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Exogenous Shocks and Growth Crises in Low-Income Countries: A Vulnerability Index

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Summary. — This paper develops a new index which provides early warning signals of a growth crisis in the event of large external shocks in low-income countries (LICs). Multivariate regression analysis and a univariate signaling approach are used to map information from a parsimonious set of underlying policy, structural, and institutional indicators into a composite vulnerability index. Both the in-sample and out-of-sample predictive power of the index are high. In particular, it explains well the growth crises observed in LICs during the global financial crisis.

Key words — vulnerability index, growth crises, low-income countries, external shocks

1. INTRODUCTION

Low-income countries are subject to a wide variety of exogenous shocks—sharp swings in the terms-of trade, export demand, natural disasters, and volatile financial flows. The amplitude and frequency of such shocks tend to be higher than in advanced and emerging market countries (International Monetary Fund (IMF), 2011). In principle, negative shocks in a standard neoclassical growth model would imply a quick reversion to the steady state level of income, implying a growth "bounce-back" and benign transitory effects. However, the resources, instruments, and policy buffers needed to absorb or mitigate shocks are often unavailable in low-income countries or difficult to implement in weak institutional and policy environments. Consequently, large adverse external shocks tend to induce breaks in trend growth rather than cycle fluctuations around a trend, imposing steep output and welfare losses, both directly and often through ensuing prolonged growth slowdowns.

Studies have found that the negative impact of exogenous shocks on growth and consumption volatility is especially pronounced in low-income countries (Becker & Mauro, 2007; Perry, 2009), and that such impact results mostly from crises or severe recessions rather than normal cyclical fluctuations (Hnatkovska & Loayza, 2005). Declines in consumption are more precipitous in LICs than in other countries because of low savings, liquidity constraints, limited risk diversification opportunities, and the greater dependence of the poor on public services, especially health and education, which exposes them to fiscal cuts in real terms, including through inflation.

Macroeconomic volatility additionally imposes indirect welfare costs through its negative impact on output growth, and thus future consumption. Research suggests that adverse shocks in LICs on average translate into substantial persistent output losses over the medium-term (Papageorgiou, Pattillo, Spatafora & Berg, 2010). Volatility impacts long-run growth through reductions in investment, a worsening of economic policy and, in extreme cases, by increasing the risk of conflict. In particular, higher volatility tends to depress investment in both physical and human capital, particularly in countries that are credit constrained. There is also evidence pointing to a higher risk of civil war and internal conflict and protracted growth downturns due to greater economic volatility, which is exacerbated by the structure of income in LICs (Bruckner & Ciccone, 2010).

Furthermore, studies point to an asymmetric effect of shocks on poverty levels: poverty levels increase sharply during deep downturns and do not recover to previous levels as output recovers (Agenor, 2004). Given nascent formal safety net mechanisms in many LICs, the poor rely to a large degree on self-protection and informal networks to protect themselves against risk. However, these coping strategies usually provide inadequate protection, and frequently lead to adjustments with detrimental long-term negative effects on their productivity and ability to climb out of poverty (Carter & Barrett, 2006; Clarke & Dercon, 2009).

A growing integration with the global economy and the pernicious effects of macroeconomic volatility in LICs thus call attention to the need for identifying emerging risks from changes in the external environment. This paper develops a vulnerability index that can help quantify low-income country risks to growth crises arising from external shocks. While predicting the timing of such events is likely to be an elusive endeavor, flagging the underlying vulnerabilities that predispose countries to growth declines in the event of external shocks can provide a first indication of a possible problem and signal the potential for pre-emptive policy action.

The index provides a systematic and forward-looking cross-country analysis of emerging risks and vulnerabilities across LICs and their mapping with existing structural and policy weaknesses that make a country more prone to economic distress in the event of an external shock before they materialize. Results from the index can help complement in depth country-specific and judgment-based analysis.

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Growth crises episodes in this paper capture the combined effects of growth declines (negative growth) and level drops in the event of shocks, which can endanger the sustainability of a country's growth path. It is well documented that macroeconomic vulnerabilities–large fiscal and external imbalances, unsustainable debt ratios, and inadequate reserve buffers, weakly diversified economic structures, narrow and concentrated tax bases, and institutional weaknesses serve to reduce resilience to exogenous shocks in low-income countries. The importance of these factors in reducing resilience to shocks is well established in the empirical literature (see Acemoglu, Johnson, Robinson, & Thaicharoen, 2003; Collier, Goderis, & Hoeffler, 2006; Loayza & Raddatz, 2007; Rodrik, 1999). In line with this literature, a range of economic, structural, and institutional indicators that capture the flow and stock vulnerabilities in the external and fiscal sectors and the real economy are used to gauge whether a country hit by a large external shock is also likely to experience a growth crisis.

Two complementary approaches are used to map information from the underlying indicators into a composite vulnerability index: multivariate regression analysis, and a univariate "signaling" approach. The multivariate regression approach uses a correlated panel probit model to estimate the probability of a growth crisis. This approach allows us to take account of correlations among different variables, to test for the statistical significance of individual variables, and to assess the constancy of coefficients across country groups.

The univariate approach entails using each indicator of crisis events separately, identifying critical thresholds that signal such events with the lowest prediction error, and then averaging the indicators into a summary index. In particular, the composite vulnerability index measures the number of indicators exceeding these thresholds, weighted by their relative signaling power. This approach can accommodate differences in data availability across countries and allows for the inclusion of a potentially larger number of vulnerability indicators than the multivariate regression method. At the same time, the results from the probit analysis provide guidance on the conditional statistical significance of the variables used in the univariate approach.

The index can be used to assess vulnerabilities to growth declines in low-income countries over time. The analysis shows that the overall vulnerability index has declined significantly from its peak in the early 1990s. Better policy and economic management, coupled with a favorable external environment, especially terms of trade improvements, and official debt relief contributed to stronger macroeconomic positions and lower vulnerabilities till the onset of the global crisis. More recently, growth crises risks in low-income countries remain elevated and well above pre-crisis years as fiscal buffers have increasingly been used up.

The rest of the paper is organized as follows. Section 2 provides a brief review of the literature. Section 3 describes the methodology for identifying crisis episodes. Section 4 presents the empirical analyses and main results using the multivariate regression analysis. Section 5 describes the statistical methodology underlying the univariate approach and presents results, and Section 6 concludes.

2. LITERATURE REVIEW

This paper is related to several strands of research. A large body of evidence finds that adverse external shocks have a significant negative impact on short- and medium-run growth through their effect on aggregate demand, external balances, and the government's fiscal position (Papageorgiou *et al.*, 2010; Collier & Goderis, 2009). Studies find that shocks impact long-run growth through reductions in investment (Aghion, Angeletos, Banerjee, & Manova, 2005), a worsening of economic policy (World Bank., 2006) and, in extreme cases, by increasing the risk of conflict (Bruckner & Ciccone, 2010). Moreover, these effects are asymmetric: while negative shocks impede growth, positive shocks do not necessarily contribute to long-run growth, particularly in resource-rich countries with weak institutions (Collier, Goderis, & Hoeffler, 2007). Our paper builds on these studies by analyzing a broad range of macroeconomic, institutional, and structural correlates of growth declines in the event of shocks, although we focus on the negative tail of the distribution.

This paper also complements previous studies that examine determinants of growth down-breaks, broadly defined as extended periods of markedly slow growth (see for e.g., Berg, Ostry, & Zettelmeyer, 2012; Hausman, Pritchett, & Rodrik, 2006; Pritchett, 2000; Rodrik, 1999). Our study focuses on sharp declines in growth over a shorter timeframe–events that, in our view, are related to, but distinct from, permanent changes in output and possibly of greater concern to policy makers. [1] If economic agents were liquidity-constrained or short-sighted, they may be more concerned about an immediately apparent sharp decline in growth than a slowdown in the long-run economic growth that has a similar impact in net present value terms (Becker, 2007). Further, our approach allows for differentiating local recoveries from severe downturns within a longer growth downbreak.

Finally, our paper is related to a large literature on early warning system models focused on a range of crises facing emerging market and advanced economies (see Kaminsky, Lizondo, & Reinhart, 1998, for currency crises; IMF, 2007 for sudden stops; Baldacci, Petrova, Belhocine, Dobrescu, & Mazraani, 2011, for fiscal crises; International Monetary Fund, 2010 for financial crises). In low-income countries, volatility in the real economy stemming from large terms of trade declines, contractions in external demand, and natural disasters can manifest in different sorts of severe economic distress–declines in consumption, balance of payments crises, and fiscal stress. An overarching focus on growth is thus an efficient way to capture most of these manifestations.

This paper is also related to Easterly, Islam, and Stiglitz (2001) who estimate a panel probit regression relating growth downturns (negative growth rates) to a large set of structural variables in developing and advanced economies. Our analysis focuses on growth decline episodes conditional on external shocks and captures relevant macroeconomic and structural vulnerabilities that predispose low-income countries to growth crises. In this respect, our paper is most closely related to Dabla-Norris *et al.* (2011) who empirically examine the benefits of international reserves in smoothing domestic absorption and consumption in response to exogenous shocks in low-income countries. Our paper draws on their methodology of shock and crisis identification to examine the determinants of growth declines.

3. METHODOLOGY

(a) *Identification of large exogenous shocks*

Large negative external shock events in countries are identified if the annual percentage change of the relevant shock variable falls below the 10th percentile in the left-tail of the country-specific distribution. In particular, shock episodes include one or more of the following six shocks: (i) external demand; (ii) terms-of-trade; (iii) FDI (Foreign Direct Investment); (iv) aid; (v) remittances; (vi) climatic shocks (large natural disasters). FDI, aid, and remittances are measured as ratios to GDP (Gross Domestic Product). Large natural disasters are identified if the number of people affected and the economic damage was considered to be among the top 25th percentile of the distribution. [1]

Defining large negative shocks over country-specific distributions implies that each country experiences the same frequency of shocks, so that the focus is on the reaction to the shock. Moreover, in the context of low-income countries, these shocks can be assumed to be exogenous to country-specific fundamentals or policy. The sample used for the analysis spans the period 1990–2009 for 71 low-income countries. For each shock, only the first year of the shock event is considered in the final set, giving us a total of 698 shock observations (out of 1420 observations). [2] Although each specific shock represents rare events, capturing the bottom 10th percentile of the distribution for the shock variable, the frequency of any of these shocks materializing turns out quite high (almost every other year) owing to independence of shocks over the sample period. Correlations among shocks are very low and statistically insignificant, except for the change in FDI to GDP and terms of trade growth (Table 9).

Although country-specific thresholds for each shock are used for identification purposes, the overall distributions of shock *versus* non-shock episodes are markedly different. Figure 1 shows the annual changes in external demand (partner country growth), terms-of-trade, aid, and FDI for the subsamples of shock *versus* non-shock episodes. As can be seen from the figures, the lowest quartile of the non-shock sample is markedly higher than the highest quartile of the shock episodes for each individual shock. This suggests that our shock definition captures reasonably severe events.

(b) *Identification of the dependent variable: Growth crisis events*

Within the sample of identified shock events, a *growth crisis* is defined as a large drop in real GDP per capita. Specifically, we assume that a crisis occurs when the following two conditions hold: (i) the post-shock 2-year average (t and $t+1$) level of real GDP per capita falls below the pre-shock 3-year trend; and (ii) growth of real GDP per capita is negative at time t. All other episodes for which either of these conditions fails are considered as normal episodes. Severe state failure events are excluded from the sample as growth in these episodes is likely to be impacted independently of the impact of covariates. [3]

Table 1 summarizes the median growth rate of real GDP per capita for the identified shock sample, distinguishing between crisis and non-crisis events. The median growth rate is positive for the entire shock sample, implying that not all shocks incur a drop in real growth. Indeed, the unconditional probability of

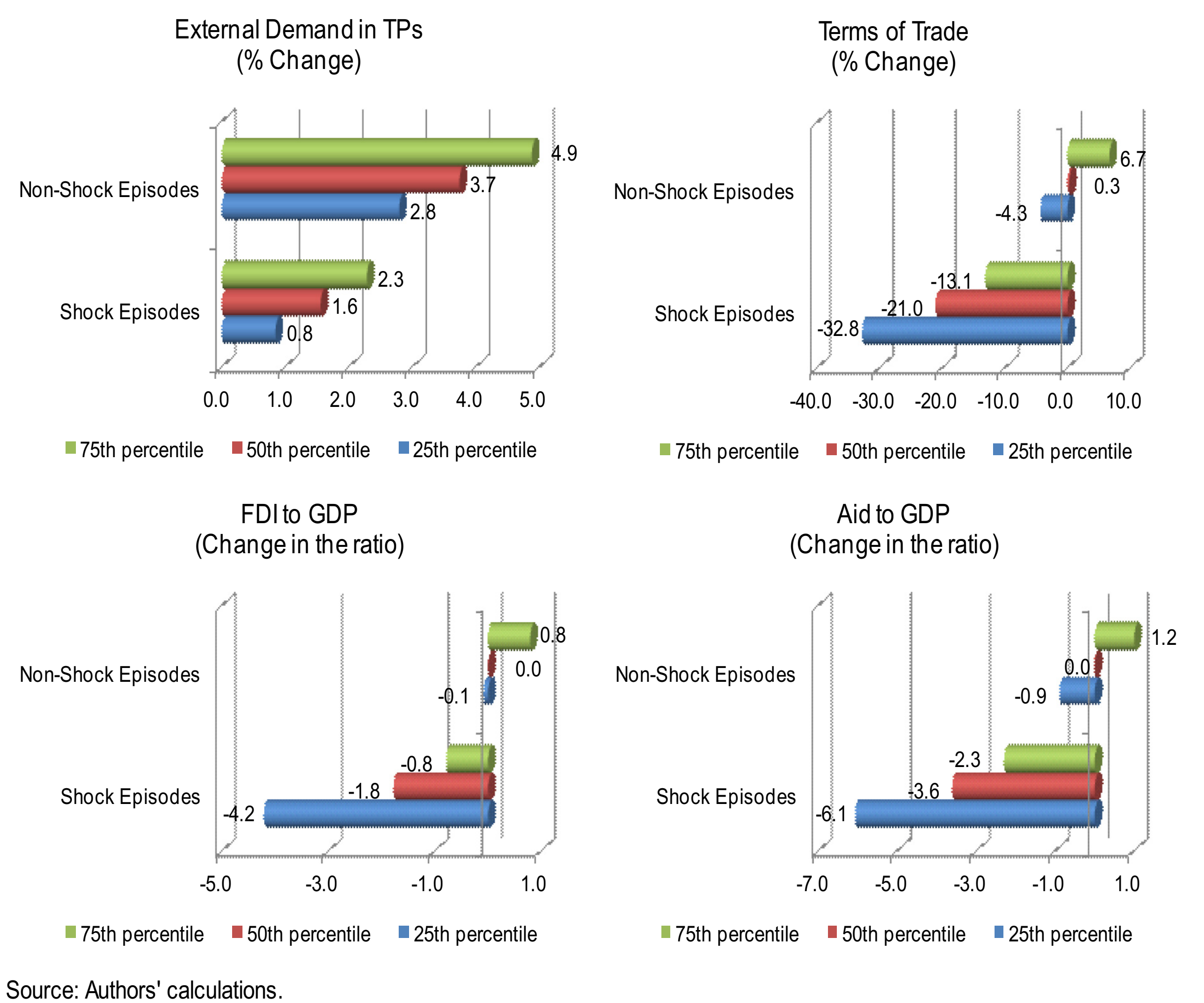


Figure 1. *Identification of external shock episodes.*

Table 1. *Median Real GDP per capita Growth (1990–2009)*

	All	Crisis episodes	Non-crisis episodes	Sample probability of crisis
Real GDP per capita growth	1.8	−4.0	2.8	0.24
Observations	674	163	511	

Source: Authors' calculations.

a crisis within the large shock sample is only about 24%. However, there is a substantial difference in real GDP per capita growth of more than 6¾ percentage points between crisis and non-crisis cases, which is also statistically significant.

In principle, a crisis event can be defined in various ways. We use the above definition to highlight the extreme nature of the event, which is the main focus of our analysis. Figure 2 presents the distribution of real GDP per capita for crisis *versus* normal episodes. In a majority of cases, the drop in growth (negative value) is also associated with a persistent decline in the level of output. In other words, as discussed above, in only a few episodes is negative real GDP growth followed by a quick recovery to the pre-shock level of output, akin to normal business cycle movements in advanced and emerging market countries. This observation underscores a key vulnerability in low-income countries: once growth drops into the negative territory, output losses tend to be persistent. [4]

4. EMPIRICAL ANALYSIS: ECONOMETRIC APPROACH

(a) *Probit model*

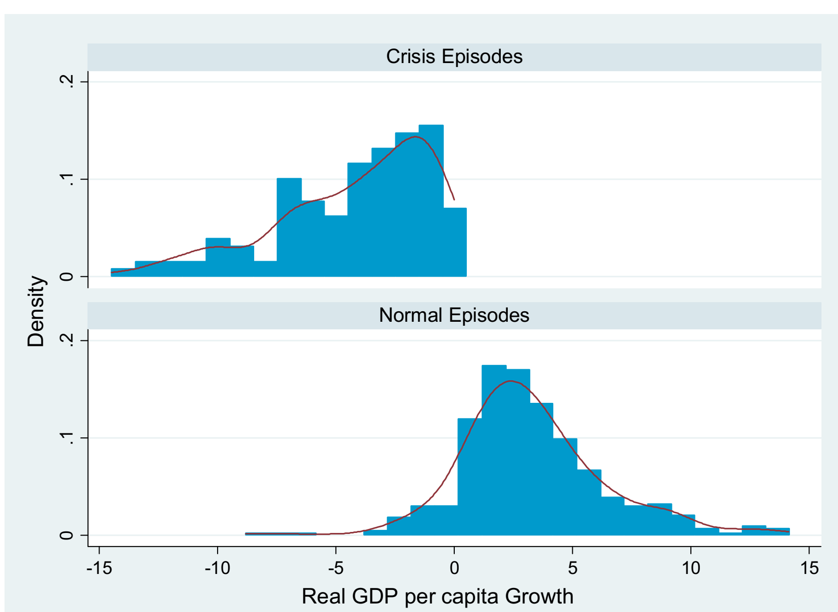
The effect of various policy and structural variables on the likelihood of a growth crisis in the presence of large exogenous shocks is assessed by estimating a binary response model for panel data. The general specification for a panel probit model is given by

$$y_{it} = 1 \quad \text{growth crisis events}$$
$$y_{it} = 0 \quad \text{normal episodes}$$
$$P(y_{it} = 1 | x_{it},\ c_i) = \Phi(x'_{it}\beta + c_i) \quad i = 1, \ldots, n \text{ and } t = 1, \ldots, T$$

where, y is the observed outcome, Φ is the cumulative normal density function (c.d.f.), x_{it} is the 1xk vector of explanatory variables, and β is kx1 vector of coefficients associated with x_{it}. Different estimators are constructed depending on their assumptions for the panel heterogeneity (i.e., how c_i is treated). Pooled probit models assume independence of observations over both t and i. A random effects (REs) probit model treats the individual specific effect, c_i, as an unobserved random variable with $c_i | x_{it} \sim \text{IN}\ (\mu_c,\ \sigma_c^2)$ if an overall intercept is excluded, and imposes independence of c_i and x_i. A fixed effects (FE) probit model treats c_i as parameters to be estimated along with β, and does not make any assumptions about the distribution of c_i given x_i. This can be problematic in short panels as both β and c_i are inconsistently estimated owing to an incidental parameters problem. Finally, a correlated model relaxes independence between c_i and x_i using the Chamberlain (1982)–Mundlak (1978) device under conditional normality. In this specification, the time average is often used to save on degrees of freedom.

In this paper, the estimations are carried out step-by-step under different estimators and a correlated pooled probit model is preferred based on the econometric tests for the significance of both the individual specific effect and the sample average for covariates. [5] Sixty-one countries are included in the sample over 1990–2009 (Table 10).

Drawing on the literature, a general-to-specific approach was used to reach the preferred specification of the model, starting from a set of 22 potential regressors (see Table 11). The final set of explanatory variables can be grouped into three clusters:



Source: Authors' calculations.

Figure 2. *Distribution of real GDP per capita: crises versus normal episodes (1980–2009).*

- *Policy variables*: These include the ratio of government balance to GDP, reserve coverage (in months of imports of goods and services) a dummy for flexible exchange rate regime, and the exchange market pressure index. The latter, drawing from indicators of speculative pressure in the crisis literature (Eichengreen, Rose, Wyplosk, Dumas, & Weber, 1995; Herrera & Garcia, 1999; Kaminsky & Reinhart, 1999), is a composite index comprising depreciation of the official exchange rate, change in the stock of international reserves (in months of imports of goods and services), and the black market premium given by:

$$EMPI_{it} = \frac{\ln\left(\frac{xr_{it}}{xr_{it-1}}\right)}{\sigma_{\Delta\ln(xr)}} - \frac{\frac{res_{it}-res_{it-1}}{mgs_{t-1}}}{\sigma_{\Delta res/mgs_{t-1}}} + \frac{\ln(1+blackpr_{it})}{\sigma_{\Delta\ln(xr)}}$$

where $EMPI_{it}$ is the exchange market pressure index for country i at time t, xr is the exchange rate of national currency to US dollar (an increase indicates a nominal depreciation), res is the stock of international reserves, mgs is the imports of goods and services, $blackpr$ is the black market premium, and σ is the standard deviation of each variable. Weights are inverses of the standard deviation of each component for all countries over the full sample after removing the outliers. Higher levels of $EMPI$ indicate increased pressures on the exchange rate. This version of the index was first used in Bal Gündüz (2009) as a sub-component of the macroeconomic instability indicator.

- *Structural and institutional variables*: These include the World Bank's CPIA,[6] real GDP growth in the previous period, and the country-specific average of real GDP per capita growth over the sample period. The latter is a proxy for cross-country differences in underlying structural and institutional conditions. For instance, long-run historical performance of income per capita can capture shock amplifiers such as the relative diversification of trade and production, internal conflict, and domestic shocks.
- *Shock size*: These include growth in trading partners weighted by the ratio of lagged exports to GDP, and the change in export prices weighted by the ratio of lagged exports to GDP. These variables capture exposure to trade-related shocks as countries experiencing larger shocks are more likely to suffer severe growth declines when shocks materialize. Conversely, a very favorable external environment may shield a country with weaker policy fundamentals from growth crises.

All explanatory variables are lagged by 1 year, except for the variables capturing exogenous shock size, and are thus predetermined with respect to the crisis event. This structure is well suited to an early warning system to detect vulnerable countries sufficiently ahead of time so that policy measures could be implemented to mitigate the vulnerability.

(b) *Estimation results: Benchmark probit specifications*

Table 2 reports the estimation results for the baseline probit regressions for all countries (Column 1) and for three subgroups (excluding commodity exporters, oil exporters, and small islands;[7] Columns 2–4). The results indicate that variables significantly associated with the likelihood of a growth crises can be broadly grouped into three categories: (i) time-varying variables that can be controlled by policies, including government balance, reserve coverage, exchange market pressure index, and to some extent the exchange rate regime for countries that are not members of currency zones; (ii) highly persistent or country-specific variables that are likely correlated with deeper institutional and structural characteristics of each country, which by their nature can be addressed only gradually over time through structural policies, including the CPIA, and the country-specific average of real GDP growth; and (iii) variables controlling for the country-specific size of exogenous shocks that turn out significant even within this sub-sample of large shocks, including the external demand and export price shocks.

We find that the probability of a growth crisis increases sharply for countries with weaker institutions (proxied by the CPIA), lower pre-shock GDP growth, and a track record of anemic past real per capita GDP growth. Importantly, sound policy fundamentals, such as higher reserve coverage and fiscal balance, are associated with a lower likelihood of a growth crisis, reflecting the role of counter-cyclical policies in supporting domestic demand. Similarly, lower pre-shock balance of payments pressures reduce the likelihood of a growth crisis. Finally, consistent with Dabla-Norris *et al.* (2011), a more flexible exchange rate regime sharply reduces the probability of a growth crisis, suggesting that exchange rate flexibility can help facilitate economic adjustment to real shocks.

As expected, shock size is significantly associated with the likelihood of a growth crisis. The shock variables enter with a negative sign, indicating that positive shocks to external demand and commodity prices lower the probability of a growth crisis. The impact of the export price shock, however, is largely driven by commodity exporters as it becomes insignificant once this country-group is excluded from the sample (Table 2, Column 2). Finally, both contemporaneous shocks are significant at the 5% level in the sample excluding small islands (Table 2, Column 4).

More informative are the marginal effects of these explanatory variables on the probability of a growth decline. Owing to the non-linearity of the model, estimated coefficients have no direct interpretation. Marginal effects of variables calculated at preset values of other explanatory variables (at their means or medians) are reported to present the relative impact of each variable. Table 3 presents average marginal effects (Column 1)[8] and the marginal effects of a specific covariate evaluated at the sample median, and worst quartiles (i.e., 75th/25th percentile if estimated coefficient of a covariate is positive/negative) of all other variables (see Table 12 for sample distribution of covariates). The coefficient estimates provide a gauge of the relative importance of each variable on the crisis probability. As can be seen from Tables 3 and 4, institutional quality and the exchange rate regime are the strongest predictors of a growth crisis. Moreover, the marginal effects of the policy variables (e.g., fiscal balance, reserve coverage) and institutional quality on the crisis probability are significantly higher for a country with weaker buffers (Column 3) as compared to the median country (Column 2). This suggests that payoffs from improvements in institutional quality and macroeconomic policy frameworks are likely to be highest in these countries.

Table 4 reports the marginal impact of a change in each explanatory variable from its median value to its best quartile (75th/25th percentile if estimated coefficient is negative/positive), evaluating all other variables at their sample medians. An improvement in the CPIA from 3.4 to 3.8 reduces the probability of a growth crisis by about 3% for the median country. Similarly, an increase in reserve coverage from 2.8 to 4.1 months of imports lowers the crisis probability by 2½ percentage points. Table 4 also suggests that shifting from a fixed to a flexible exchange rate regime has a significant impact

Table 2. *Probability of Growth Crisis (Correlated Pooled Probit Regression, 1990–2009)*

	All LICs (1)		Excluding commodity exporters (2)		Excluding oil exporters (3)		Excluding small islands (4)	
CPIA ($t-1$)	−0.3438	***	−0.2814	**	−0.3637	***	−0.4087	***
	(0.1259)		(0.1319)		(0.1304)		(0.1464)	
GDP growth ($t-1$)	−0.0632	***	−0.0606	***	−0.0649	***	−0.0684	**
	(0.0198)		(0.0235)		(0.0198)		(0.0266)	
Government balance, % of GDP ($t-1$)	−0.0162	*	−0.0148		−0.0133		−0.0222	**
	(0.0089)		(0.0095)		(0.0089)		(0.0087)	
Reserve coverage, months of imports ($t-1$)	−0.0852	**	−0.1086	***	−0.1032	***	−0.0684	*
	(0.0380)		(0.0410)		(0.0392)		(0.0378)	
Exchange market pressure index ($t-1$)	0.0525	**	0.0312	*	0.0372	**	0.0511	**
	(0.0204)		(0.0162)		(0.0162)		(0.0243)	
Exchange rate regime (flexible:1; fixed:0) ($t-1$)	−0.3783	**	−0.3882	**	−0.3488	**	−0.4432	**
	(0.1630)		(0.1817)		(0.1693)		(0.1990)	
Growth in trading partners weighted by lagged exports to GDP	−0.1899	*	−0.3254		−0.2145	*	−0.2867	**
	(0.1119)		(0.2077)		(0.1268)		(0.1252)	
Change in export prices weighted by lagged exports to GDP	−0.0335	**	−0.0176		−0.0230		−0.0350	**
	(0.0161)		(0.0254)		(0.0179)		(0.0176)	
Country-specific averages for 1990–2008								
Real GDP growth	−0.1847	***	−0.2333	***	−0.1807	***	−0.1876	***
	(0.0479)		(0.0566)		(0.0482)		(0.0520)	
Constant	1.5295	***	1.6463	***	1.6777	***	1.7247	***
	(0.3699)		(0.3870)		(0.3850)		(0.4202)	
Pseudo R-squared	0.26		0.28		0.25		0.30	
No of observations	561		410		537		447	
Growth decline events	120		93		116		88	
Normal episodes	441		317		421		359	
Sample probability	0.21		0.23		0.22		0.20	
No of countries	61		42		58		49	
Wald test (Chi-square)	119 (0.00)		98 (0.00)		128 (0.00)		120 (0.00)	

Source: Authors' calculations.
Note: Estimated by a correlated pooled probit model with cluster-robust standard errors.
Standard errors are in parentheses.
[*] Significant at 10%.
[**] Significant at 5%.
[***] Significant at 1%.

in the crisis probability, reducing the likelihood of a growth crisis by 9 percentage points. Finally, the results confirm the importance of path dependence as countries with a stronger past track record of real GDP growth have a significantly lower likelihood of a growth crisis.

Predicted probabilities from the benchmark probit regressions can be used to call crisis events based on a threshold probability. Following Demirgüc-Kunt and Detragiache (1999), a loss function minimization approach is used to derive the threshold probability. The expected loss function is the weighted average of missed crises (Type I errors) and false alarms (Type II errors), with the weights reflecting costs attached to each type of error. In this paper, asymmetric weights are used that place higher weights on missing crises, resulting in a threshold probability of 0.19, with associated Type I and Type II errors of 20% and 27%, respectively (Table 5). A growth crisis is predicted when a country with weak policy buffers and poor institutions is hit by adverse external shocks (Table 3, Column 3). In this case, the 95% confidence interval of predicted probabilities also lies above the threshold probability. On the other hand, the predicted probability for the median low-income country (including the 95% confidence interval) lies comfortably below the crisis threshold.

The relationship between each covariate and the threshold crisis probability is further illustrated in Figure 3 (other variables evaluated at the sample median) and Figure 4 (variables evaluated at their worst quartiles). As can be seen from Figure 3, only extreme values of some covariates could push the predicted probability above the threshold for the median country. These include an exceptionally weak institutional quality, high exchange market pressure, a significantly poor track record of past GDP growth, and negative tail shocks to external demand and export prices. On the other hand, barring an exceptionally good track record of past GDP growth or an extremely favorable tail shock to external demand, changes in most explanatory variables are insufficient to lower the predicted probability below the threshold for a weakly-positioned country (Figure 4).[9]

(i) *Goodness of fit*

Measuring the "goodness" of fit of the model is not straightforward as the empirical model predicts conditional probabilities that must be compared to actual events. For instance, a predicted probability of less than one still assigns a non-zero probability to the alternative event. Nonetheless, an examination of the distribution of in-sample and out-of-sample predicted probabilities for growth crises *versus* normal episodes can provide a gauge of the goodness of fit of the model. As can be seen from Table 5, the distributions of predicted probabilities for crisis and non-crisis events are distinct.

Table 3. *Benchmark Regression: Average and Conditional Marginal Effects*

	Average marginal effects[a] (1)		Marginal effects: Median LIC[b] (2)		Marginal effects: LIC with weak fundamentals[c] (3)	
CPIA ($t-1$)	−0.0744	***	−0.0822	***	−0.1304	***
	(0.0275)		(0.0305)		(0.0486)	
GDP growth ($t-1$)	−0.0137	***	−0.0151	***	−0.0240	***
	(0.0040)		(0.0044)		(0.0073)	
Government balance, % of GDP ($t-1$)	−0.0035	*	−0.0039	*	−0.0061	*
	(0.0019)		(0.0021)		(0.0034)	
Reserve coverage, months of imports ($t-1$)	−0.0184	**	−0.0204	**	−0.0323	**
	(0.0084)		(0.0097)		(0.0148)	
Exchange market pressure index ($t-1$)	0.0113	***	0.0125	***	0.0199	***
	(0.0044)		(0.0047)		(0.0076)	
Exchange rate regime (flexible:1; fixed:0) ($t-1$)	−0.0818	**	−0.0904	**	−0.1435	**
	(0.0345)		(0.0386)		(0.0595)	
Growth in trading partners weighted by lagged exports to GDP	−0.0411	*	−0.0454	*	−0.0720	*
	(0.0235)		(0.0266)		(0.0428)	
Change in export prices weighted by lagged exports to GDP	−0.0072	**	−0.0080	**	−0.0127	**
	(0.0034)		(0.0038)		(0.0061)	
Country-specific averages for the sample						
Real GDP growth	−0.0400	***	−0.0442	***	−0.0701	***
	(0.0101)		(0.0117)		(0.0185)	
Threshold probability[d]			0.19		0.19	
Predicted probability			0.16		0.40	
95% confidence interval			[0.12 0.20]		[0.34 0.46]	

Source: Authors' calculations.
Note: Average and conditional marginal effects are estimated from the benchmark correlated pooled probit model for all LICs. Standard errors are in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
[a] Marginal effects of a specific covariate on the response probability averaged across the distribution of covariates in the sample.
[b] All covariates are set at their median for the full sample.
[c] Covariates are set at their 75th (25th) percentile if their estimated coefficient is positive (negative).
[d] The threshold probability is obtained by the minimization of weighted misclassification errors.

Table 4. *Marginal Effects of Explanatory Variables on Crisis Probability (Percentage point, unless otherwise indicated)*

	Median to best quartile	Change in predicted crisis probability
CPIA ($t-1$)	3.4 → 3.8	−2.9
GDP growth ($t-1$)	4.3 → 6.3	−2.8
Government balance, % of GDP ($t-1$)	−3.4 → −1.7	−0.7
Reserve coverage, months of imports ($t-1$)	2.8 → 4.1	−2.5
Exchange market pressure index ($t-1$)	0.2 → −0.6	−1.0
Exchange rate regime (flexible:1; fixed:0) ($t-1$)	Fixed → Flexible	−9.0
Growth in trading partners weighted by lagged exports to GDP	0.5 → 1.0	−2.0
Change in export prices weighted by lagged exports to GDP	0.0 → 1.6	−1.2
Country-specific averages for 1990–2008		
Real GDP growth	3.5 → 4.7	−4.8

Source: Authors' calculations.

Moreover, the predicted probabilities are well dispersed in the [0, 1] interval, indicating the ability of the empirical model to differentiate between alternative outcomes. The less informative the model, the less dispersed the predicted probabilities, the limiting case being the flat sample probability predicted for both types of events. The median predicted probability for a growth crisis is 0.38 *versus* 0.10 for normal episodes. Moreover, in contrast to non-crisis episodes, more than 75% of growth crisis episodes have probabilities above the crisis threshold.

Table 5 also presents the out-of-sample predictions for the benchmark model. These are obtained by estimating the sample for 1990–2004 and calculating predicted probabilities for 2004–09. Using the threshold probability of 19%, the model

Table 5. *Predicted Probabilities (Percentiles)*

	In sample		Out of sample[a]	
	Growth crisis (1)	Normal episodes (2)	Growth crisis (3)	Normal episodes (4)
1%	0.03	0.00	0.04	0.00
5%	0.05	0.00	0.04	0.00
10%	0.09	0.01	0.19	0.01
25%	0.19	0.04	0.26	0.04
50%	0.38	0.10	0.39	0.10
75%	0.60	0.20	0.63	0.24
90%	0.68	0.39	0.63	0.50
95%	0.86	0.47	0.69	0.56
99%	1.00	0.60	0.69	0.77
Obs.	120	441	15	119
Type I		0.20		0.07
Type II		0.27		0.34
Sample probability[b]		0.21		0.11

[a] Same model is estimated for 1980–2004. Predicted probabilities are for 2005–09.
[b] Number of growth crises divided by total observations.

correctly calls 14 out of 15 crises, with only 7% of crises missed (even lower than the in-sample prediction) and false alarms occurring in 34% of the non-crises episodes. On account of the sharply lower Type I error, the overall misclassification errors (sum of the two errors as percent of total observations) are even lower than in the in-sample predictions. While out-of-sample predictions tend to be weaker than in-sample performance, these results provide evidence of the index's goodness-of-fit.

(ii) *Robustness check*

As an important robustness check we examined whether the benchmark specification holds for all growth crises, and not just those induced by large exogenous shocks, controlling for shock covariates in the regression. As seen in Table 13 (Columns 1 and 2), the results remain qualitatively unchanged. When all growth crises are included in the sample, climatic shocks and shocks to remittances turn significant. A key difference with the benchmark specification reported in Table 2 is that reserves are far more effective in reducing the likelihood of a growth crisis induced by large exogenous shocks. This result is intuitive as reserve buffers can be depleted quite quickly in the absence of a significant adjustment to policies when a growth crisis originates from macroeconomic mismanagement.

5. EMPIRICAL ANALYSIS: SIGNALING APPROACH

(a) *Methodology: Signaling Approach*

The estimation of thresholds for growth crises for each indicator is based on a "signaling" approach (IMF, 2010, 2011). This consists of defining cut-off values for each individual indicator that discriminate between crisis and non-crisis episodes. If an indicator exceeds the cut-off level, the model issues a signal of an upcoming growth crisis episode. The optimal cut-off point balances Type I and II errors since the lower the threshold, the more signals send (i.e., Type I errors decrease), but at the expense of higher false alarms (i.e., Type II errors increase). Using a higher threshold reduces the number of incorrect signals, but at the expense of increasing missed crises.

Formally, we can define a signaling variable at time t, d_t, for the following j time periods as follows:

$$d_t = \begin{cases} 1 \text{ for } \forall j, & \text{if } x_{t-1} > C \\ 0, & \text{otherwise} \end{cases}$$

where x_t refers to an indicator variable, which is a monotonically increasing function of crisis probabilities, and C represents a fixed cut-off for x_t. The signaling window j is set to 1 year in the analysis. Two methods are commonly used to determine the optimal value of C: the minimization of the total misclassification errors and the maximization of the signal-to-noise ratio (SNR). We implemented both approaches, but as in previous studies, the maximization of the signal-to-noise ratio led to corner solutions associated with very high Type I or Type II errors. Therefore, we report thresholds based on the minimization of misclassification errors.

Under the total misclassification errors (TME) method, for each cut-off point C, the TME value can be expressed as the sum of Type I and Type II errors,

$$TME(C) = \frac{\text{Missed crises } (C)}{\text{Total crises}} + \frac{\text{False alarms } (C)}{\text{Total non-crises}}$$

The optimal threshold C^* is the value that minimizes $TME(C)$.

The overall vulnerability index is calculated based on the signaling power of each indicator. This entails two steps. In the first step, an index summarizing a cluster of variables is calculated. Thresholds that yield the best split are used to map indicator values into zero–one scores, with each indicator assigned a weight based on its predictive power.[10] In the second step, the predictive power of the cluster indices is evaluated and the indicators are aggregated in the vulnerability index based on their own predictive power and the predictive power of the cluster indices:

$$\text{Overall Index} = \sum_g w_g \sum_i w_{i,g} d_i$$

where $w_{i,g}$ is the weight of each individual indicator i in group g, w_g is the weight of the group, and d_i is a dummy that takes the value of 1 if the indicator is above (below) the threshold, and zero otherwise. As before, the methodology puts a higher weight on not missing crises, motivated by the high costs associated with crises and the benefits from being able to take mitigating steps.

(b) *Results: Signaling approach*

The analysis uses 13 variables, starting with the set included in the benchmark probit regressions and adding a number of variables identified in the literature as determinants of growth down-breaks. The composition of the growth decline vulnerability index and information on performance of individual indicators are presented in Table 6.

The variables are grouped into three clusters: overall economy and institutions, external sector, and the fiscal sector. The first cluster includes the CPIA index, the Gini coefficient (measuring the extent of income inequality), real GDP growth, and the sample average of GDP per capita growth. The external sector indicators comprise reserve coverage, growth in the volume of exports of goods and services, exchange market pressure index, and the contemporaneous variables controlling for the country-specific size of exogenous shocks to external demand and export prices. Finally, the fiscal cluster includes government balance, public debt, tax revenue (all in percentage of GDP), and the cumulative growth in real government revenue over the past 2 years. As before, all indicators except

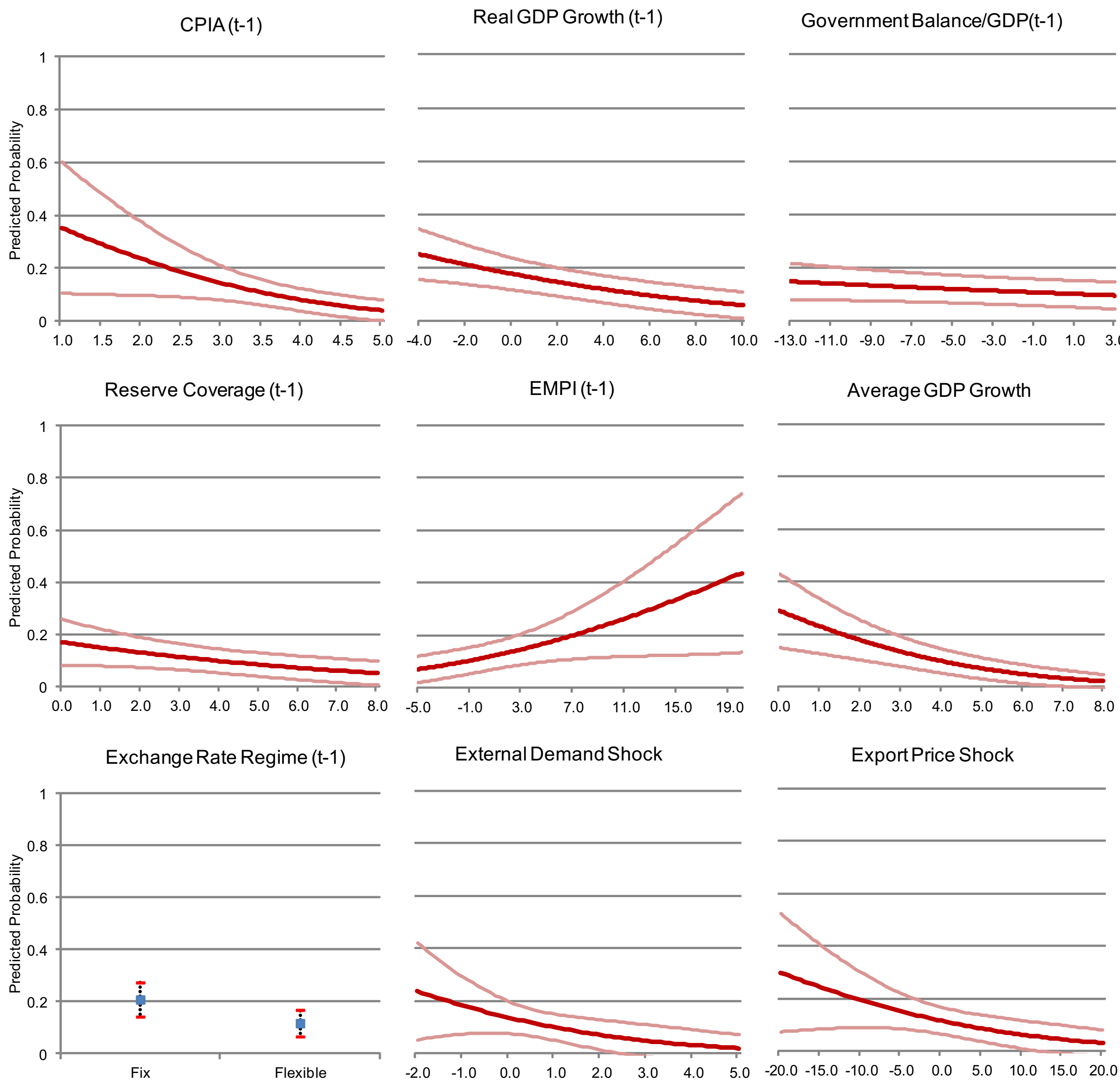
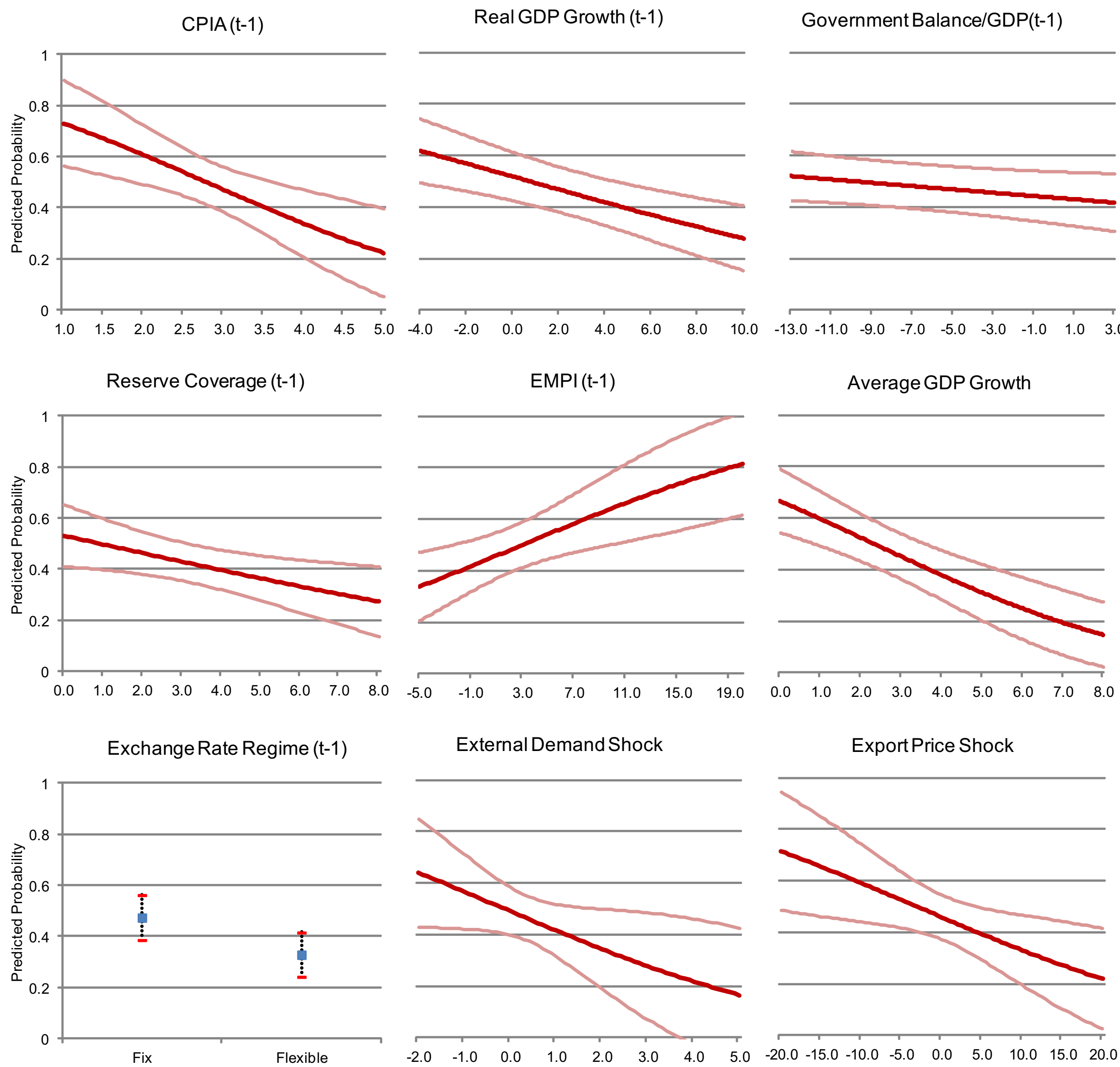


Figure 3. *Effects of explanatory variables on predicted probability of growth crises for the median low-income country (other covariates are fixed at their median). 95% confidence intervals for predicted probabilities are presented.*

for the contemporaneous shock size variables are lagged by one period.

For each indicator, the first two columns in Table 6 present the crisis *versus* non-crisis observations. The third column shows the estimated thresholds followed by the corresponding Type I and Type II errors (Columns 4 and 5). The weight of each indicator in the composite vulnerability index is determined by its relative signaling power (defined as one minus the total error; Column 6). We rebalanced unconstrained weights predicted from the signaling power of indicators to account for potential correlation among variables both within a cluster and across clusters. Unconstrained weights obtained were 51% for overall economy and institutions; 28% for external index; and 21% for fiscal index. Adjustments to the weights were guided by model performance. The top predictor of growth crises is the overall economy and institutions index (accounting for 37% of the index weight). Within this cluster, lagged real GDP growth, which provides information on the state of the pre-shock economy, and the Gini coefficient are the main predictors. Aggregate weights for the external and fiscal sector indices within the overall index are broadly similar, with reserve coverage ratio and exchange market pressure index, and government balance and real revenue growth the top predictors, respectively. The overall index threshold of 0.44 is obtained by minimizing an asymmetrically-weighted loss function which penalizes missing crises more.

We estimated univariate and multivariate probit regressions to assess the relative ability of the sub-indices as well as the overall vulnerability index to provide early warning signals of growth crises. In the univariate probit regressions, the overall index and its sub-components are entered one-by-one as the only covariate in addition to the constant. In the multivariate probit regressions, all sub-components of the index are included simultaneously. In the univariate regressions, both the overall index and the three sub-indices are highly significant determinants of growth crises. Figure 5 plots the predicted probabilities against the value of each index, ranging



Source: Authors' calculations.

Figure 4. *Effects of explanatory variables on predicted probability of growth crises for a low-income country (LIC) with weak fundamentals (other covariates are fixed at their 75th (25th) percentile if their estimated coefficient is positive (negative), i.e., at their worst quartiles). 95% confidence intervals for predicted probabilities are presented.*

from zero (no signal is issued in any indicator within the cluster) to one (all indicators issue signals).

As can be seen from Table 7 and Figure 5, the predicted probability for the overall index is well dispersed within a relatively narrow 95% confidence band and fares much better than any of its components. The significant impact of overall economy and institutions and external sector indices on the predicted probability provide support to assigning higher weights to these clusters. The impact of the fiscal index, however, is comparatively lower. This could be driven by the limited availability of fiscal indicators during the first half of the sample period. As a result, we assign a somewhat lower weight to the fiscal index.

Multivariate probit regressions, which control for the correlation among sub-components, provide similar results. The economy and institutions and external sector indices are significant at the 1% level, while the fiscal index is significant at the 10% level. The relative impacts of the sub-components on predicted probabilities are presented in Figure 6 for the median low-income country, and for a country with weak fundamentals.

For a country with weak fundamentals (indicator values in 75th/25th percentile), all indicators issue a signal and the vulnerability index adds up to its highest value of one. When all indicators are fixed at the sample median, the overall vulnerability index is 0.11, safely below the index threshold of 0.44. On the other hand, only strong policies and a benign global environment can protect a country with weak institutions and anemic pre-shock growth from a crisis. Although a growth crisis would not be predicted, the index would still be rather high at 0.37, and the country could be considered at medium vulnerability.

Table 6. *Non-parametric Signaling Approach: Performance of Indicators and Model Fit*

Indicators	Direction to be safe	Crisis observations (1)	Non-crisis observations (2)	Thresholds[a] (3)	Type I error (4)	Type II error (5)	Index weight (6)
Overall economy and institutions							0.37
Real GDP growth ($t-1$)	>	125	453	2.96	0.24	0.26	0.11
CPIA ($t-1$)	>	125	453	3.00	0.49	0.20	0.07
Gini coefficient ($t-1$)	<	26	84	44.95	0.23	0.36	0.11
Real GDP per capita growth, sample average	>	125	456	0.84	0.30	0.33	0.09
External sector							0.33
Reserve coverage (months of imports) ($t-1$)	>	125	456	2.30	0.42	0.33	0.09
Real export growth (G and S) ($t-1$)	>	117	441	1.77	0.52	0.33	0.05
Exchange market pressure index ($t-1$)	<	120	453	0.48	0.37	0.39	0.08
Growth in trading partners weighted by lagged exports to GDP	>	125	456	0.48	0.37	0.43	0.06
Change in export prices weighted by lagged exports to GDP	>	124	452	0.35	0.27	0.55	0.06
Fiscal sector							0.30
Government balance (% of GDP) ($t-1$)	>	125	456	−4.21	0.40	0.36	0.10
Public debt (% of GDP) ($t-1$)	<	36	154	65.32	0.05	0.80	0.05
Real government revenue (% change over 2 years) ($t-1$)	>	110	408	4.73	0.43	0.27	0.13
Tax revenue (% of GDP) ($t-1$)	>	70	286	10.51	0.64	0.29	0.02
Fit of the model							
Overall Index threshold[b]							0.44
Proportion of Crises Missed							0.17
Proportion of Non-crises mis-specified (false alarms)							0.31
Overall error[c]							0.28

Source: Authors' calculations.
[a] The thresholds are achieved by minimizing Type I plus Type II errors.
[b] Threshold for the overall index is derived by minimizing the asymmetrically weighted loss function giving more weight to Type I error.
[c] Missed crises plus false alarms as percent of total observations.

(i) *Goodness of fit*

The vulnerability index performs fairly well in identifying crisis-prone countries. Table 8 presents the distribution of the vulnerability index for crisis *versus* non-crisis episodes. The median predicted vulnerability index for growth crises is 0.66 *versus* 0.33 for normal episodes. Seventy-five percent of growth crises have vulnerability indices above 0.50, and only 10% of crisis events have the vulnerability index below 0.31.With respect to in-sample performance, the index correctly calls 83% of growth crises with an overall model misclassification error of 28%. A secondary threshold of 0.3 is selected to differentiate low *versus* medium vulnerability cases. At this threshold, less than 9% of crisis events are missed while false alarms increase to about 56%.

The out-of-sample model performance is obtained by deriving thresholds and weights for each indicator over the 1990–2008 period and evaluating predictions during the 2009 global crisis. The vulnerability index performs well in explaining growth crises in low-income countries during the global crisis. It correctly flags 9 out of 13 countries (70%) that experienced a growth crisis in 2009, with false alarms occurring in 28% of the non-crisis episodes. Moreover, one out of the four crisis cases missed would have been flagged as being moderately vulnerable by the index.

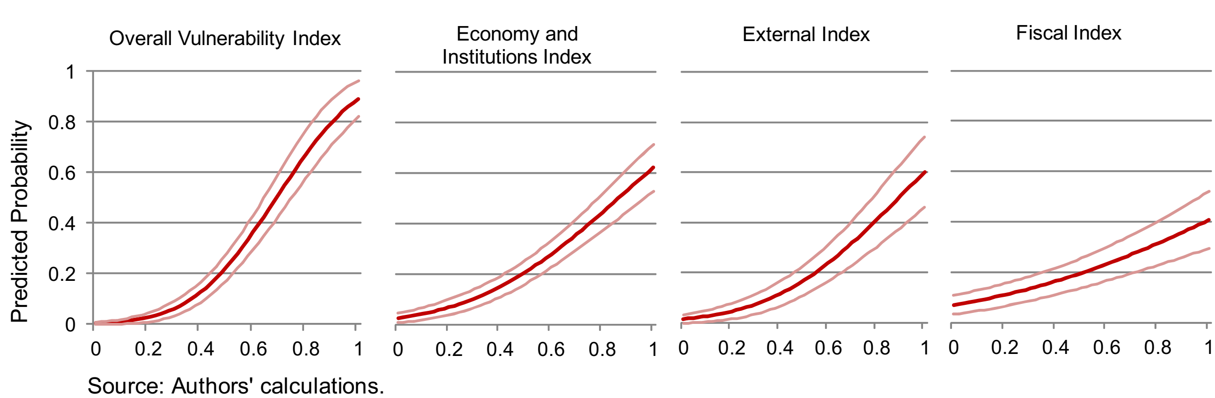


Figure 5. *Predicted probability of growth crises: performance of the vulnerability index and its sub-components. Predicted probabilities are estimated from univariate probit regressions when the overall index or each of its sub-components is included as the only covariate. 95% confidence intervals for predicted probabilities are presented.*

Table 7. *Distribution of Predicted Probabilities: Vulnerability Index versus its Sub-Components (Percentiles)*

	Vulnerability Index		Economy and Institutions Index		External Index		Fiscal Index	
	Growth crisis	Normal episodes	Growth crisis	Normal episodes	Growth crisis	Normal episodes	Growth crisis	Normal episodes
1%	0.02	0.00	0.03	0.03	0.03	0.02	0.07	0.07
5%	0.05	0.01	0.03	0.03	0.06	0.02	0.07	0.07
10%	0.07	0.01	0.09	0.03	0.10	0.02	0.07	0.07
25%	0.26	0.02	0.19	0.03	0.13	0.04	0.15	0.07
50%	0.49	0.07	0.39	0.09	0.25	0.12	0.23	0.14
75%	0.69	0.20	0.62	0.27	0.42	0.25	0.36	0.21
90%	0.79	0.41	0.62	0.39	0.60	0.31	0.41	0.36
95%	0.82	0.54	0.62	0.62	0.60	0.47	0.41	0.41
99%	0.87	0.68	0.62	0.62	0.60	0.60	0.41	0.41
Obs.	126	454	126	454	126	454	126	454

Source: Authors' calculations.

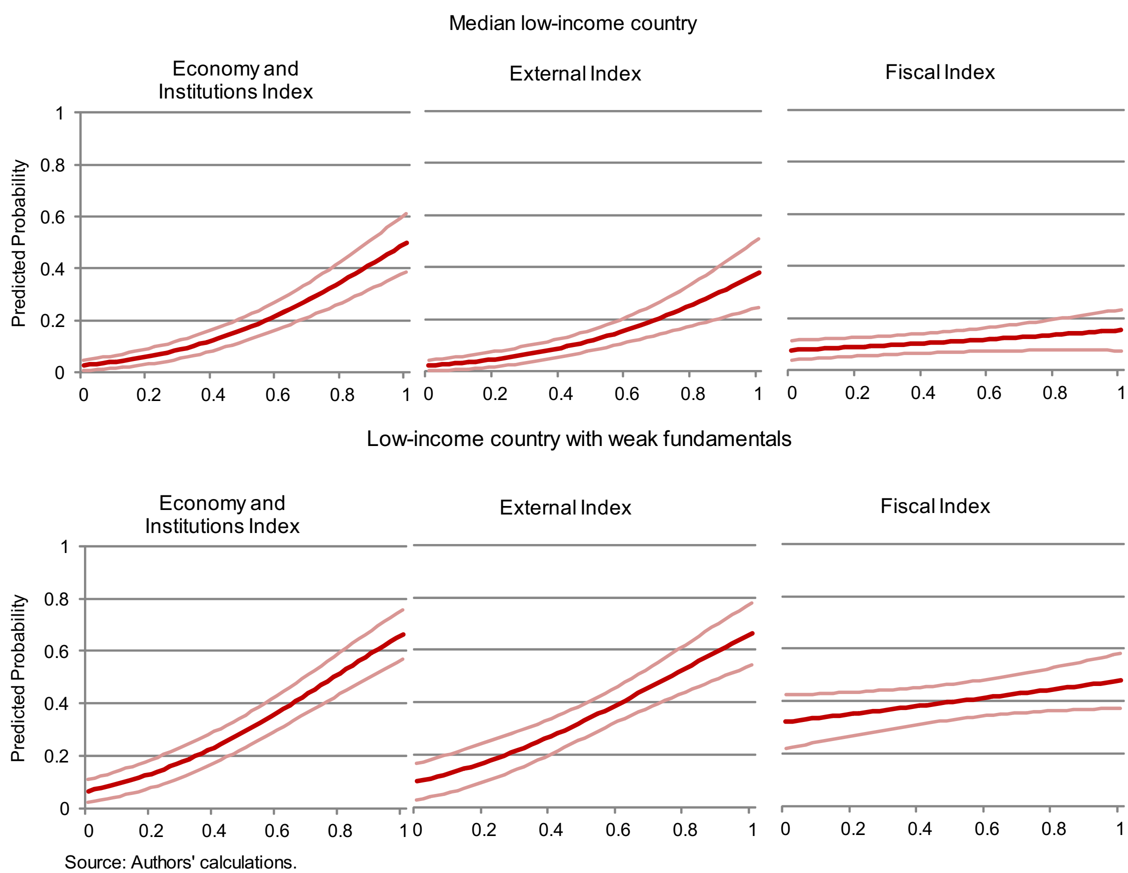


Figure 6. *Marginal effects of sub-components on predicted probability of growth crises. Predicted probabilities are estimated from a multivariate probit regression when all sub-components of the vulnerability index are included. For median low-income country (LIC), two sub-components are fixed at their median while the third sub-component is varied from zero (no signals) to one (all indicators within the cluster issue signals). For a LIC with weak fundamentals, two sub-components are fixed at their 75th percentile while the third one is varied from zero to one. 95% confidence intervals for predicted probabilities are presented.*

(c) *Assessment of vulnerabilities since 1990s*

The vulnerability index exhibited a trend decline since the 1990s until the onset of the twin crises in 2007–08 (food and fuel and the global financial crisis) (Figures 7 and A1). During this period, most low-income countries made significant strides in achieving macroeconomic stability and undertaking growth-supporting structural reforms. The trend decline in vulnerabilities was underpinned by a build-up of reserve buffers, improvements in fiscal performance and official debt-relief, substantial progress in removing policy-induced exchange market pressures, and strong growth. The benign global environment during the "great moderation" further contributed to an unprecedented drop in the index.

Although the vulnerability index rose significantly in the years following the global crisis, it remained lower than levels observed in the early-90s. At the onset of the crisis, while exceptional tail shocks to external demand and export prices

Table 8. *Vulnerability Index (Percentiles)*

	In sample	
	Growth crisis	Normal episodes
1%	0.18	0.00
5%	0.25	0.07
10%	0.31	0.10
25%	0.50	0.18
50%	0.66	0.33
75%	0.80	0.47
90%	0.89	0.63
95%	0.91	0.71
99%	0.97	0.80
Obs.	126	454
Type I		0.17
Type II		0.31
Sample probability[a]		0.22

Source: Authors' calculations.
[a] Number of growth crises divided by total observations.

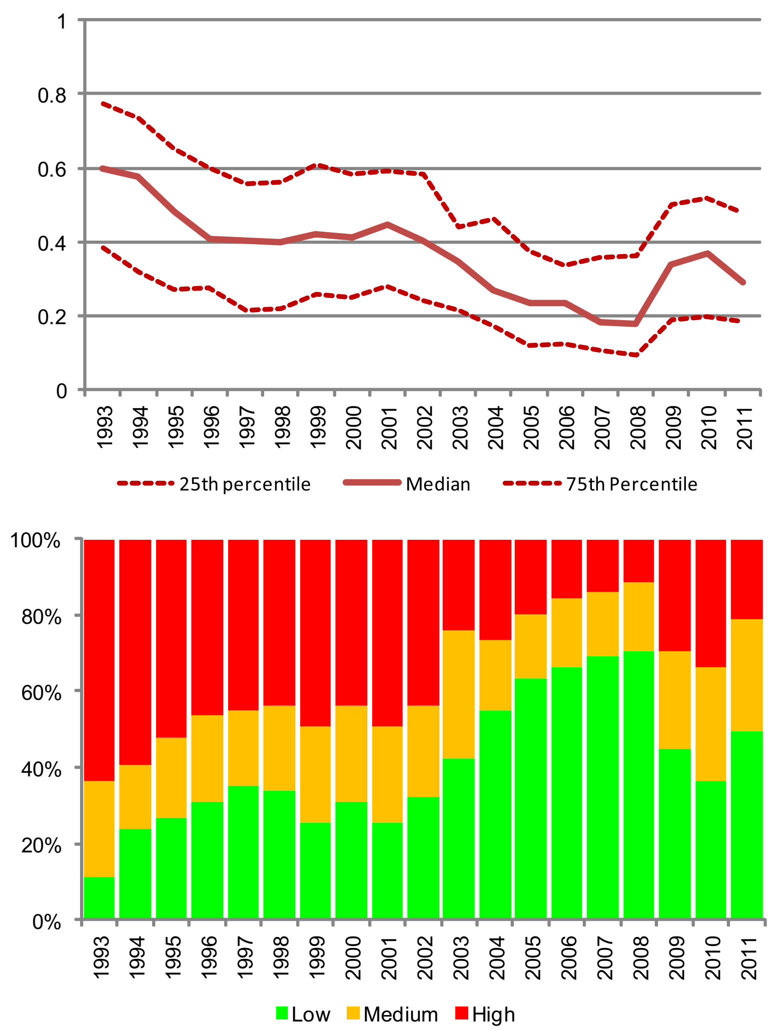
contributed to a deterioration in the index, high pre-crisis policy buffers rendered resilience to the risk of a growth crisis for most countries.

Vulnerabilities remained high during 2010–11 as policy buffers were expended in the wake of the global crisis. The increased vulnerabilities are attributable to the deterioration in fiscal indicators, in particular a worsening government balance and weaker revenue growth, as well as the pronounced decline in growth in 2009, while external sector indicators largely remained sound (Figure 8). Although the aggregate index showed some easing from its peak in 2010, reflecting more buoyant external conditions and stronger than expected growth in low-income countries, fiscal vulnerabilities remain elevated.

6. CONCLUDING REMARKS

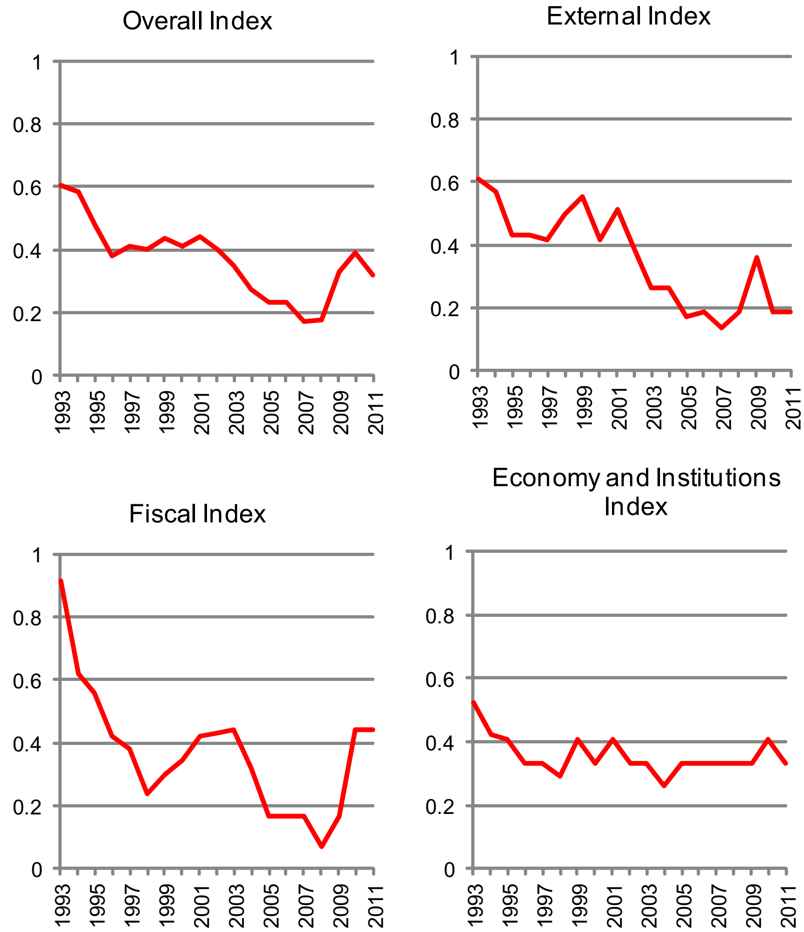
This paper presents an index which provides early warning signals of a growth crisis in low-income countries. The index uses a parsimonious set of macroeconomic and institutional indicators, aggregated using two complementary approaches. The role of these indicators in signaling growth crises is robustly established through regression analysis and a statistical signaling approach.

The vulnerability index provides a useful tool to monitor individual country risks to sharp growth declines arising from



Source: Authors' calculations

Figure 7. *Growth decline vulnerability index, 1993–2011 (quartiles of the index and distribution of vulnerability flags).*



Source: Authors' calculations.

Figure 8. *Vulnerability index and its components (median, 1993–2011).*

external shocks and to inform judgment-based approaches. The results show that country fundamentals, exchange rate regimes, institutional quality, and the size of shocks are important determinants of growth crises in low-income countries. The analysis also suggests that the sensitivity of crisis risks to varying policy and institutional fundamentals differs across countries. In particular, a strengthening of policy and institutional frameworks results in a larger reduction in the crisis probability in countries with initially weak buffers.

The vulnerability index and its sub-indices are calculated for a large sample of low-income countries during 1993–2011. The results show that sounder policy fundamentals and a benign global environment contributed to a marked decline in vulnerabilities till the onset of the global financial crisis. While most low-income countries recovered swiftly from the global crisis and have grown strongly since 2010, fiscal risks remain elevated compared to the pre-crisis period.

NOTES

1. Data on natural disasters are drawn from the Emergency Events Database. See Dabla-Norris, Kim, and Shirono (2011) for details.

2. Shock episodes that were contiguous or less than three years apart were recorded as one shock event occurring in the earliest available year. Moreover, shock events were derived independently from each other. Finally the threshold of 10^{th} percentile was derived from the country specific distribution of the shock variable excluding the 1^{st} and 99^{th} percentiles so as to limit the impact of outliers on the analysis.

3. The severe state failure events are taken from Political Instability Task Force (PITF) dataset. Four types of political crises are included in this dataset: revolutionary wars, ethnic wars, adverse regime changes, and genocides. From this dataset the variable SFTPMMAX, which presents the maximum magnitude of all events in a year, exceeding 3.9 is taken as a severe state failure event.

4. We tested several alternative definitions of the crisis event. (i) A sharp slowdown in growth compared to its pre-crisis trend: a growth crisis is identified when the difference between GDP growth in year t and the average between years t- − 5 and t − -1 is in the bottom 5 percent% of the sample. We used also the 10th percentile as a threshold. (ii) A hybrid definition: current definition of the growth crises is complemented by years with very sharp slowdown in GDP growth as identified in (i). We also tried increasing the "distance" between normal episodes and crises by taking out normal episodes with negative per capita growth or sharp growth slowdowns exceeding the threshold identified from the cross-country

distribution. Definition (i) substantially deteriorated the model's ability to distinguish economic conditions leading up to crises, while definition (ii) that involved increasing the distance between normal and crises episodes did not significantly change the results compared with the current definition. Accounting for persistent output losses in identifying crises turned out to be critical for distinguishing the impact of pre-crises economic conditions on output losses that could be triggered by shocks.

5. Results are available from authors upon request. This involved including the average real GDP growth rate in the estimation of the probit, and then in the univariate approach, which results from estimation of a correlated random effects probit model using the Chamberlain (1982)–Mundlak (1978) device to relax independence between the country-specific effect and covariates. In this specification, the time average of covariates is often used to save on degrees of freedom. The average over 1990-–2008 of all covariates have been added when estimating the correlated RE probit specification to account for potential correlation between the country-specific effect and covariates. Of these variables only the average real GDP growth turned out to be highly significant, indicating high correlation between the country-specific effect and GDP growth. Intuitively, average real GDP growth reveals country-specific, and possibly slow-changing, factors like geography and institutional capacity on long-run growth performance. As we average 19 years of data adding one year of unusually high or low growth would only have a marginal affect on average growth.

6. The World Bank's CPIA (the Country Policy and Institutional Assessment) is a broad indicator of the quality of a country's present policy and institutional framework. It is based on 16 criteria which are grouped into four clusters: economic management, structural policies, policy for social inclusion and equity, and public sector management and institutional quality. It is strongly correlated with other indices of institutional quality. As alternative variables, we also consider the index of economic freedom compiled by the Heritage Foundation and the Economic Freedom of the World index compiled by the Fraser Institute (both the overall and the subcomponents of private property rights). These variables did not turn out to be significant. Data availability is an issue as the sample size dropped significantly when these variables are included.

7. Small islands are defined as islands with a population less than 1 million.

8. Marginal effects of a specific covariate are averaged across the sample distribution of other covariates.

9. The ranges for individual covariates in Figure 3 are determined after removing outliers on both tails of their distributions in the estimation sample.

10. The weights of individual indicators are determined on the basis of their goodness of fit.

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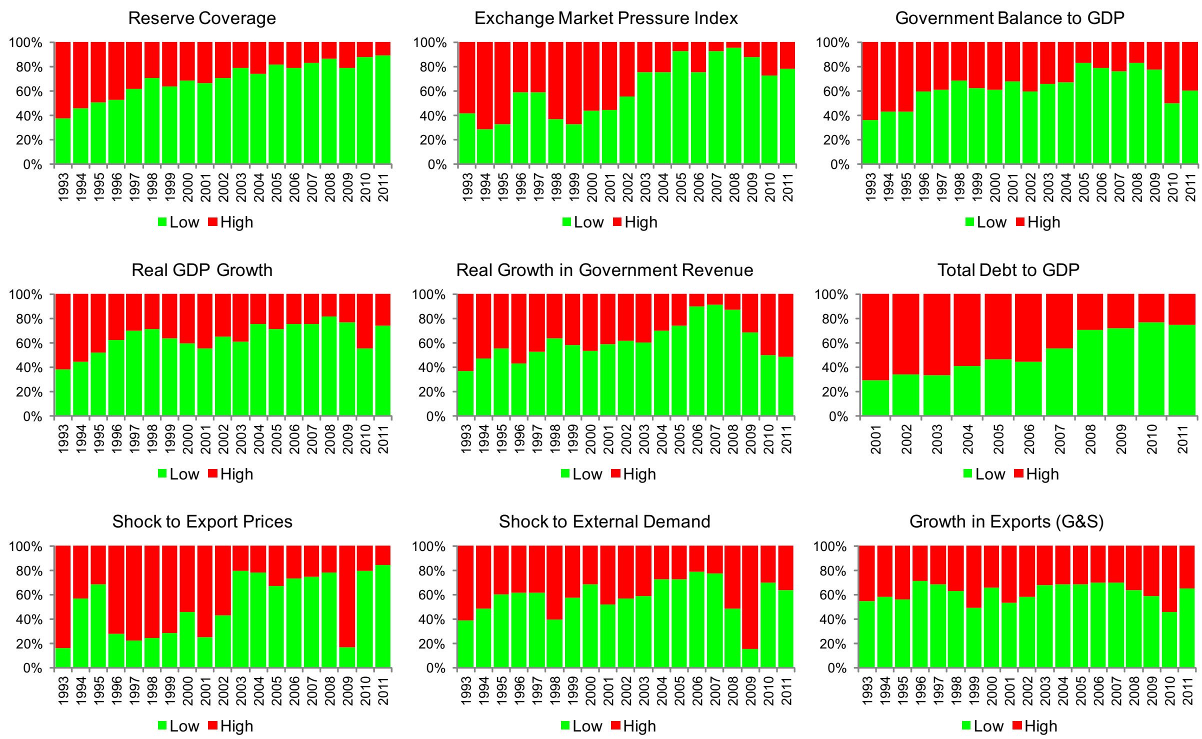
APPENDIX A



Source: Authors' calculations.

Figure A1. *Flags raised by selected indicators of the vulnerability index (1993–2011).*

Table 9. *Correlation Matrix for Exogenous Shocks (1990–2008)*

		Growth in trading partners % Change	ToT growth % Change	FDI to GDP Change	Remittances to GDP Change	Aid to GDP Change
				Full sample (630 observations)		
Growth in trading partners	% Change	1				
ToT growth	% Change	0.060	1			
FDI to GDP	Change	0.048	0.082	1		
Remittances to GDP	Change	−0.001	−0.043	−0.017	1	
Aid to GDP	Change	−0.008	−0.024	−0.010	0.044	1
				Large shock episodes (316 observations)		
Growth in trading partners	% Change	1				
ToT growth	% Change	0.033	1			
FDI to GDP	Change	0.029	0.076	1		
Remittances to GDP	Change	0.018	−0.053	−0.050	1	
Aid to GDP	Change	−0.060	−0.084	−0.014	0.070	1

Source: Authors' calculations.
Note: Correlations among variables are reported for the common sample for which all shock variables are available. Results are very similar for the pair-wise correlation matrix relaxing the common sample restriction and in the sub-sample excluding commodity exporters. Pair-wise correlations are not statistically significant except for the negative correlation between a change in FDI to GDP and a terms of trade shock.

Table 10. *List of Countries in the Sample*

71 LICs		61 Countries used in the regressions	
Afghanistan, I.S. of	Madagascar	Armenia	Mali
Armenia	Malawi	Bangladesh	Mauritania
Bangladesh	Maldives	Benin	Moldova
Benin	Mali	Bhutan	Mongolia
Bhutan	Mauritania	Bolivia	Mozambique
Bolivia	Moldova	Burkina Faso	Myanmar
Burkina Faso	Mongolia	Burundi	Nicaragua
Burundi	Mozambique	Cambodia	Niger
Cambodia	Myanmar	Cameroon	Nigeria
Cameroon	Nepal	Cape Verde	Papua New Guinea
Cape Verde	Nicaragua	Central African Republic	Rwanda
Central African Republic	Niger	Chad	São Tomé and Príncipe
Chad	Nigeria	Comoros	Senegal
Comoros	Papua New Guinea	Congo, Dem. Rep. of	Sierra Leone
Congo, Dem. Rep. of	Rwanda	Congo, Republic of	Solomon Islands
Congo, Republic of	Samoa	Côte d'Ivoire	St. Lucia
Côte d'Ivoire	São Tomé and Príncipe	Djibouti	St. Vincent and the Grenadines
Djibouti	Senegal	Dominica	Sudan
Dominica	Sierra Leone	Eritrea	Tajikistan
Eritrea	Solomon Islands	Ethiopia	Tanzania
Ethiopia	Somalia	Gambia, The	Togo
Gambia, The	St. Lucia	Georgia	Uganda
Georgia	St. Vincent and the Grenadines	Ghana	Uzbekistan
Ghana	Sudan	Grenada	Vietnam
Grenada	Tajikistan	Guinea	Zambia
Guinea	Tanzania	Guinea-Bissau	
Guinea-Bissau	Timor-Leste, Democratic Republic of	Guyana	
Guyana	Togo	Haiti	
Haiti	Tonga	Honduras	
Honduras	Uganda	Kenya	
Kenya	Uzbekistan	Kyrgyz Republic	
Kiribati	Vanuatu	Lao PDR	
Kyrgyz Republic	Vietnam	Lesotho	
Lao PDR	Yemen, Republic of	Madagascar	
Lesotho	Zambia	Malawi	
Liberia		Maldives	

Table 11. *Variables Used in the Probit Regressions and the Signaling Approach*

Variables	Description	Source
Probit regressions		
Identification of growth crises	*Real GDP per capita*	WEO
Growth	*Lag of real GDP growth*	WEO
	Country-specific average real GDP growth over 1980–2009	
Fiscal policy	*Lag of fiscal balance to GDP*	WEO
Monetary policy	*Lag of inflation rate*	WEO
External vulnerability	*Lag of gross international reserves in months of imports*	WEO
	Lag of exchange market pressure index	WEO
	Lag of current account deficit to GDP	WEO
	Lag of current account deficit plus FDI to GDP and its interaction with a dummy excluding small islands	WEO
	Lag of volume growth in exports of goods	WEO
	Lag of black market premium	Reinhart and Rogoff (2004)
Exchange rate regime	*De facto exchange rate regime dummies*	Reinhart and Rogoff (2004)
	De jure exchange rate regime dummies	AREAR, IMF
Institutions	*CPIA index*	World Bank

(*continued on next page*)

Table 11 (*continued*)

Variables	Description	Source
Shock variables	*Natural Disasters. Large natural disasters identified by the number of people affected and the economic damage among the top 25th percentile of the distribution*	Emergency Events Database (EM-DAT) published by the Center for Research on the Epidemiology of Disasters (CRED).
	Lag of aid to GDP	OECD
	FDI to GDP	WEO
	Remittances to GDP	
	External demand growth in trading partners	WEO
	External demand growth in trading partners weighted by lagged exports (goods) to GDP ratio	WEO
	Growth in terms of trade	WEO
	Growth in export prices of goods weighted by lagged exports (goods) to GDP ratio	WEO
Signaling approach		
In addition to variables used in probit regressions the following variables are examined:		
Fiscal policy	*Lag of total public debt to GDP*	WEO
	Growth in government revenue in previous 2 years deflated by CPI	WEO
	Lag of tax revenue to GDP	WEO
	Lag of total government revenue to GDP	WEO
Monetary policy	Lag of growth in private sector credit deflated by CPI in previous 3 years	Beck, Demirgüç-Kunt and Levine dataset (2010)
	Lag of non-performing loans	Above dataset complemented by staff reports.
	Lag of capital adequacy ratio	Above dataset complemented by staff reports.
	A dummy variable indicating a banking crisis in the last 2 years	Above dataset complemented by staff reports.
External vulnerability	Lag of change in real effective exchange rate	IMF INS dataset
	Lag of trade balance to GDP	WEO
	Lag of exchange rate overvaluation to GDP (REER minus HP-filtered REER)	IMF INS dataset and authors' calculations.
	Lag of monthly standard deviation of NEER and REER	IMF INS dataset and authors' calculations.
	Lag of external debt to GDP	WEO
Structural variables	Lag of Gini coefficient	WB GDI (Global Development Indicators)
	Lag of commodity exports to GDP	WB GDI (Global Development Indicators)
	Lag of agricultural value added to GDP	WB GDI (Global Development Indicators)

Table 12. *Distribution of Explanatory Variables (1990–2009)*

	10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile
CPIA	2.48	2.98	3.38	3.75	4.00
GDP growth	−0.98	1.78	4.33	6.32	8.37
Real GDP growth (country-specific sample average)	1.58	2.69	3.48	4.69	6.47
Government balance (% of GDP)	−9.35	−5.83	−3.42	−1.70	0.49
Reserve coverage (months of imports)	0.93	1.68	2.81	4.11	6.35
Exchange market pressure index	−1.76	−0.60	0.19	1.70	4.82
Growth in trading partners weighted by lagged exports to GDP	0.07	0.23	0.52	0.99	1.74
Change in export prices weighted by lagged exports to GDP	−3.39	−1.14	0.00	1.56	4.51

Source: Authors' calculations.
Note: The distribution of explanatory variables is provided for the estimation sample.

Table 13. *Robustness Check with Alternative Specifications: All Growth Crisis Events*

	All crises (1)	Average marginal effects[a] (2)	Benchmark specification (large shocks) (3)	Average marginal effects[a] (4)
CPIA ($t-1$)	−0.3627***	−0.0666***	−0.3438***	−0.0744***
	(0.1107)	(0.0203)	(0.1259)	(0.0275)
GDP growth ($t-1$)	−0.0861***	−0.0158***	−0.0632***	−0.0137***
	(0.0146)	(0.0027)	(0.0198)	(0.0040)
Government balance, % of GDP ($t-1$)	−0.0205*	−0.0038*	−0.0162*	−0.0035*
	(0.0107)	(0.0020)	(0.0089)	(0.0019)

(*continued on next page*)

Table 13 (*continued*)

	All crises (1)	Average marginal effects[a] (2)	Benchmark specification (large shocks) (3)	Average marginal effects[a] (4)
Reserve coverage, months of imports ($t-1$)	−0.0502	−0.0092	−0.0852**	−0.0184**
	(0.0322)	(0.0059)	(0.0380)	(0.0084)
Exchange market pressure index ($t-1$)	0.0460**	0.0084**	0.0525**	0.0113***
	(0.0194)	(0.0036)	(0.0204)	(0.0044)
Exchange rate regime (flexible:1; fixed:0) ($t-1$)	−0.4638***	−0.0852***	−0.3783**	−0.0818**
	(0.1475)	(0.0273)	(0.1630)	(0.0345)
Growth in trading partners weighted by lagged exports to GDP	−0.1738*	−0.0319*	−0.1899*	−0.0411*
	(0.0926)	(0.0169)	(0.1119)	(0.0235)
Change in export prices weighted by lagged exports to GDP	−0.0226*	−0.0042*	−0.0335**	−0.0072**
	(0.0124)	(0.0023)	(0.0161)	(0.0034)
Change in remittances weighted by lagged remittances to GDP	(−0.0483)*	(−0.0089)		
	(0.0281)	(0.0051)		
Climatic shocks	(0.2505)*	(0.0460)		
	(0.1447)	(0.0265)		
Country-specific averages for 1990–2008				
Real GDP growth	−0.1974***	−0.0362***	−0.1847***	−0.0400***
	(0.0577)	(0.0104)	(0.0479)	(0.0101)
Constant	1.4169***		1.5295***	0.0000
	(0.4009)		(0.3699)	(0.0000)
Pseudo R-squared	0.20		0.26	
No of observations	1042		561	
Growth decline events	210		120	
Normal episodes	832		441	
Sample probability	0.20		0.21	
No of countries	61		61	
Wald test (Chi-square)	148 (0.00)		119 (0.00)	

Source: Authors' calculations.
Note: (1) is estimated by correlated random effects probit model based on the significance of country-specific effect and (2) is estimated by a correlated pooled probit model with cluster-robust standard errors.
Standard errors are in parentheses.
[a] Marginal effects of a specific covariate on the response probability averaged across the distribution of covariates in the sample.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.