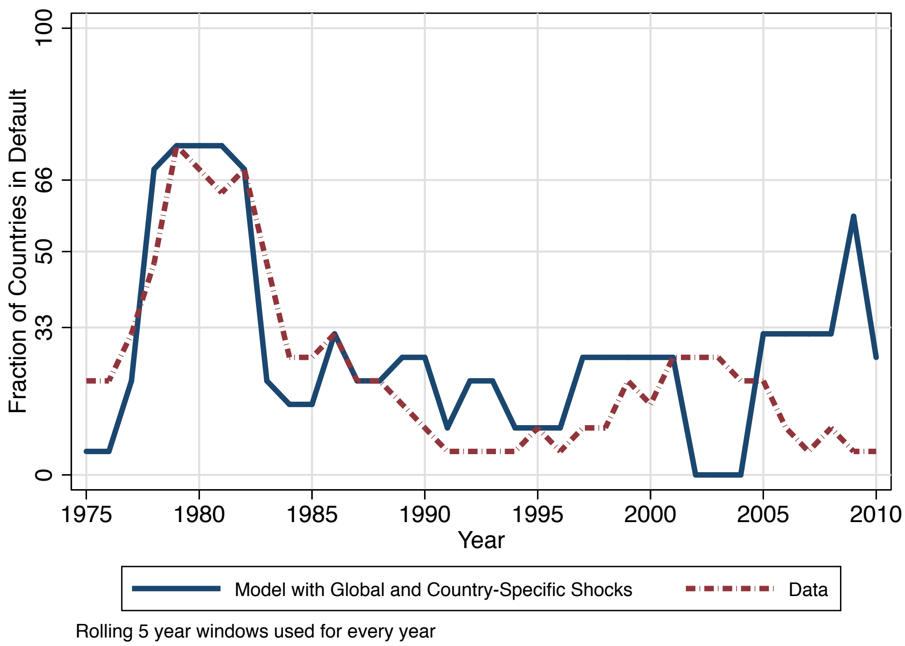


Figure 10 shows that the model predicts the clustered default of 1982 very well. The model also shows a subsequent decline in defaults, and a small surge of defaults in the early 2000s. This surge is predicted a bit early in the model—in late 1990s. Additionally, the model overpredicts the defaults at the time of the great recession. 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.

[33]The results are robust to changes in the initial level of debt.

The model succeeds in generating the cluster, but it raises the next question: Are global shocks essential in generating the cluster of 1982? To capture the effect of global shocks, I perform two exercises. First, I shut down all the global shocks by equating the global transitory shock with 0 and the growth rate in global permanent shock with 1 for the entire period from 1960 to 2014. In this exercise, only country-specific shocks move the output of countries; hence, default decisions are affected only by country-specific shocks. In the second exercise, I do the opposite: I shut down all the country-specific shocks by equating the country-specific transitory shock with 0 and the growth rate in country-specific permanent shock with the average growth rate of the country for the entire period from 1960 to 2014. In this exercise, only global shocks move the output of countries; hence, default decisions are affected only by global shocks.

Figure 11: Aggregated default decisions of all countries: model with only country-specific shocks vs model with only global shocks vs data

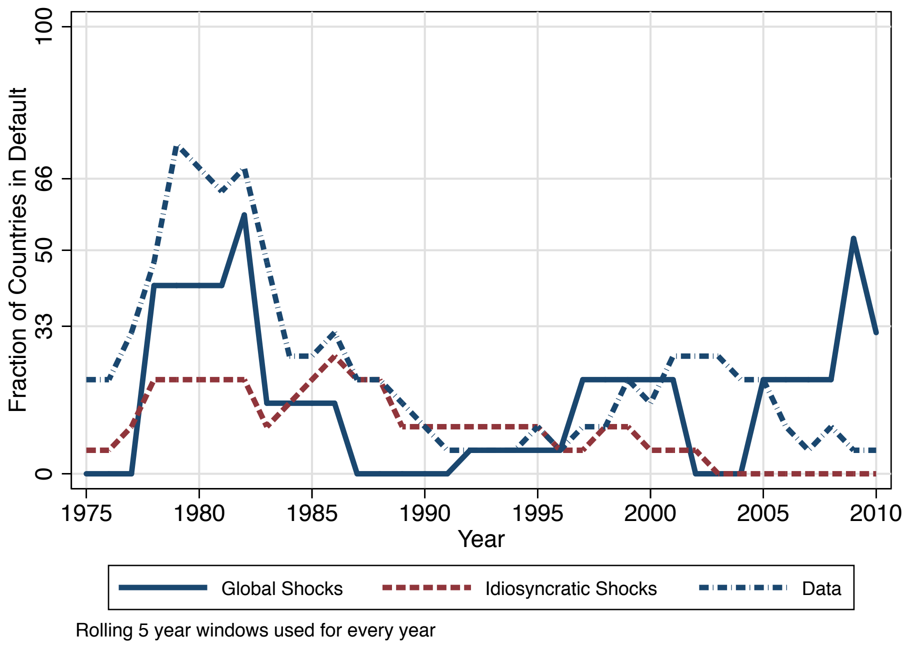


Figure 11 shows the results of the two aforementioned exercises and the observed defaults in the data. With only country-specific shocks, the percentage of countries defaulting is very small, and we do not observe a cluster. With global shocks, in contrast, a cluster reappears. The size of this cluster is smaller than that observed in the data, portraying the relative importance of country-specific shocks.

The success of global variables in generating the cluster raises a new question: Which type of global shock—global transitory shock or global permanent shock—matters more in generating the cluster of 1982? To capture the effect of individual global shocks, I perform two more exercises. First, I shut down only the global permanent shock by equating the growth rate in global permanent shock with 1 for the entire period from 1960 to 2014. In this exercise, both the country-specific shocks and global transitory shocks move the output of countries; hence, default decisions are affected by all three. In the second exercise, I shut down only the global temporary shock by equating the global transitory shock with 0 for the entire period from 1960 to 2014. Thus, both the country-specific shocks and the global permanent shocks move the output of countries, thereby affecting the default decision.

Figure 12: 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

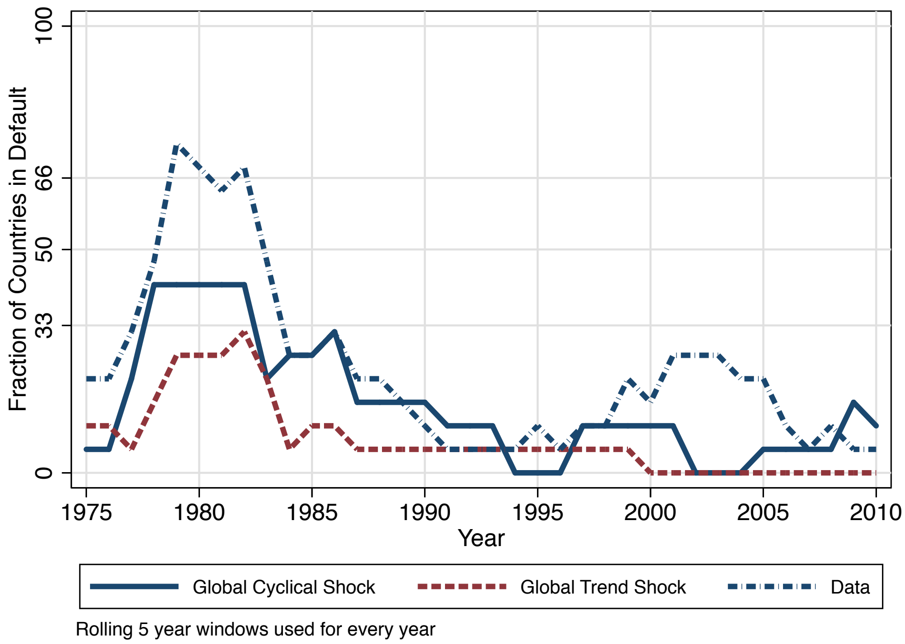


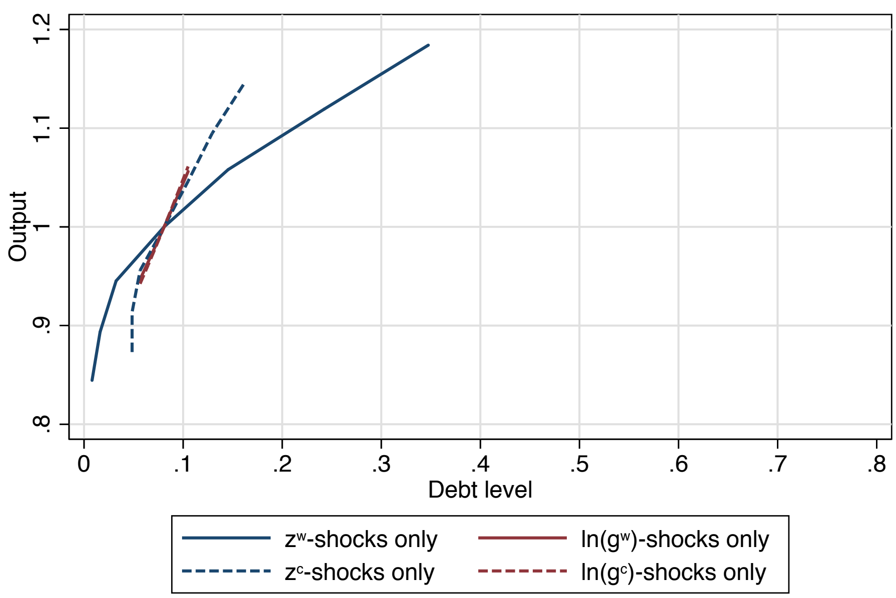
Figure 12 illustrates that global temporary shocks are relatively more important in replicating the cluster than global permanent shocks. Though the difference in the figure from the two exercises is not as stark as in the previous case, the finding that temporary shocks are more important than permanent shocks is surprising and counterintuitive. This result is surprising because it contradicts the finding of Aguiar and Gopinath (2006) that permanent shocks rather than temporary shocks are more important in generating sovereign defaults. It therefore becomes interesting to understand the mechanism through which transitory shocks cause relatively more defaults.

Role of Global Transitory Shocks in Causing Defaults

There are three elements in the model that make global transitory shocks important in causing clustered defaults. First, high fluctuations in global transitory shocks. Second, and the most important, the convex output cost of default. Third, high persistence of global transitory shocks.

Though the impact of global shocks on different countries depends on the coefficients α, let us begin with example of Argentina. One standard deviation shock to the global transitory component changes the detrended GDP of Argentina by 6%. One standard deviation shock to the global permanent component changes the detrended GDP by almost 2%. One standard deviation shocks to the country-specific transitory and permanent components changes the detrended GDP by 5% and 2%, respectively. Thus, in the case of Argentina, the global transitory shocks have a greater impact on the detrended GDP. For countries other than Argentina, this might not be the case, but as I will show, global transitory shocks have a greater impact on default decisions even with shocks of similar sizes.

Figure 13: 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.

To discuss the importance of the global transitory shocks in default decisions over other output shocks of similar sizes, I return to the model solution of Argentina. Though the simulations already confirm the importance of global transitory shocks in causing clustered default of 1982, the indifference curve between the value functions from the model provides more details about the mechanism. Figure 13 shows the default region for different shocks.

The y-axis shows the output of Argentina in different scenarios, while the x-axis represents the debt level of the country. The solid navy line corresponds to the case in which the economy is hit by global transitory shocks only. All other shocks remain constant at their mean values. Given that the shocks are only to the global transitory component (z^w-shocks), the y-axis shows the output in the presence of z^w-shocks only. The area to the right of this line is the default region, while the area to the left of it shows different combinations of z^w and d for which the country chooses not to default.

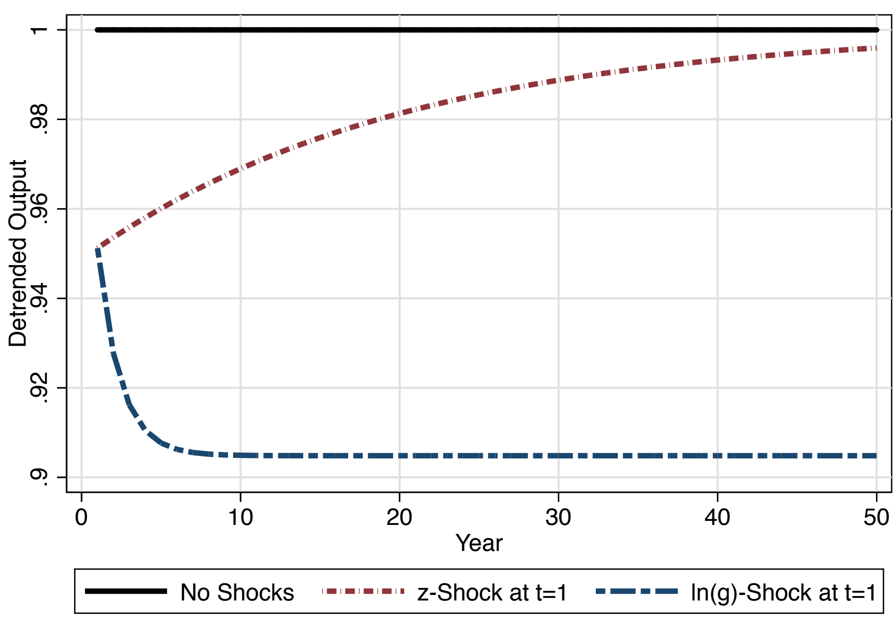
According to the solid navy line of Figure 13, after a few consecutive positive shocks to the global transitory component, the country can accumulate much debt and still be in the nondefault region. More specifically, with an output of 12% above the detrended mean in the presence of global transitory shocks, Argentina can accumulate a debt of up to 25% and still remain in the nondefault 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 Argentine must deleverage substantially when it experiences a negative z^w shock. Thus, in some cases, Argentina might prefer to default than undergo a large deleveraging.

Moving on to the remaining three shocks, the indifference lines between default and non-default regions are much steeper for other shocks. Thus, under these shocks, the amount of deleveraging required to stay in nondefault status is not high. Thus, countries default much less under these shocks than under global transitory shocks. This result holds even when the size of shocks are similar. Figure 13, therefore, raises two questions: (1) Why do transitory and permanent shocks behave differently? (2) Why do global and country-specific transitory shocks behave differently?

The answer to the first question lies in the convex default cost assumption. Figure 14 shows the detrended output of a country struck by a 5% transitory shock (maroon line) and by 5% permanent shock (navy line). When the country is struck by a negative transitory shock, the output decreases today but increases in the future as it starts recovering tomorrow. Thus, with the convex cost of default, defaulting tomorrow entails a 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 decrease causes the borrowing or 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 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 effect causes the borrowing or 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.

Thus, a spread-out distribution of debt causes countries to accumulate much debt after transitory shocks compared to similar levels of permanent shocks. Additionally, when countries face a negative shock after a series of positive shocks, the deleveraging required to stay in nondefault 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.

Figure 14: Output decrease: transitory vs permanent shock



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

The difference between global and country-specific transitory shocks arises due to high persistence of global transitory shocks. With shocks that have low persistence, the accumulated debt level after a series of positive shocks is not as great as with more persistent shocks. Additionally, after a series of negative shocks that have low persistence, i.e. they last for fewer periods, the country does not acquiore as low debt as with more persistent shocks. Combining both side of the arguments, the debt distribution is less spread out with less persistent shocks, which is why the dotted navy line is steeper than the solid navy line in Figure 13.

The results are different from those in Aguiar and Gopinath (2006) because they had a proportional default cost. The debt distribution here is much more spread out than in the case of proportional default cost. In the proportional default cost case, agents do not hold much debt even after positive transitory shocks because when default costs are proportional, and not convex, then the probability of default is higher even at a high level of output. This situation causes defaults to occur in both good as well as bad times, rather than specifically in bad times.

6.3.2 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 by performing two exercises and comparing their results. First, I simulate the optimal default choices of countries by using all five shocks—four output shocks and one interest rate shock. Second, I shut down the interest rate shock and use a constant interest rate of 3.67% across all periods from 1960 to 2014. The comparison is shown in Figure 15, and surprisingly, it shows that the presence of the stochastic interest rate *does not* cause clustered defaults. Output shocks still explain all the defaults in the clustered default period of 1982. 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 15: Aggregated default decisions of all countries: model with world interest rate shocks vs model without world interest rate shocks vs data

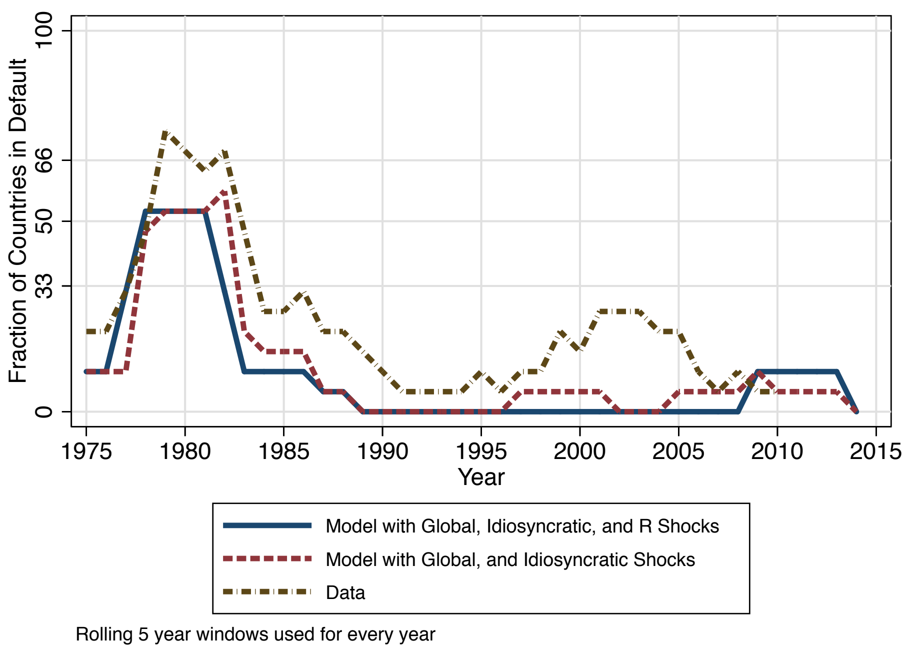
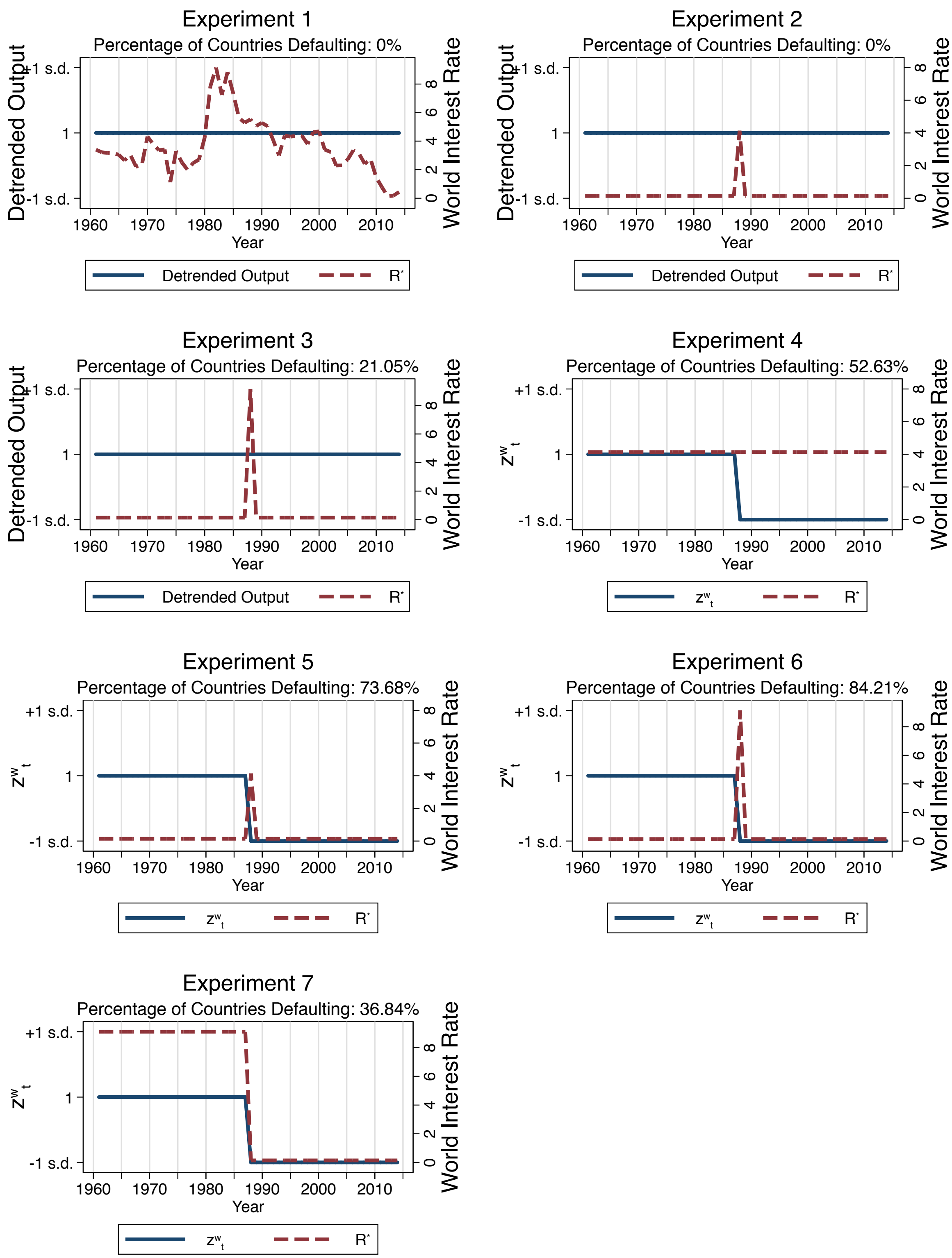


Figure 16: Percentage of countries defaulting when faced with different output and interest rate shocks



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

The result showing a negligible role of the Volcker interest rate hike does not rule out the role of interest rate shocks, in general, in causing clustered defaults. Therefore, I perform a series of experiments, and the results of those experiments are shown in Figure 16.

For the first three experiments, I simulate the time series of all the countries using detrended output as 1 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 16, therefore, shows that without fluctuations in output, the Volcker interest rate hike could not have forced any country to default. Thus, output shocks are important in causing defaults.

The absence of defaults with no output shocks raises a concern about the effectiveness of the interest rate shocks in the model. More specifically, Does increase in the interest rate cause defaults? To test whether the interest rate shocks can influence default decisions at all in the absence of negative output shocks, I run two experiments. In Experiment 2, I increase the interest rate to 4% for one period in 1988, and it returns to aproximately 0 from the next period onward.[34] In Experiment 3, I increase the interest rate to 9% for one period in 1988, and it returns to approximately 0 from the next period onward. I find that the 4% increase in the interest rate is still not enough to cause default even in a single country in the absence of output shocks. 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. This debt is the debt that is forgotten, i.e., not repaid by the borrowers after netting for haircuts.[35] Thus, countries have a higher incentives to default if the level of forgotten debt is high. 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 8%, plus any change in the probability of default. If the probability of default does not change much, 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.

Having shown that interest rate shocks *can* cause defaults even in the absence of output shocks, proceed to the next question: what occurs when the increase in the interest rate is accompanied by a decrease in the output?

[34] 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.

[35] Haircuts are realized investor losses out of the lending. For example, a 90% haircut means 90% of the debt is forgotten.

To evaluate the effect of an interest rate hike when output decreases, I use changes only in the global transitory component of output. Thus, for the next four experiments, the global transitory component decreases by 1 standard deviation in 1988 and remains there forever. Given the change in the global transitory component of output, I perform different experiments with interest rate changes. Even when interest remains constant, 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 I decrease it by 9%, 3 fewer countries default, bringing the total number of defaulters to 7 of 19.

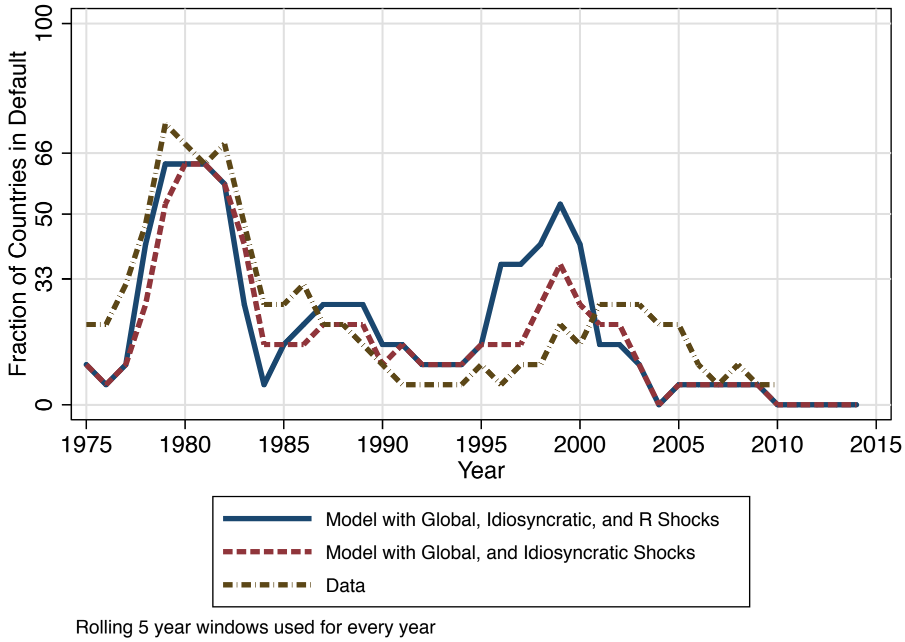
The set of experiments shows that interest rate shocks can be an important driving force that can cause clustered defaults. Both increasing and decreasing the interest rate can be a vital policy measure, depending on the type and size of the output shocks as well as the debt level in countries. Nonetheless, 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 shows that interest rate policy can be redundant in cases when the countries are experiencing huge output shocks.

6.3.3 Extended Model with Stochastic World Interest Rate

In the previous section, the effect of interest rate came only from the *debt-pricing channel* and not the *endogenous output channel*. Thus, to capture the full effect of interest rate shocks, I continue to the full version of the model with the stochastic interest rate. I again feed in the time series of output shocks, and the time series of the world interest rate from 1960 onward and set the initial level of debt in 1960 to 0. I repeat the same exercise with a constant interest rate and compare the two results.

As evident in Figure 17, interest rate shocks still have a negligible effect in causing the cluster of 1982. There seems to be an effect of the interest rate in the defaults of 1999-2000, however. This finding again shows that interest rate changes can have an effect on default decisions, but not when the decline in output is too large, as was the case in the early 1980s.

Figure 17: Aggregated default decisions of all countries: full model with world interest rate shocks vs full model without world interest rate shocks vs data



7 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) capturing 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 second finding shows, contrary to what is commonly believed, 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.

Both the essential elements of the framework—capturing the global shocks, and understanding the mechanism through which global shocks influence defaults—makes this study crucial for future policy work on clustered defaults. The same spirit is expressed succinctly in the words of Paul Krugman from Diaz-Alejandro et al. (1984):

> ... why does it matter how we got where we are? ... If the problems of debtor countries basically reflected irresponsible behavior, such a bailout would provide encouragement for more such behavior in the future. If, on the other hand, the debt crisis can be viewed basically as an act of God (or his earthly manifestation, Paul Volcker), this is not a concern.

References

Abbas, S.M. Ali, Nazim Belhocine, Asmaa El-Ganainy, and Mark Horton, "A Historical Public Debt Database," *IMF Working Paper*, 2010, *WP/10/245.* (pages 9.)

Aguiar, Mark and Gita Gopinath, "Defaultable debt, interest rates and the current account," *Journal of international Economics*, 2006, *69* (1), 64–83. (pages 2, 3, 4, 5, 12, 35, 54, 57.)

_ **, Satyajit Chatterjee, Harold Cole, and Zachary Stangebye**, "Quantitative models of sovereign debt crises," in "Handbook of Macroeconomics," Vol. 2, Elsevier, 2016, pp. 1697–1755. (pages 44.)

Arellano, Cristina, "Default risk and income fluctuations in emerging economies," *American Economic Review*, 2008, *98* (3), 690–712. (pages 2, 3, 5, 35, 44.)

__ , **Yan Bai, and Sandra Lizarazo**, "Sovereign Risk Contagion," Technical Report, National Bureau of Economic Research 2017. (pages 6.)

Benjamin, David and Mark LJ Wright, "Recovery before redemption: A theory of delays in sovereign debt renegotiations," 2009. (pages 6.)

Bocola, Luigi and Alessandro Dovis, "Self-fulfilling debt crises: A quantitative analysis," Technical Report, National Bureau of Economic Research 2016. (pages 6.)

Bordo, Michael D and Antu P Murshid, "Are financial crises becoming increasingly more contagious? What is the historical evidence on contagion?," Technical Report, National Bureau of Economic Research 2000. (pages 1, 7.)

Borri, Nicola and Adrien Verdelhan, "Sovereign risk premia," 2011. (pages 6.)

Chatterjee, Satyajit and Burcu Eyigungor, "Maturity, indebtedness, and default risk," *American Economic Review*, 2012, *102* (6), 2674–99. (pages 4, 44.)

Cruces, Juan J and Christoph Trebesch, "Sovereign defaults: The price of haircuts," *American economic Journal: macroeconomics*, 2013, *5* (3), 85–117. (pages 9.)

Dedola, Luca, Giulia Rivolta, and Livio Stracca, "If the Fed sneezes, who catches a cold?," *Journal of International Economics*, 2017, *108*, S23–S41. (pages 5.)

Diaz-Alejandro, Carlos F, Paul R Krugman, and Jeffrey D Sachs, "Latin American debt: I don't think we are in Kansas anymore," *Brookings papers on economic activity*, 1984, *1984* (2), 335–403. (pages 63.)

Eaton, Jonathan and Mark Gersovitz, "Debt with potential repudiation: Theoretical and empirical analysis," *The Review of Economic Studies*, 1981, *48* (2), 289–309. (pages 2, 5.)

Georgiadis, Georgios, "Determinants of global spillovers from US monetary policy," *Journal of International Money and Finance*, 2016, *67*, 41–61. (pages 5.)

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W Huffman, "Investment, capacity utilization, and the real business cycle," *The American Economic Review*, 1988, pp. 402–417. (pages 36.)

Hatchondo, Juan Carlos, Leonardo Martinez, and Horacio Sapriza, "Quantitative properties of sovereign default models: solution methods matter," *Review of Economic dynamics*, 2010, *13* (4), 919–933. (pages 45.)

Hébert, Benjamin and Jesse Schreger, "The costs of sovereign default: Evidence from argentina," *American Economic Review*, 2017, *107* (10), 3119–45. (pages 4.)

Iacoviello, Matteo, Gaston Navarro et al., "Foreign Effects of Higher US Interest Rates," Technical Report 2018. (pages 5.)

Kaminsky, Graciela Laura and Pablo Vega-Garcia, "Systemic and idiosyncratic sovereign debt crises," *Journal of the European Economic Association*, 2016, *14* (1), 80–114. (pages 1, 3, 7, 9, 26.)

Kose, M Ayhan, Christopher Otrok, and Charles H Whiteman, "International business cycles: World, region, and country-specific factors," *american economic review*, 2003, *93* (4), 1216–1239. (pages 5.)

_ , _ , and Eswar S Prasad, "Global business cycles: convergence or decoupling?," Technical Report, National Bureau of Economic Research 2008. (pages 5.)

Lane, Philip R and Gian Maria Milesi-Ferretti, "The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004," *Journal of international Economics*, 2007, *73* (2), 223–250. (pages 9.)

Lizarazo, Sandra Valentina, "Default risk and risk averse international investors," *Journal of International Economics*, 2013, *89* (2), 317–330. (pages 6.)

Lorenzoni, Guido and Ivan Werning, "Slow moving debt crises," Technical Report, National Bureau of Economic Research 2013. (pages 6.)

Mallucci, Enrico, "Domestic debt and sovereign defaults," 2015. (pages 6.)

Mendoza, Enrique G, "Real business cycles in a small open economy," *The American Economic Review*, 1991, pp. 797–818. (pages 20, 44.)

_ and Vivian Z Yue, "A general equilibrium model of sovereign default and business cycles," *The Quarterly Journal of Economics*, 2012, *127* (2), 889–946. (pages 4, 6.)

Miyamoto, Wataru and Thuy Lan Nguyen, "Business cycles in small open economies: Evidence from panel data between 1900 and 2013," *International Economic Review*, 2017, *58* (3), 1007–1044. (pages 5.)

Na, Seunghoon, Stephanie Schmitt-Grohé, Martín Uribe, and Vivian Z Yue, "A model of the twin ds: Optimal default and devaluation," 2015. (pages 4.)

Padilla, César Sosa, "Sovereign defaults and banking crises," in "Technical Report," MPRA Working Paper, 2013. (pages 6.)

Park, JungJae, "Contagion of Sovereign Default Risk: the Role of Two Financial Frictions.," 2014. (pages 6.)

Pouzo, Demian and Ignacio Presno, "Sovereign default risk and uncertainty premia," *American Economic Journal: Macroeconomics*, 2016, *8* (3), 230–66. (pages 6.)

Reinhart, Carmen M and Kenneth S Rogoff, "The forgotten history of domestic debt," *The Economic Journal*, 2011, *121* (552), 319–350. (pages 7.)

_ and _ , "From financial crash to debt crisis," *American Economic Review*, 2011, *101* (5), 1676–1706. (pages 1, 9, 45.)

_ , Vincent Reinhart, and Christoph Trebesch, "Global cycles: Capital flows, commodities, and sovereign defaults, 1815-2015," *American Economic Review*, 2016, *106* (5), 574–80. (pages 1.)

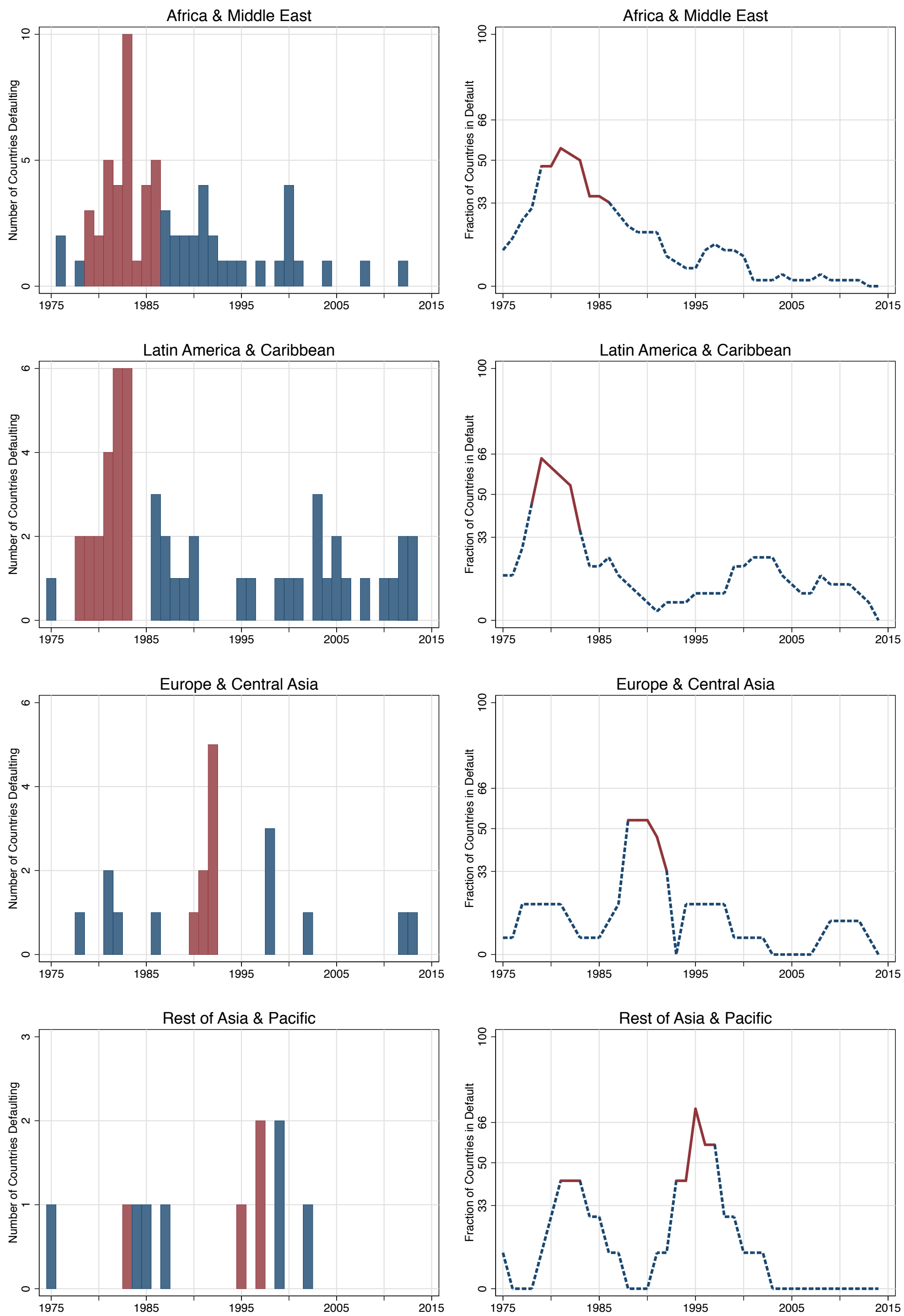
Uribe, Martín and Stephanie Schmitt-Grohé, *Open economy macroeconomics*, Princeton University Press, 2017. (pages 4, 8, 9, 26, 44, 45, 46.)

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

Appendix

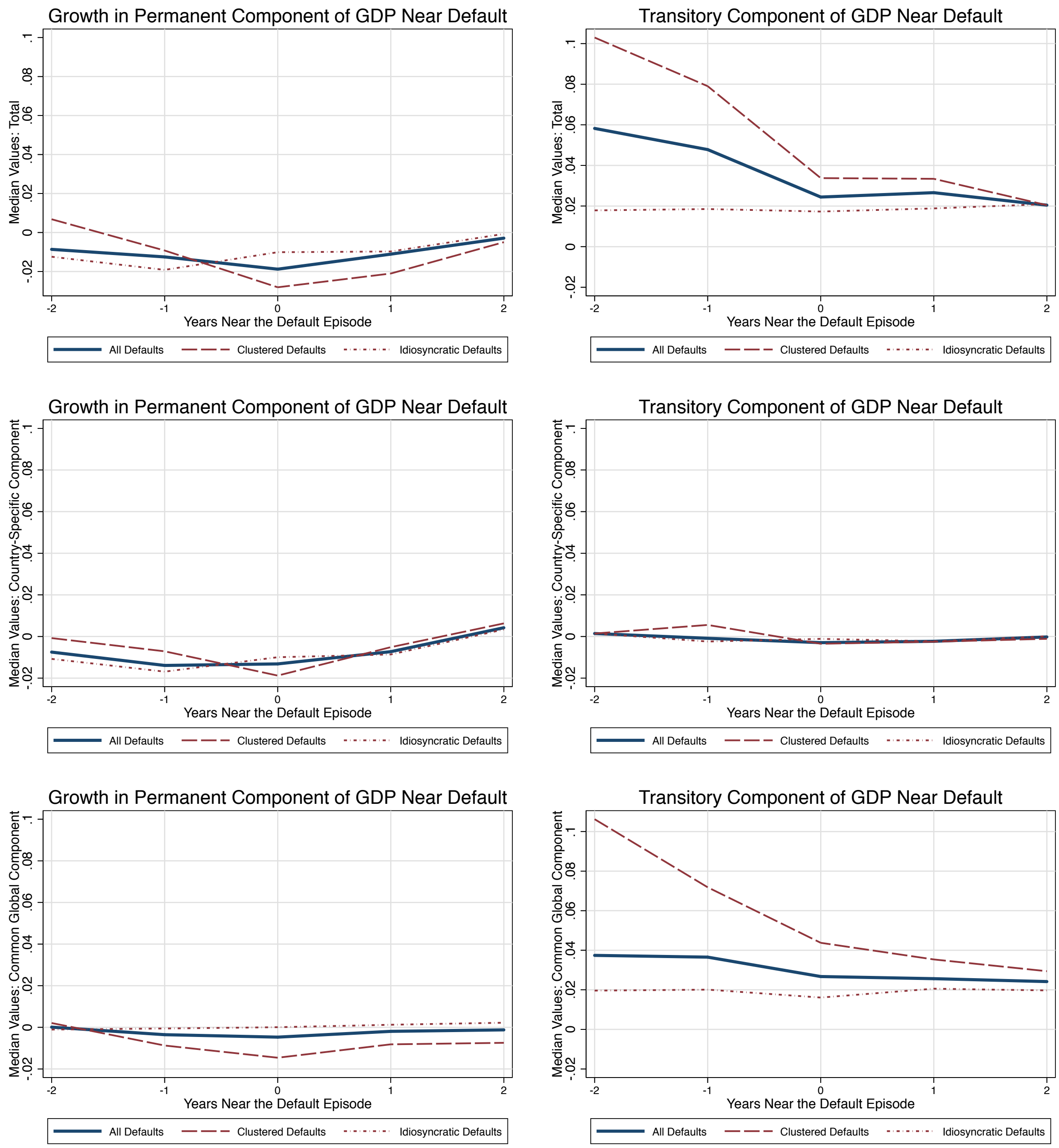
A Figures and Tables

Figure A1: 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.

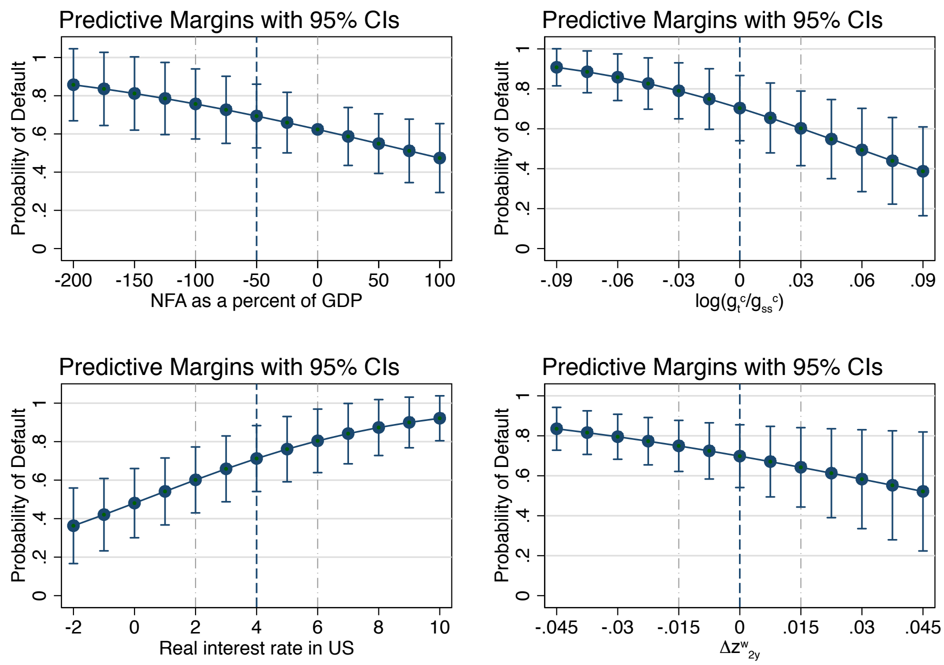
Figure A2: Transitory and Permanent Components of Output Near Default



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 A3: 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 A4: Predicted probabilities: Specifications 1 vs Specifications 2

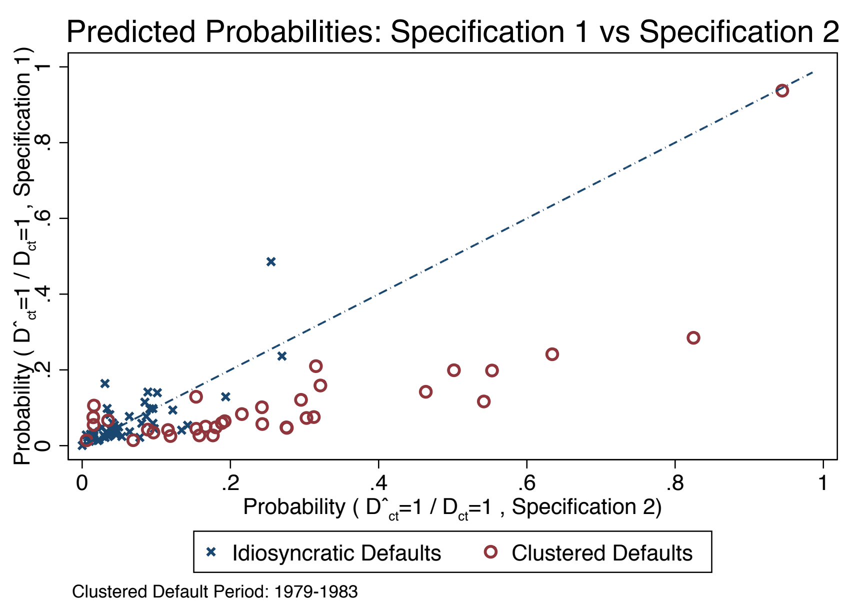
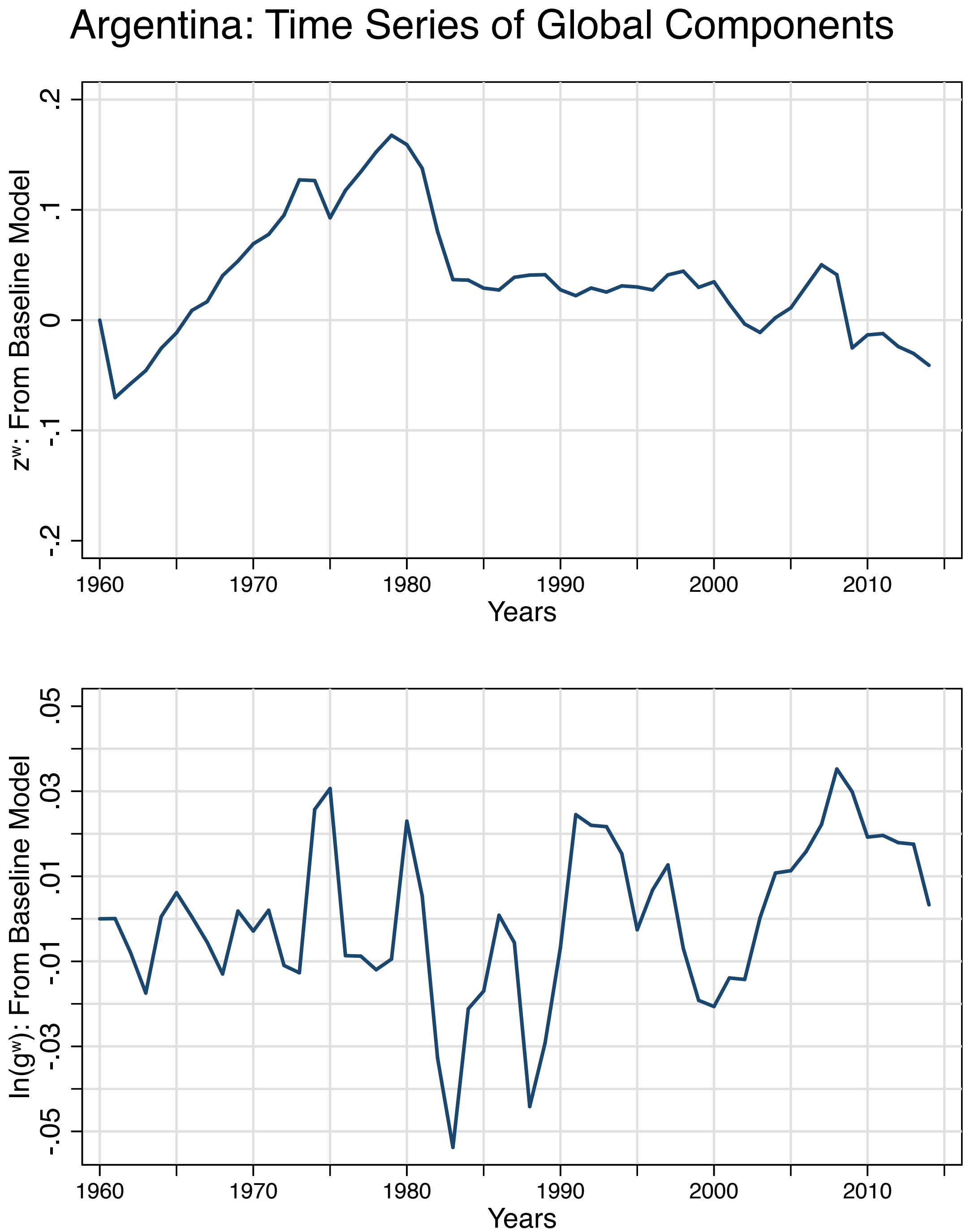
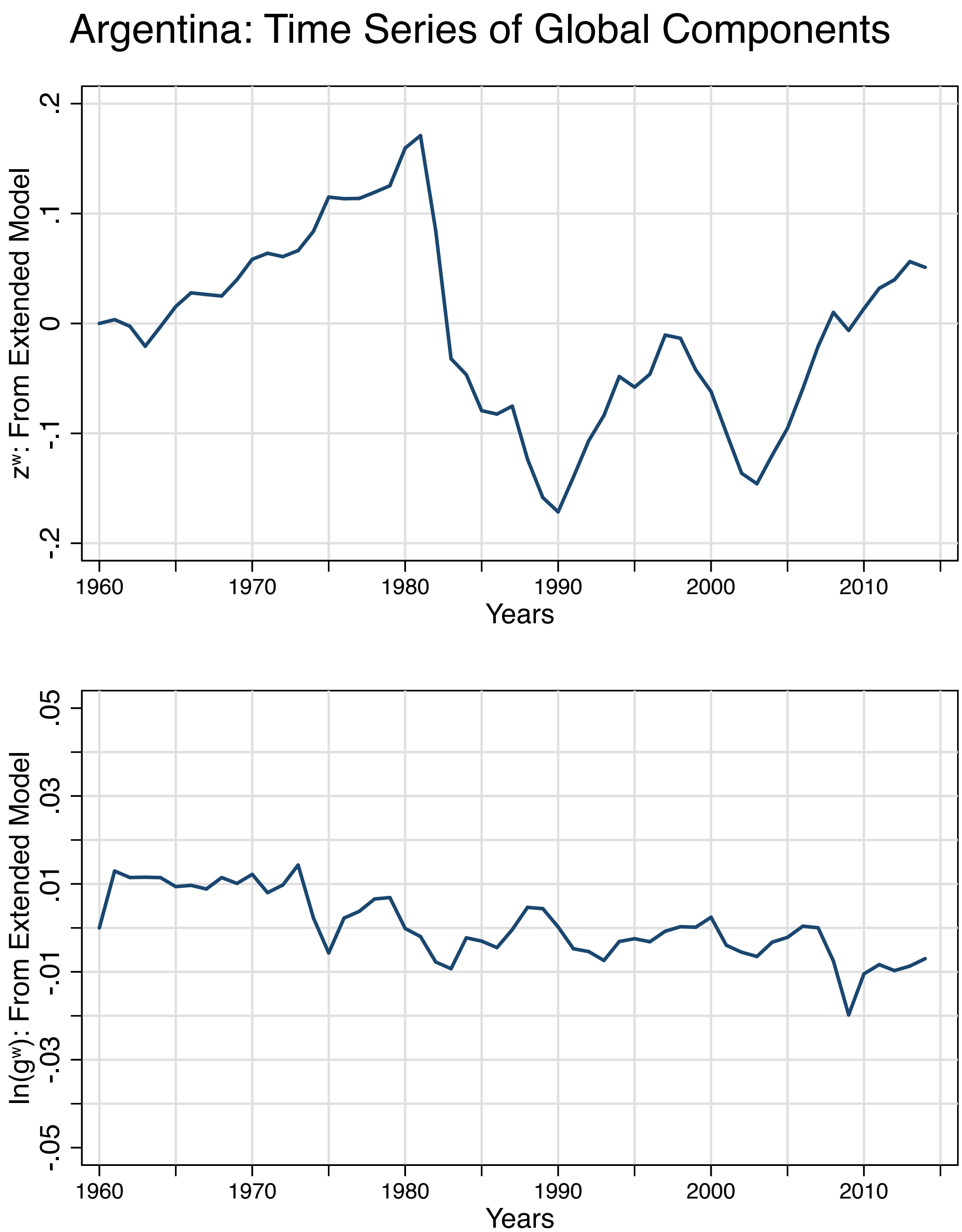


Figure A5: global constituent for the transitory component of output/TFP



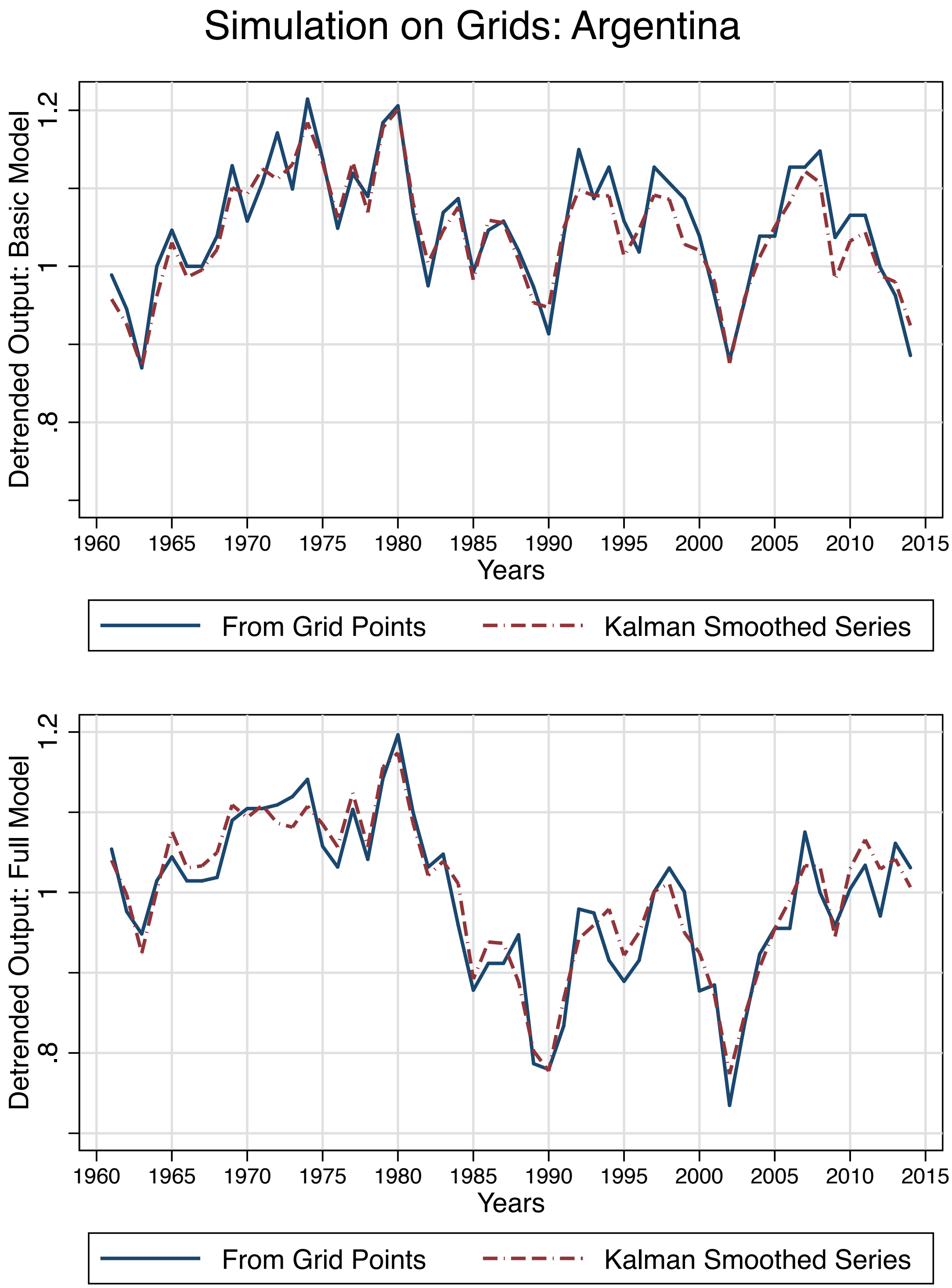
The figure shows global transitory component scaled for Argentina from different models. The top panel shows $\alpha_z^{ARG} z_t^w$ from the basic model. The bottom panel shows $\psi^{ARG} \alpha_z^{ARG} z_t^w$ from the full model.

Figure A6: Global Permanent Component of Output/TFP



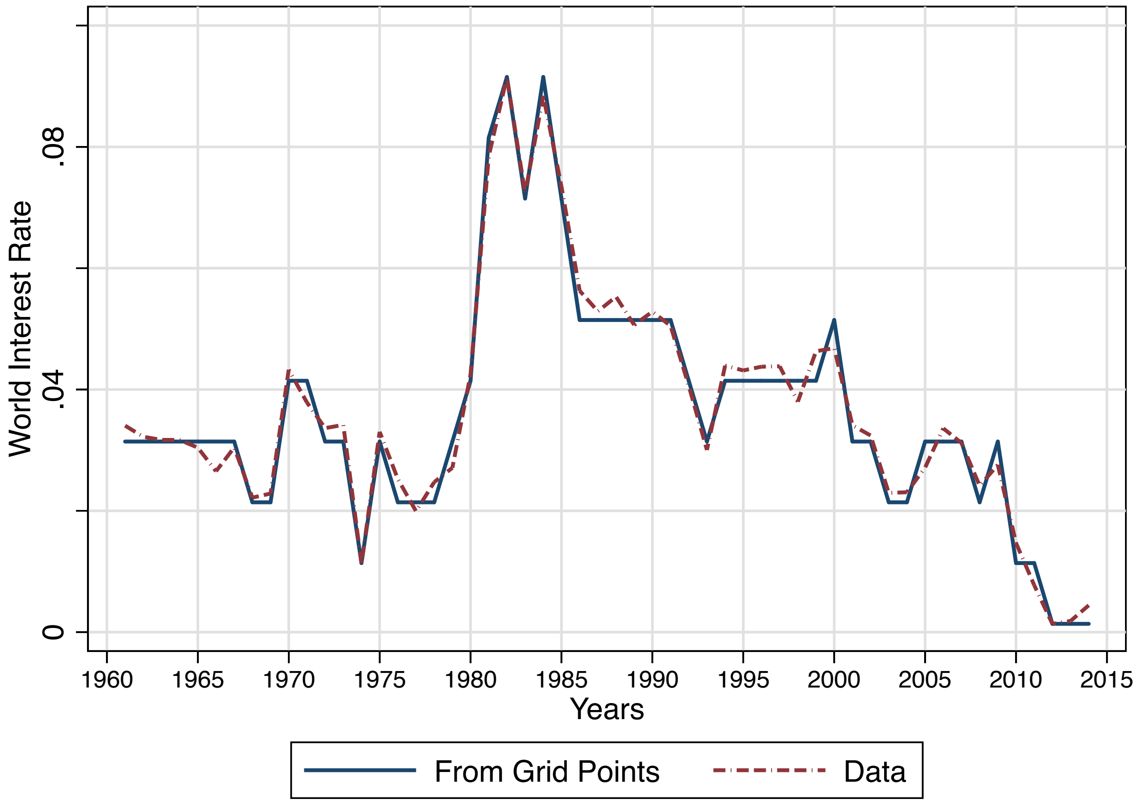
The figure shows growth in global permanent component scaled for Argentina from different models. The top panel shows $\alpha_X^{ARG} \ln(g_t^w)$ from the basic model. The bottom left panel shows $\psi^{ARG}\alpha_X^{ARG} \ln(g_t^w)$ from the full model.

Figure A7: 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 A8: 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.

Table A1: 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 A2: 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 A3: 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 A4: 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 A5: Prior Distribution for Bayesian Estimation

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

σ_z^w and σ_g^w are normalized to 1

Table A6: Prior Distribution for Bayesian Estimation: Full Model

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

σ_z^w and σ_g^w are normalized to 1

Table A7: Bayesian Estimation Results from Basic Model: Posterior means

Country	Statistic	Posterior (Mean & Standard Deviation)					
		ρ_z^c	ρ_g^c	σ_z^c	σ_g^c	α_z^c	α_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	ρ_z^w	ρ_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 A8: Bayesian Estimation Results from Full Model: Posterior means

Country	Statistic	Posterior (Mean & Standard Deviation)							
		ρ_z^c	ρ_g^c	σ_z^c	σ_g^c	ψ^c	η^c	α_z^c	α_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	ρ_z^w	ρ_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.

B Estimation Equations

B.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 Δy_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, θ_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

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

B.2 state-spaceForm: The Full Version

Measurement Equation

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

where,

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

$$W_t = \left[\ln(g_{ss}^1) + \alpha_X^1 \ln(g_{ss}^w) - (\psi^1 - 1)\eta^1 \Delta r_t^*, \cdot, \ln(g_{ss}^c) + \alpha_X^c \ln(g_{ss}^w) - (\psi^c - 1)\eta^c \Delta r_t^*, \cdot \right.$$
$$\left. , \ln(g_{ss}^{nc}) + \alpha_X^{nc} \ln(g_{ss}^w) - (\psi^{nc} - 1)\eta^{nc} \Delta r_t^*\right]^{\mathrm{T}}$$

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

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 Δy_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 θ_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 $\epsilon_g^c \sim N(0, (\sigma_g^c)^2)$.

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 γ 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 ϕ, that governs output loss in default, will also be non-zero. The function ϕ and thus, the output loss in default depends on individual technology shocks.

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

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

The default rule is therefore be given as:

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

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

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

C.2 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 ν 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 Γ_{t-1}. This is because of the peculiar form of utility function used.[36] The detrended utility function can thus be 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:

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

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

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

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:

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

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

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