# Real output costs of financial crises: a loss distribution approach

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# Real Output Costs of Financial Crises: A Loss Distribution Approach*

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**Abstract**

The adverse effects of financial crises in terms of output losses or output growth below its potential can be treated like losses from catastrophic events which have a low likelihood but a large impact in the event that they occur.

We therefore analyze GDP losses in terms of frequency (number of loss events per period) and severity (loss per occurrence). Crises' frequency, severity, and the associated global output losses over periods of five years are identified on the basis of Laeven and Valencia (2008). Applying the Loss Distribution Approach used in insurance and operational risk theory and practice, we estimate a multi-country aggregate GDP loss distribution and thus approximate the conditional losses in the event of financial crises.

The analysis of losses produced in the paper suggests that the LDA approach is a useful tool in discussions about the existence and capital requirements of a potential insurance against the risk of financial crises at the aggregate level.

**JEL classification**: G01, G17, G22, G32, C15.

**Keywords**: Financial Crisis, Severity, Frequency, LDA.

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# 1 Introduction

Financial crises have played a quintessential role after the collapse of the Bretton Woods system of fixed exchange rates. Episodes like the Latin American debt crises in the 80's, the 1987 Black Monday, the 1992-1993 ERM crisis, the 1994-1995 Tequila crisis, the 1997-1998 South East Asian meltdown, the 1998-1999 Brazilian and Russian crisis, the 2000-2001 Turkish crisis, the 2001 Argentine crisis and the 2007-2009 global financial crisis all resemble disaster events, just like hurricanes or earthquakes.

Like catastrophic events, financial crises can be characterized by frequency and severity. In fact, analysis made in the financial crises literature often refer to terms such as frequency and/or severity (see e.g. Bordo et al. (2001)). The insurance and operational risk theory and practice offer toolkits to analyze frequency and severity of losses as well as aggregate losses due to catastrophic or operational risk events. Given that the losses to country economies from financial crises (in terms of GDP drop or forgone GDP) are similar to operational risk losses, we can apply the loss distribution approach[1] (LDA) common in the actuarial literature to analyze frequency and severity of losses and thus study rare events and their probabilities. To the best of our knowledge, there is no attempt to quantify the frequency and severity of financial crises using the LDA.

The LDA allows us to estimate a multi-country aggregate GDP loss distribution and thus estimate conditional losses in the event of a financial crisis occurring in the near future. We can also determine the probability of rare economic disasters as defined for example in Barro (2006) for example. In contrast to Barro (2006) however, we do not make any assumptions on the channel through which crises occur (e.g. catastrophic events like earthquakes or regular/cyclical disaster events).

In terms of methodology, we first use the financial crises database of Laeven and Valencia (2008) to date financial crises across 170 countries from 1970 onwards. The number of such events over a predetermined period is called the frequency of events. We then estimate specific country output losses per event with a number of methods. Afterwards, we aggregate the losses over the countries in the sample. Those aggregate losses are the severity of each event. Since a particular crisis event can generate output losses over various years, we set the minimum span of analysis to be five years. Finally, we compound frequency and severity to generate a loss distribution of aggregate

[1]See Panger (2006); Shevchenko (2011) for definitions.

losses that will allow us to report standard risk measures.

The analysis of losses produced in the paper can be a useful tool in discussions about the existence of insurance against the risk of financial crises at the aggregate level. For example, Caballero (2003) proposes such an arrangement for emerging market economies.

In what follows, we will provide a short literature review and discuss the possibilities at hand to calculate output costs of financial crises. In section 3, we introduce the methodology of crisis identification and loss calculation, while the Loss Distribution Approach is explained in Section 4. Results are presented in Section 5. Section 6 discusses a potential form of international insurance and Section 7 concludes.

# 2 The costs of financial crises

In order to quantify the costs of financial crises, a cost measure must be established. This task has been approached in different manners by various authors. Costs have been estimated as fiscal costs, costs to the stock market, and output costs. Amongst authors analyzing the same kinds of losses, methodologies differ widely. In addition, one of the main obstacles to measuring losses caused by financial crises is the identification issue.

## 2.1 Fiscal costs, costs to the stock market and output losses

In an attempt to quantify the costs of banking crises to the economy, Hoggarth et al. (2001) consider direct resolution costs as well as broader welfare costs to the economy, approximated by output losses. They argue that resolution costs are a rather limited proxy for costs incurred through banking crises, as they may reflect a transfer of income from taxpayers to banks rather than costs imposed to the economy as a whole. The authors reason that there could be a positive correlation between fiscal costs and output losses if crises are systemic. On the other hand, if fiscal costs are a good proxy for effective crisis resolution, higher spending on crisis resolution should lead to lower output losses during a crisis period. No clear statistical relationship between fiscal costs and crisis length is found, while output losses and the length of crises do depict a clear positive correlation[2].

Frydl (1999) presents a comparative analysis of prior banking crisis studies. As one of the reasons for the non-significant statistical relation between resolution costs and crisis length, he claims that resolution costs usually measure fiscal costs of banking crises, which are often subject to various errors and do not incorporate many indirect costs to the government or economy. Having dismissed fiscal costs as a reliable indicator for crisis severity, Boyd et al. (2000), amongst other measures, uses the discounted value of corporate returns to measure crisis impact. Under the condition that corporate profits represent a relatively constant fraction of total output, a decline in the real values of stock prices at the onset of a crisis in percentage terms is approximately equal to the decline in the present discounted value of total output.[3]

With regards to the impact and depth of currency crises, possible measures to be considered (in addition to output losses) are the loss of international reserves and the depreciation of the real exchange rate (Kaminsky and Reinhart, 2002). The most utilized method, however, is to proxy costs to the economy with losses in GDP since economic growth is a natural final performance indicator.

Two strains of literature approximating real GDP losses after financial crises can be identified. The first utilizes a dummy variable approach to estimate growth losses over samples of countries, while the second proxies welfare losses by comparing GDP during a crisis period with some estimate of potential output. Representatives of the former approach are Demirguc-Kunt et.al (2006), Gupta et al. (2007), Hanna and Huang (2002) and Barro (2001). A main criticism of the former approach is that it can only identify average magnitudes of growth contractions associated with crises for all countries in a sample. It therefore does not seem to be well suited in the case of crisis losses being highly heterogeneous. Output costs calculated through cross-section or panel data regressions are usually found to be lower than losses calculated based on output gap estimations.

Hoggarth et al. (2001) is one representative study for the latter approach.

[2]Part of their analysis responds to studies carried out in Demirguc-Kunt and Detragiache (1998) and in Caprio et al. (1997), who consider fiscal costs of crisis resolution to measure the severity of banking crises.

[3]Focusing on fiscal costs of banking crises, Honohan et al. (2000) use government spending and costs of rescue policies as shares of GDP as an indicator for output losses. In an econometric analysis, the authors attempt to model the cross-country variation in fiscal costs as a function of various policy tools.

The authors estimate potential output assuming that output would have grown at the same constant rate based on its past performance. Various studies, such as Bordo et al. (2001), Aziz et al. (2000), Frydl (1999), Boyd et al. (2000, 2002) and Cecchetti et al. (2009) calculate output losses from banking crises in a similar fashion, even though their trend estimates are based on differing pre-crises windows, methods, definitions about onsets, ends and durations of crisis episodes[4].

In a comparative analysis, Angkinand (2008) suggests that the output deviation technique (or output gap approach) is more appropriate than a dummy variable approach in capturing the output costs of crises, the main reason being that individual output costs across crises vary substantially. As output does take up to ten years before recovering its pre-crisis *growth* rate (Hoggarth et al., 2001), and in many cases never returns to potential output *level* (Boyd et al., 2002), the output gap approach is judged to be preferable to the dummy variable endeavor.

## 2.2 Output gap calculations

### Determining the length of a crisis

No unanimously agreed upon method to date the beginning of financial crises has been established in the literature. Banking crisis start dates are usually defined through a mixture of quantitative and qualitative criteria. Caprio et al. (1996) rely on the assessment of finance professionals. Including and expanding on this approach, Demirguc-Kunt and Detragiache (1998) compile five studies of banking crises' starting dates. [5]

The onset of a currency crisis is generally defined as a situation where a sufficiently large devaluation of the domestic currency and/or a loss in international reserves[6] occurs, while a debt crisis is classified in the event of a country defaulting or renegotiating on all or parts of its private debt. The most recent financial crises compilation, widely used in younger empirical studies on the topic, stems from Laeven and Valencia (2008) and comprises banking, currency, and debt crises over the period of 1970 to 2008.

[4]Barro (2001) e.g. estimates growth losses considering growth rates over five year pre-crises episodes.

[5]Other studies identifying banking crises' dates are Dziobek et al. (2008), Kaminsky and Reinhart (2002), and Lindgren et al. (1996).

[6]Sometimes an additional criterion of increased speed of depreciation as compared to some prior time window is introduced.

In order to date the end of a crisis episode, one possibility is to define the end date based on "expert" opinions or on the "consensus" view from various studies. An alternative is to define the end of a crisis endogenously once a country returns to a certain pre-crisis *growth rate* or recovers its potential output *growth path*.

Studies determining the end of a crisis based on the recovery of the average *growth rate* of a pre-crisis window are, amongst others, Bordo et al. (2001) and Aziz et al. (2000). Authors such as Boyd et al. (2002) argue that summing up deviations from an estimated trend up to the point at which the observed *growth rate* returns to its pre-crisis average is problematic since output typically remains well below its pre-crisis absolute output trend once the growth rate has recovered.

Cecchetti et al. (2009) avoid calculating a counterfactual and define the end of a crisis as the point in time when real GDP has reached its absolute pre-crisis level. This method is problematic in at least two ways. Firstly, the method does not take opportunity costs of foregone output growth into account. Secondly, the method implies that a crisis is only counted as such if output growth actually turns negative during the crisis year. It can be argued, however, that a financial crisis has negative effects without having caused an actual recession, e.g. through a transitory or permanent slowdown in growth. Moreover, since potential growth rates vary across countries, dating the end of a recession by reaching its pre-crisis level of real GDP can lead to an underestimation of total losses incurred.

**Estimation of a counterfactual**

In order to measure output losses during crisis periods according to some methods described above, it is necessary to compare actual output with its trend or potential. Several approaches have been used in the literature and differ mainly by the pre-crisis time window chosen, which in turn depends on the assumption about financial crises either following economic booms or a slowdown in economic activity.

Hoggarth et al. (2001) assume that output would have grown at a constant rate based on past growth performance and extrapolate linear three- and ten-year trends, while Bordo et al. (2001) use five-year pre-crises trends to compute the potential growth path. Frydl (1999) exclusively makes use of a ten year pre-crisis period to calculate potential output growth. Boyd et al. (2000) advance in the same manner, extrapolating a linear pre-crisis growth trend in order to establish a counterfactual. [7]

[7]Due to the need of relatively long time series without gaps, the HP filter is a less

A large part of the heterogeneity in the magnitude of output losses in the study of crises stems from the calculation of potential trend output. Several studies have found that banking crises follow economic booms.[8] In this case, a trend estimated over a short period prior to a crisis would overestimate potential output and lead to an overestimation of crisis length and depth. On the other hand, several studies find that banking crises are often preceded by a slowdown of economic activity,[9] in which case losses would be understated.

If one assumes that pre-crisis growth deviates (in either direction) from the long-term potential output growth path, one option is to increase the pre-crisis trend calculation period in order to capture mostly "normal" years. An alternative is to exclude a certain period prior to the onset of a crisis. Lastly, more sophisticated trend estimations such as the HP Filter method can be applied to diminish the influence of booms or recessions on the potential growth path. [10]

Once having established the counterfactual, total output losses are estimated by adding up the difference between actual and potential output over the duration of the respective crisis.

Even though the general concept is agreed upon across the studies mentioned above, several methodological issues remain debated. Identification of crises accompanied by output losses varies among studies. While some authors include a crisis if output is below its trend or if output growth is negative during the crisis year, other studies include crises even though output is above its trend in the crisis year, given that output is below trend in the subsequent year (Angkinand, 2008). Further issues arise in the case of multiple crises per country within short periods of time. In the case that output has not yet recovered from one crisis at the point of outbreak of a following crisis, some studies choose to sum losses of subsequent crises and report a single loss, while others divide losses across crises or simply choose to exclude countries with multiple crises during the sample period.[11]

applied but attractive technique in order to estimate potential output (Cerra et al., 2000).

[8] See e.g. Kindleberger (1978), Borio et al. (1996) and Logan (2001). Bicaba, Kapp, and Molteni (2011) find no evidence for the hypothesis that financial crises are more likely to occur after periods of strong economic growth but that on the contrary periods of high growth tend to extend periods of stability between financial crises

[9] See e.g. Kaminsky and Reinhart (2002), Gorton (1998)

[10] While the IMF (1998) and Aziz et al. (2000) base potential output on the average output of the three years prior to crises, Bordo et al. (2001) use five-year pre-crisis growth rates and Hoggarth et al. (2001) calculate potential output trends based on ten-, three-, and one-year pre-crises growth rates; for a comparative study see Angkinand (2008).

[11] As Angkinand (2008) points out, most studies estimating output costs of crises mea-

## 2.3 Identification of causality

In order to assess the direction of causality between economic growth and banking crises, Hoggarth et al. (2001) compare a sample of 29 countries experiencing banking crises with neighboring countries which did not face banking crises at the same time. The hypothesis is that "the movement in output relative to trend during the crisis period would have been, in the absence of a banking crisis, the same or similar to the movement in the pairing country" (Hoggarth et al., 2001). Their analysis hints at the point that output losses are in most cases caused by banking crises and come as unforeseen events.

Bordo et al. (2001) find, across all countries and crisis periods considered, that recessions with crises are more severe than recessions without them. These results are in line with various studies such as Frydl (1999).[12]

# 3 Methodology

## 3.1 Crisis identification

We identify financial crises based on Laeven and Valencia (2008). Currency crises, banking crises, and debt crises are identified over the period 1970 to 2008.[13] The number of currency crises peaked during the early eighties and the early nineties with around 30 currency crises per year, while banking crises have in general been less frequent and peaked during the early nineties. The number of debt crises per year has been decreasing since the mid-1980's

sure the magnitude of growth contractions by adding deviations of the actual GDP growth rate from its potential, while a number of studies estimate losses by the deviation of the actual level of GDP from the level of its trend. Examples of the former are Aziz et al. (2000), Bordo et al. (2001), Hohohan and Klingebiel (2003), Claessens et al. (2004), and Gupta et al. (2007), while examples of the latter are Hutchinson and McDill (1998), Hoggarth et al. (2001), and Boyd et al. (2002).

[12]For potential channels of crisis transmission mechanisms see e.g. Lindgren et al. (1996), Hoggarth et al. (2001), Stone (2000), Kaminsky and Reinhart (2002), Reinhart and Rogoff (2009), Gupta et al. (2007).

[13]Laeven and Valencia (2008) identify banking crises on the basis of a number of quantitative and subjective criteria, such as a large number of defaults and a high quantity of non-performing loans. The starting year of a currency crisis is identified by building on an approach developed in Frankel and Rose (1996). Sovereign debt crises are reported in the case of sovereign defaults to private lending as well as in a year of debt rescheduling.

and debt crises have nearly ceased to exist until recently. [14]

We identify the starting date of a financial crisis as the year of outbreak of any one of the three types of crises. Real GDP data is taken from the World Economic Outlook database and spans the time period from 1960 to 2010.

In order to calculate output losses caused by crises, the first step is to define whether a crisis has had an impact on the economy. In the case where output is compared to a counterfactual, we identify a crisis if output in the crisis year is below its potential output trend (potential output trend calculations are discussed below). In an alternative calculation of crisis losses, no counterfactual is established and a crisis accompanied by output losses is considered as such if output growth is negative during the crisis year.

For countries with multiple crises during the sample period it is possible that a crisis occurs before the economy has recovered from a previous crisis. In this case, we assign subsequent losses to the later crisis date, establishing a new counterfactual. This method is problematic, though other alternatives suffer from larger errors. Allocating output losses from subsequent crises to the first crisis would largely overstate output losses in various cases.[15]

## 3.2 Output losses

We estimate three kinds of potential output trends and propose several cutoff points to determine the end of a crisis. In short, there is no perfect method to estimate an objective output trend. Every method presented shows both advantages and disadvantages depending on the assumptions about the mechanics of financial crises development.

Following the literature, we estimate potential GDP after the onset of a crisis in three ways. We estimate a Hodrick-Prescott Filter trend (HP), where potential output during a crisis episode is based on the average HP growth rate of the ten and three year pre-crisis periods. In addition, we use average growth rates from three year and ten year pre-crisis time windows. We compare the losses against trend outputs to absolute losses (for episodes of negative growth) without considering opportunity costs. In total we have thirteen possible ways to measure output losses as well as their severity and frequency.

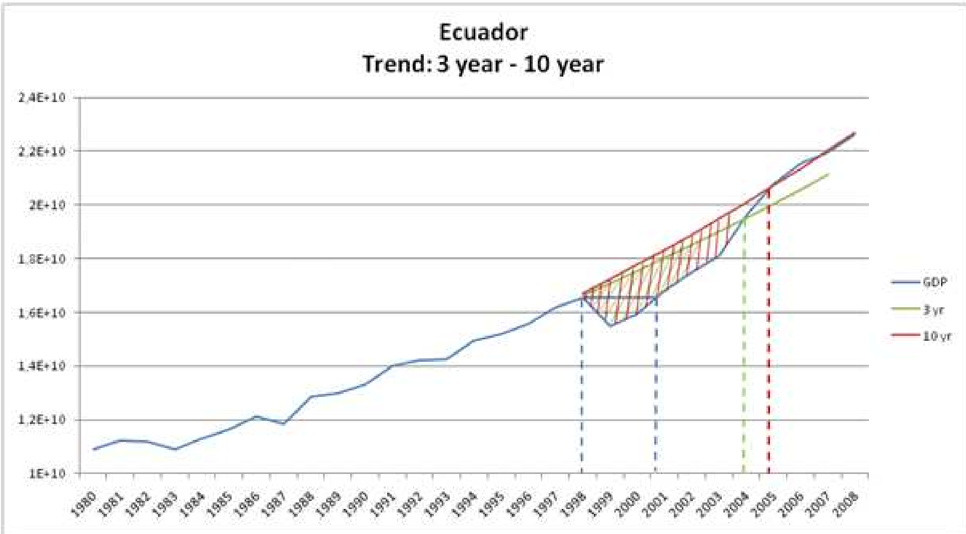
[14] For a more detailed discussion see Bicaba, Kapp, and Molteni (2011).

[15] Boyd et al. (2002) exclude countries with multiple crises from their analysis, and Angkinand (2008) truncates the computation of the output deviations of previous crisis.

Output losses are calculated as the difference between actual real GDP and the output trend. As can be seen in Figure 1, depicting output during the Ecuadorian Banking crisis of 1998, losses depend not only on the definition of the counterfactual but largely on establishing an end-point to a crisis.

According to the most simple definition of the time span during which crises losses should be considered, the time output needs to recover its pre-crisis *level* of GDP, the effects of the crisis lasted two years and led to an output loss of 10% of GDP. If crisis length is calculated until real GDP growth reached its pre-crisis *growth rate*, output losses occurred over a period of two and three years and led to output losses of 10.1% and 22.4% of GDP, calculated against a three- and ten-year pre-crisis growth trend respectively.

Figure 1: Ecuador 1998

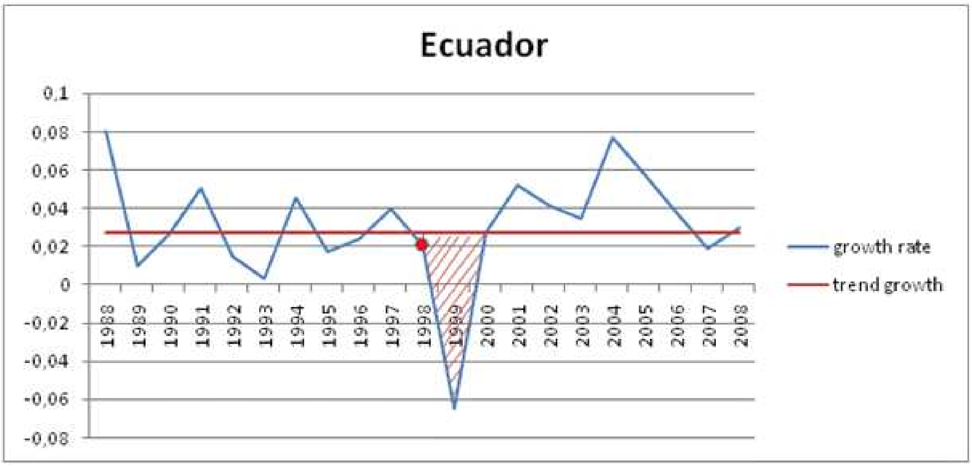



Source: Authors' calculations

As shown in Figures 1 and 2, this calculation most likely still does not account for the total output loss caused by the 1998 Ecuadorian banking crisis. The period of output loss increases to six and seven years, and output losses accumulate to 38.1% and 51.4% of GDP if losses are calculated until the level of real GDP has recovered its three- and ten-year pre-crisis *trend*. As illustrated in Figures 1 and 2, output losses seem to be underestimated if crisis recovery is defined as being completed at the point where the pre-crisis *growth rate* or the pre-crisis *level* of real GDP are recovered.

As mentioned above, we estimate losses using various trends and various cut-off points to determine the end of a crisis. In total, 13 loss estimations are

Figure 2: Ecuador 1998




Source: Authors' calculations

presented.

We distinguish between three definitions as to when an economy has recovered from a crisis. According to the first definition, a crisis ends once real output has reached the level of its counterfactual. The alternative is that recovery is completed once the average pre-crisis growth rate is recovered. As some countries never recover according to these definitions, accumulated losses against the counterfactuals based on linear three- and ten year trends, based on simple averages of pre-crises growth, are considered over maximum periods of five and ten years, while the losses against trends based on the HP filter are allowed to accumulate over periods of maximum ten years. In the absence of a counterfactual, a crisis is supposed to be ended once output reaches its absolute pre-crisis level of real GDP.

# 4 Loss Distribution Approach (LDA)

The estimated output losses across countries obtained in the previous section allow us to study the frequency and severity of losses. In the analysis of a financial crisis hitting the world economy, two usual questions appear: i) what is the frequency of financial crisis? and b) given a financial crisis, how severe is it? The frequency of financial crises is the number of such events over a specific period of time. Since a financial crisis duration spans generally more than a year, we choose a five-year reference period. The severity of a financial crisis is the amount of output loss incurred in each crisis episode.

Given the frequency and severity of losses occurring within 5-year periods, we can use the LDA analysis common in the insurance and operational risks literature. We estimate two possible parametric distribution functions commonly used to describe the frequency of events $n_t$ over a period of time $t$. We also estimate a set of six severity probability density functions[16] for events $z_{t,i}$. As opposed to the standard one year period, our $t$ represents periods of 5 years. This is because GDP losses due to financial crises consider losses over more than one year. The index $i$ tracks each event within the period of analysis $t$.

During a 5-year period of time $t$, total losses are given by the sum of each loss event $i$ across countries in the sample.

$$S_t = \sum_{i=1}^{n_t} z_{t,i} \tag{1}$$

The variable $n_t$ is by nature a discrete one while the variables $z_{t,i}$ are non-negative (positive losses). The aggregated loss $S$ depends on the realization of the discrete random variable $(n)$ and the continuous random variable $(z_i)$. Therefore, the aggregation $S$ is itself a random variable whose distribution has to be determined by convolution methods (Panger, 2006; Shevchenko, 2011).

Specifically, the frequency of loss events $(n)$ has a probability distribution denoted by $p_n = Pr(N = n)$ while the loss severity $z$ has a density distribution and cumulative distribution functions denoted by $f_z$ and $F_z$, respectively. According to (Panger, 2006), the cumulative probability distribution function of $S$ is defined as:

$$\begin{aligned} F(S) &= Pr(\omega \leq S) \\ &= \textstyle\sum_{n=0}^{\infty} p_n Pr(\omega | N = n) \\ &= \textstyle\sum_{n=0}^{\infty} p_n F_Z^n(S) \end{aligned} \tag{2}$$

A simple way to estimate $F(s)$ is via Monte Carlo simulations. First we draw $n$ from $p_n$ and then we draw $z$ from $f_z$ as many times as indicated by $n$ and sum up the $z$ draws.

[16]The set is composed of the gamma, exponential, generalized extreme value, generalized pareto, log normal and weibull density functions.

# 5 Results

In total, we observe 62 debt crises, 122 banking crises, and 196 currency crises. As some of these crises in effect form twin crises, a total of 340 crises episodes are examined. Depending on the method applied, between 110 and 219 contractionary crises episodes can be found. While around 210 contractionary crises episodes are identified against HP trends, only 110 crises were accompanied by negative growth rates during the crisis year.

Average losses are found to be higher than in several past studies, one reason being that while econometric studies usually estimate losses over a sample comprising expansionary and recessionary crises, we only consider crises leading to output losses (against a trend or absolute). From a total of 196 currency crises in our sample, between 90 and 120 crises (depending on the calculation method applied) can be considered to have led to a loss of output compared to some measure of potential output, while 63 crises were accompanied by negative output growth. This result is in line with previous studies such as Gupta et al. (2007), who find that about 60 percent of currency crises lead to output contractions while the rest were accompanied by output expansions.

The analysis that follows concentrates on a benchmark loss classification group that relies on the HP filter: losses until recovering average 10 year HP filtered GDP growth rates (HP(10)perc), the level of a 10 year HP filtered GDP trend (HP(10)trend), 3 year HP filtered GDP growth rates (HP(3)perc), and the level of a 3 year HP filtered GDP trend (HP(3)trend).

## 5.1 The frequency of financial crisis

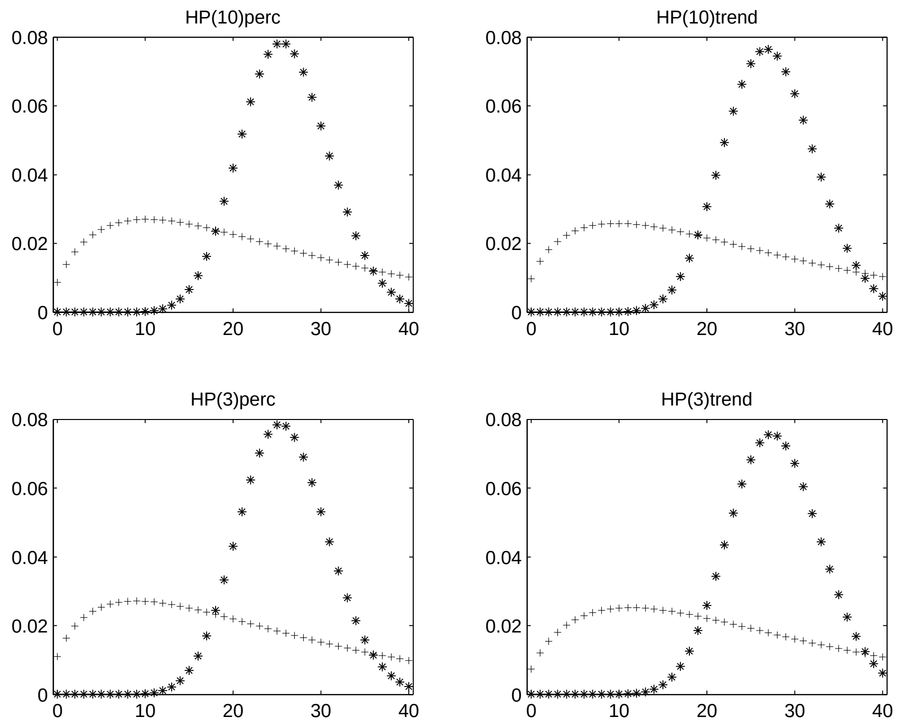
In order to carry out the LDA, we first estimate distribution functions for the frequency of losses from financial crises. We assume two commonly used distributions. The Poisson and the Negative Binomial Distribution. The key parameter in the Poisson Distribution is $\lambda$ which is also the mean and variance of the data. This is the difficult point for the fit of the Poisson, the data in our benchmark case (the four HP trend counterfactuals) have number of crisis events with a variance of about sixteen times the mean.[17] Therefore,

[17]The number of crisis events for the other loss classifications have a variance to mean ratio of more than 13, except for the case where opportunity costs are not considered (ABS).

the two parameter Negative Binomial distribution is a more flexible way to accommodate our data.

In figure 3 we depict the estimated distributions for our benchmark loss classification. The Negative Binomial has a lower mode but allows a more extreme number of losses relative to the Poisson distribution. The probability that the data comes from the Negative Binomial is higher for all cases (the benchmark and all types of loss classifications).

Figure 3: Estimated distribution for frequency of losses




Note: +++: Negative Binomial, ***: Poisson. Horizontal axis measures the number of financial crisis in the world over a typical five-year period

## 5.2 Severity

The average accumulated loss caused by financial crises varies from 9% of real GDP to 15% of real GDP if output losses are accumulated against trends based on HP filtered data (table 1). In total, depending on the loss measure applied, 186 to 219 crises episodes can be observed. Average losses are largest when calculated against a ten year trend and if losses are considered until the level of trend output has been recovered over a maximum time span of 10 years.

A "normal" crisis episode, as measured by the median of percentage losses of initial GDP, leads to losses of 4.9% to 27.7% of GDP across various loss measures.[18] As can be seen in table 7 (Appendix), output losses are very heterogeneous and large average percentage losses are driven by few especially severe crises events. Of these most severe events, potential output has not been reached again within a period of ten years.[19] Amongst the largest losses observed are those of several Asian countries, namely Indonesia in 1998 and Thailand in 1997, both experiencing severe losses in the wake of the Asian crisis.

As can be seen in table 7 in the appendix, output losses are larger if a crisis is considered as overcome once its potential output *trend* has been recovered. Median losses lie between 4.9% and 7.15% of initial GDP. The most severe crises destroy up to three years of economic output[20]

Table 1: **Severity of financial crises** (as percentage of initial GDP)

| Loss Measure | Obs. | Mean | Median | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| HP10 perc | 204 | 0.14 | 0.06 | 0.24 | 0.0001 | 2.30 |
| HP10 trend | 214 | 0.15 | 0.07 | 0.25 | 0.0003 | 2.30 |
| HP3 perc | 203 | 0.09 | 0.05 | 0.17 | 0.0000 | 2.04 |
| HP3 trend | 219 | 0.10 | 0.06 | 0.12 | 0.0000 | 1.06 |

NOTE: Estimation of losses to recover average 10 year HP filtered GDP growth rates (HP10 perc), to recover the level of a 10 year HP filtered GDP trend (HP10 trend), to recover 3 year HP filtered GDP growth rates (HP3 perc), and to recover the level of a 3 year HP filtered GDP trend (HP3 trend)

Severity data due to financial crisis has a key feature, it is extreme valued. In figure 4 we see that the mean-excess-over-threshold plots[21] have positive slope at the right extreme of losses. Figure 5 shows that the long-tailed

[18]See table 1 and table 7 (Appendix)

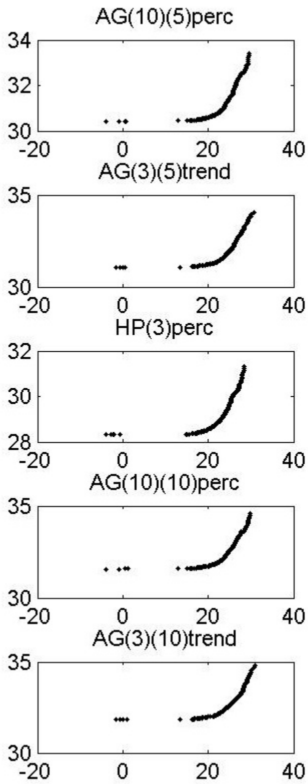
[19]This result is in line with (Furceri et. al., 2011), who find that the growth rate after debt crises eight years after the onset is still suppressed be nearly 10 percentage points.

[20]Crises' percentage losses are calculated as the sum of the difference between real output observed and potential output after the onset of a crisis until its end, divided by the real output in the year of crisis onset. Losses are usually larger if calculated on the basis of other trend estimations as presented in the appendix.

[21]The sample mean excess plot is defined by: $mep = \frac{\sum_i^n (X_i - u) I_{(X_i > u)}}{\sum_i^n I_{(X_i > u)}}$, with $u > 0$ and $I_{(.)}$ and indicator function.

nature of severity data is generated by specific types of crises. Currency and twin currency-banking crises produce the more extreme type of losses.

Figure 4: Mean excess over threshold for severity data. Both axes are in log scale



We fit the severity data with six possible probability density functions using the maximum likelihood estimator for the corresponding parameters. The six distributions are the Gamma, Exponential, Generalized Extreme Value (GEV), Generalized Pareto, Log-normal, and Weibull. Some distributions, like the GEV, fit the right end side better, while others have a better fit over the entire range of data. Our benchmark choice is the Weibull distribution because it maintains a better fit over the entire range of data for all severity classifications.

**Types of financial crises**

Consistent with previous studies, we find that currency crises lead to smaller output losses than debt and banking crises.[22] About 70 of the 122 banking crises in our sample lead to output losses. It can not be concluded from our analysis that banking and currency crises are generally preceded by high or low periods of growth as we do not observe a general dominance of losses calculated against three year pre-crisis trends as opposed to losses against ten year pre-crisis trends.

We find that average output losses after debt crises[23] are 9% higher than losses after banking crises. The median debt crisis is accompanied by output losses of 11.7%, three percentage points larger than the median banking crisis. A large share of debt crises has, however, been accompanied by banking crises. Of the 62 debt crises in our sample, 36 have led to periods of negative growth. Of these 36 episodes, 26 have been accompanied by banking crises with mean losses about 30% higher than if debt crises occur alone. Currency crises[24] incur smaller losses than banking or debt crises of 15% in the mean and 5% in the median.[25]

Banking and debt crises alone are found to be more severe than twin crises consisting of banking and currency crises or debt and currency crises. While twin crises between banking or debt and currency crises mostly lead to larger growth reductions in the very short run than banking or debt crises alone, long term losses are often found to be smaller. A possible explanation could

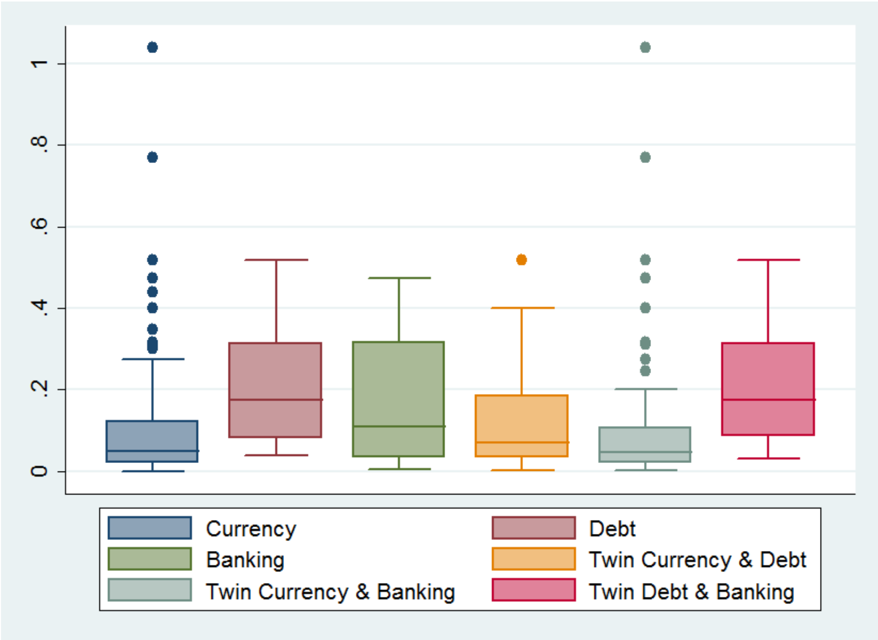
[22]Distributions of these three types of crises' losses, calculated as losses accrued over a maximum period of five years until the average growth rate of a ten year pre-crises period is recovered, are depicted in figure 6, while descriptive statistics of all calculation methods are provided in tables 8 to 14.

[23]23% of initial GDP if recovery of the average HP *growth rate* ten years before a crisis is considered (HP10 perc)

[24]according to HP10 perc

[25]This result is in line with (Furceri et. al., 2011), who using an econometrical approach, conclude that debt crises tend to be more detrimental than banking and currency crises.

Figure 5: Severity distributions




Source: Authors' calculations, For graphical reasons, distributions are cut at 1.5

be that a depreciation in the wake of a twin crisis (including a currency crisis) allows for a competitiveness gain which is not present when a banking crisis occurs alone and allows for a faster recovery. Twin crises consisting of debt and banking crises consequently incur the highest losses in our sample.[26]

**Severity by region**

The highest losses after financial crises are experienced in Asia with average losses ranging from 9.8% to 21.8% of initial GDP[27]. The second highest losses are observed in Europe, followed by Latin America and Africa. The highest frequency of financial crises is ,however, observed for Africa. Europe and Asia are mostly struck by currency and banking crises, while Africa and Latin America have suffered from all three types of crises to nearly equal degrees. In a joint analysis, debt crises were observed to be more severe than currency or banking crises. This result holds for all regions except for Asia, where banking crises lead to the most severe losses. Since a high share of currency and banking crises reported are in effect twin crises, it is however difficult to disentangle losses from both types separately.[28]

[26]For detailed descriptive statistics of other loss measures, please see tables 8 to 14.
[27]Calculated against counterfactuals based on average HP filtered growth rates
[28](Furceri et. al., 2011) confirm our results by controlling for the other types of crises.

Table 2: **Severity of crises by Regions - All crises**(Losses as percentage of initial GDP)

| Variable | Nr. | Africa | Nr. | Europe | Nr. | Latin A. | Nr. | Asia | Nr. | North A. |
|---|---|---|---|---|---|---|---|---|---|---|
| HP10 perc | 79 | 0.13 | 22 | 0.17 | 39 | 0.10 | 39 | 0.20 | 1 | 0.013 |
| HP10 trend | 85 | 0.13 | 24 | 0.18 | 40 | 0.12 | 40 | 0.22 | 1 | 0.013 |
| HP3 perc | 78 | 0.07 | 24 | 0.10 | 41 | 0.12 | 36 | 0.10 | 1 | 0.008 |
| HP3 trend | 86 | 0.08 | 24 | 0.14 | 45 | 0.08 | 39 | 0.12 | 1 | 0.008 |

NOTE: Estimation of losses to recover a 10 year HP filtered GDP growth (HP10 perc), to recover the level of the 10 year HP filtered GDP (HP10 trend), to recover a 3 year HP filtered GDP growth (HP3 perc) and to recover the level of the 3 year HP filtered GDP (HP3 trend)

### Severity by Income Groups

In order to compare losses across different income groups, we classify countries into low, middle, and high income categories.[29] On average, middle income countries experience the highest output losses (15%), followed by high and low income countries ( 12% and 11% of initial GDP respectively, see table 3). This observation holds for currency and banking crises, while losses from debt crises are almost exclusively observed for low and middle income countries.

The median crisis is more severe in high income than middle income countries. High average losses in middle income countries are driven by some severe crisis events, such as Thailand in 1998, experiencing losses of 229%.[30] The median loss is 9% for high income countries, 7% for middle income countries, and 4% for low income countries. In total, middle income countries suffer more from financial crises than high income countries as they experience a larger number of crises per country over the period observed.

Table 3: **Severity by income groups**(as percentage of initial GDP)

| Variable | Nr. | High Income | Nr. | Middle Income | Nr. | Low Income |
|---|---|---|---|---|---|---|
| HP10 perc | 21 | 0.13 | 122 | 0.18 | 61 | 0.11 |
| HP10 trend | 22 | 0.16 | 128 | 0.17 | 64 | 0.12 |
| HP3 perc | 22 | 0.07 | 120 | 0.11 | 61 | 0.07 |
| HP3 trend | 23 | 0.09 | 128 | 0.11 | 68 | 0.07 |

NOTE: Estimation of losses to recover a 10 year HP filtered GDP growth (HP10 perc), to recover the level of the 10 year HP filtered GDP (HP10 trend), to recover a 3 year HP filtered GDP growth (HP3 perc) and to recover the level of the 3 year HP filtered GDP (HP3 trend)

[29] World Bank classification

[30] See figure 9, Appendix

**Severity of financial crises over time**

As expected, financial crises were especially harmful during the 1990's and depict the lowest losses during the 1970's and the period after the year 2000. This does however not necessarily mean, however, that financial crises have become smaller in magnitude. The impact of the latest global financial crisis cannot yet be compared to previous crises with our methodology.

Table 4: **Severity over time - All crises** (as percentage of initial GDP)

| Period | HP10 perc | HP10trend | HP3 perc | HP3 trend |
|---|---|---|---|---|
| 1970 -75 | 0.02 | 0.05 | 0.02 | 0.06 |
| 1975 -80 | 0.11 | 0.14 | 0.19 | 0.09 |
| 1980 -85 | 0.18 | 0.14 | 0.09 | 0.10 |
| 1985 -90 | 0.12 | 0.10 | 0.06 | 0.07 |
| 1990 -95 | 0.15 | 0.16 | 0.09 | 0.12 |
| 1995 -00 | 0.19 | 0.20 | 0.06 | 0.07 |
| 2000 -05 | 0.11 | 0.12 | 0.07 | 0.07 |

NOTE: Estimation of losses to recover a 10 year HP filtered GDP growth (HP10 perc), to recover the level of the 10 year HP filtered GDP (HP10 trend), to recover a 3 year HP filtered GDP growth (HP3 perc) and to recover the level of the 3 year HP filtered GDP (HP3 trend)

## 5.3 The distribution of total losses

Given our choice of the frequency distribution and the severity probability density function, we perform Monte Carlo simulations to obtain a numerical probability density function (PDF) of total losses over five years. These PDF's are markedly skewed to the right. Table 5 summarizes the results. The 99.9 percentile of the total loss distribution ranges from 390 to 540 trillions of 2005 USD. These losses might however be too extreme. A closer figure is the 99 percentile, which is compatible with financial crisis events occurring every hundred years (190 to 240 USD trillions).

The median cumulative loss ranges from 10 to 15 trillion (in 2005 USD). This figure is higher than, for example, the cumulative losses due to the 2008 financial crisis, estimated to be roughly 5 trillions (in current USD) in IMF (2009). Regarding this crisis, Chinn and Frieden (2011) estimate a cumulative GDP loss for only the USA alone to be about 3.5 trillions in 2005 USD.

Table 5: Features of the PDF of total losses.

| | HP10perc | HP10trend | HP3perc | HP3trend |
|---|---|---|---|---|
| 99.9 percentile | 4.4e+014 | 5.4e+014 | 3.9e+014 | 4.5e+014 |
| 99 percentile | 1.9e+014 | 2.4e+014 | 1.7e+014 | 1.9e+014 |
| median | 1.3e+013 | 1.5e+013 | 1.0e+013 | 1.3e+013 |
| mean | 2.6e+013 | 3.3e+013 | 2.2e+013 | 2.6e+013 |
| Std deviaiton | 4.3e+013 | 5.4e+013 | 3.8e+013 | 4.4e+013 |

Notes:

(1) Number of simulations equal to 500 000. In all cases, the frequency distribution is the Negative Binomial, the severity pdf is a Weibull

(2) Losses are measured in constant 2005 USD and correspond to five-year periods

# 6 Financial crises insurance

Can output losses from financial crises be diminished or crises prevented ex ante through an insurance scheme? As financial crises are relatively rare events, one could imagine countries paying a certain amount during financially stable times and in return having access to these funds during times of need.

As financial crises are not comparable to natural disaster events in terms of causality, a moral hazard problem arises. It has to be assured that access to an insurance does not lead to lax government spending nor defer reforms.

The potential worldwide costs from financial crises over periods of 5 years in percentage terms of 2005 World GDP are presented in table 6. Average costs of financial crises during a period a five years are relatively small and amount to less than one percent of 2005 World GDP. A period of extreme crisis events, occurring with a probability of one percent, produces output costs of up to 5.5% of World GDP.

Many of the debt crises included in the above calculations are in fact destabilizing confidence crises or liquidity crises, during which rollover costs of debt become too high. In a similar manner, liquidity risk is often the cause for the occurrence of banking crises. The IMF provides a de facto interest rate insurance[31] for these cases in the form of standard IMF programs.

As one type of national insurance against currency crises, nearly all emerging economies have accumulated large amounts of international reserves in order

[31] See e.g. Cordella and Yeyati (2005a)

Table 6: **LDA, Losses in constant 2005 USD, over periods of five years, as percentage of 2005 World GDP**

| | HP10perc | HP10trend | HP3perc | HP3trend |
|---|---|---|---|---|
| 99.9% perctl | 9.9% | 12.6% | 8.8% | 10.4% |
| 99 % perctl | 4.4% | 5.5% | 3.8% | 4.5% |
| Median | 0.2% | 0.3% | 0.2% | 0.2% |
| Mean | 0.6% | 0.7% | 0.5% | 0.6% |

Notes:

(1) Number of simulations equal to 500 000. In all cases, the frequency distribution is the Negative Binomial, the severity pdf is a Weibull

to possess a buffer against pro-cyclical international capital flows. Caballero (2003) argues that hedging the financial mechanism behind macroeconomic disasters is a problem of a magnitude larger than a single market can handle.

Various authors have therefore already proposed an international "insurance" scheme, under which countries could have access to funds under certain circumstances.[32]

The moral hazard problem arising through a potential insurance scheme is addressed in various studies. Cordella and Yeyati (2005b) examines to what degree the presence of a country insurance scheme affects the policymakers' incentives to undertake reforms. An important channel through which insurance can foster reforms can be identified: Insurance reduces the probability that deteriorating fundamentals evolve into large crises, which may enhance the expected political reforms and increase reform incentives.

Participation in a potential crisis insurance fund would therefore have to be subject to ex ante compliance with a number of clearly defined eligibility criteria, such as low budget deficits and a clear debt to GDP threshold. The potential insurance coverage must be forfeited as soon as the country does not fulfill all criteria. As stated in Cordella and Yeyati (2005a), it would also be crucial to characterize and standardize the procedures followed after funds from the insurance facility have been accessed. In the optimal case, the existence of this insurance would incite fiscal discipline and, at the same time, provide liquidity if needed which in turn would lead to fewer crises.

[32]The IMF is usually proposed to act as an insurance facility, see e.g. Cordella and Yeyati (2005a), Cordella and Yeyati (2005b) or Caballero (2003).

# 7 Conclusion

Having used the financial crises database of Laeven and Valencia (2008) to date financial crises, we have characterized the heterogeneity of output losses thereafter under a number of methods. The number of such events over a certain period has been analyzed as the frequency of events, while the aggregate losses served to estimate the severity. Finally, we have compounded frequency and severity in order to generate loss distributions and reported standard risk measures, fitting both the severity as well as the frequency data with various possible probability density functions.

In line with the existing literature, we found that output losses after financial crises are strongly heterogeneous and a large number of countries never recovered their pre-crises growth rates or trends. Loss distributions have shown to be skewed to the right, with average losses ranging between 9% and 15% of initial GDP.

We show that currency crises lead to smaller output losses than debt and banking crises, while the largest losses are found after debt crises. The presence of a debt crisis also exacerbates any of the other two forms of crises, while the presence of a currency crisis in the wake of a debt or banking crisis diminishes output losses through faster recovery. Banking and debt crises alone are found to be more severe than twin crises consisting of banking and currency crises or debt and currency crises.

We compared output costs from financial crises over regions, income groups, and time, finding that Asia has suffered from the most severe financial crises, while Africa experiences the highest frequency of financial crises. Congruently, middle income countries experience the highest output losses, followed by high and low income countries. Financial crises are observed to have been especially harmful during the 1990's, while an assessment of the severity of the recent 2008 financial crisis cannot yet be undertaken with our approach.

The LDA approach leads us to conclude that mean worldwide costs of financial crises within periods of 5 years are in the range of 0.5% to 0.7% of 2005 World GDP. Extreme crises episodes, occurring with a probability of one percent, can lead to losses in the range of 3.8% to 5.5% of world GDP.

The possibility to calculate potential losses from financial crises leads us to propose an international insurance scheme in the case of financial crises which in the optimal case would incite fiscal discipline and at the same time provide liquidity if needed, in turn leading to fewer crises.

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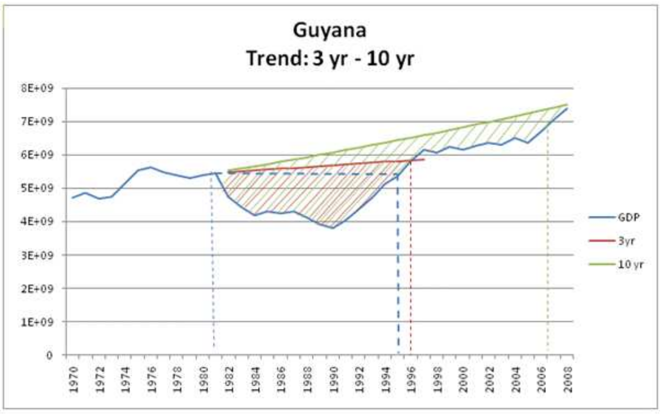
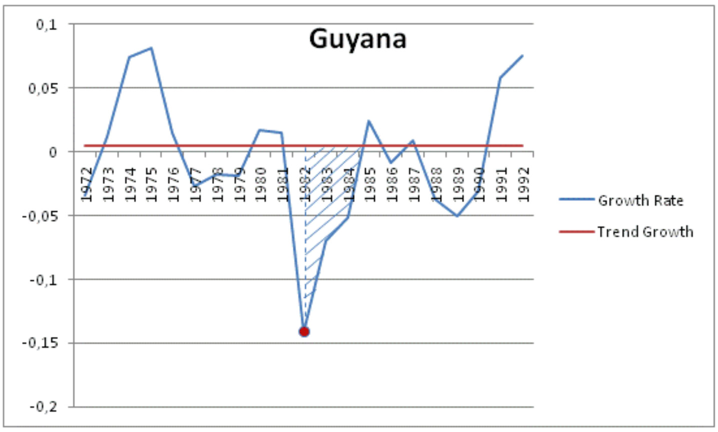
# 8 Appendix

Figure 6: Guyana 1982




[33]Source: Authors' calculations

Figure 7: Guyana 1982




[34]Source: Authors' calculations

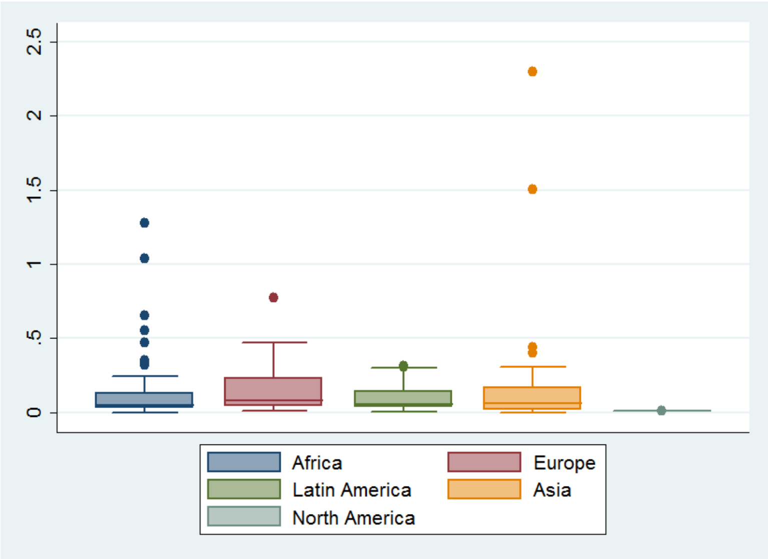
Figure 8: Percentage loss distributions, Currency, debt, and banking crises


[35]Source: Authors' calculations; Distributions are cut at 100 percent

Figure 9: Percentage loss distributions over income groups

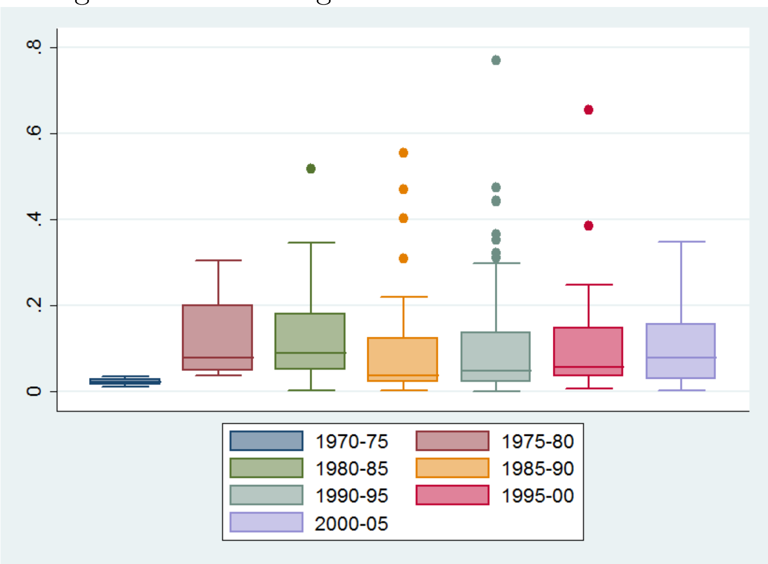

[36]Source: Authors' calculations

Figure 10: Percentage loss distributions over regions




[37]Source: Authors' calculations

Figure 11: Percentage loss distributions over time




[38]Source: Authors' calculations, Cut at 100 percent

Table 7: **Losses after financial crises** (as percentage of initial GDP)

| Loss Measure | Obs. | Mean | Median | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| AG(10)(5)perc | 186 | 0.3241 | 0.1632 | 0.4358 | 0.0005 | 2.7310 |
| AG(10)(5)trend | 186 | 0.4257 | 0.2417 | 0.5217 | 0.0005 | 3.6159 |
| AG(3)(5)perc | 182 | 0.3249 | 0.1696 | 0.3997 | 0.0000 | 2.0615 |
| AG(3)(5)trend | 186 | 0.4567 | 0.2776 | 0.5667 | 0.0000 | 4.4838 |
| ABS | 110 | 0.8509 | 0.1111 | 2.2077 | 0.0000 | 16.0377 |
| AG(10)(10)perc | 186 | 0.5441 | 0.1632 | 1.1689 | 0.0005 | 8.2695 |
| AG(10)(10)trend | 186 | 1.0587 | 0.2604 | 1.9302 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 180 | 0.5809 | 0.1732 | 1.2679 | 0.0000 | 9.2046 |
| AG(3)(10)trend | 181 | 0.9878 | 0.3403 | 1.6139 | 0.0000 | 9.2046 |

Table 8: **Losses after currency crisis**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 101 | 0.2794 | 0.3949 | 0.0006 | 1.8448 |
| AG(10)(5)trend | 101 | 0.3702 | 0.4870 | 0.0006 | 2.2125 |
| AG(3)(5)perc | 94 | 0.2861 | 0.3658 | 0.0000 | 1.7087 |
| AG(3)(5)trend | 94 | 0.3874 | 0.4260 | 0.0000 | 1.7598 |
| HP(10)perc | 118 | 0.1352 | 0.2825 | 0.0001 | 2.2993 |
| HP(10)trend | 122 | 0.1563 | 0.2947 | 0.0003 | 2.2993 |
| HP(3)perc | 114 | 0.0918 | 0.2111 | 0.0013 | 2.0370 |
| HP(3)trend | 125 | 0.0904 | 0.1293 | 0.0013 | 1.0627 |
| ABS | 61 | 0.6811 | 1.4726 | 0.0001 | 7.0657 |
| AG(10)(10)perc | 101 | 0.3674 | 0.7658 | 0.0006 | 6.2588 |
| AG(10)(10)trend | 101 | 0.8587 | 1.8207 | 0.0006 | 11.1335 |
| AG(3)(10)perc | 94 | 0.3635 | 0.7025 | 0.0000 | 5.4637 |
| AG(3)(10)trend | 94 | 0.8509 | 1.4290 | 0.0000 | 8.3445 |

Table 9: **Losses after banking crisis**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 69 | 0.3650 | 0.4636 | 0.0033 | 2.7310 |
| AG(10)(5)trend | 69 | 0.4834 | 0.5726 | 0.0033 | 3.6159 |
| AG(3)(5)perc | 71 | 0.3321 | 0.3925 | 0.0049 | 2.0615 |
| AG(3)(5)trend | 71 | 0.4793 | 0.6519 | 0.0049 | 4.4838 |
| HP(10)perc | 66 | 0.1424 | 0.1914 | 0.0014 | 1.2766 |
| HP(10)trend | 71 | 0.1547 | 0.2084 | 0.0014 | 1.3075 |
| HP(3)perc | 70 | 0.0800 | 0.0763 | 0.0000 | 0.4705 |
| HP(3)trend | 74 | 0.0958 | 0.1075 | 0.0000 | 0.7574 |
| ABS | 35 | 0.7631 | 2.1609 | 0.0000 | 12.5942 |
| AG(10)(10)perc | 69 | 0.7637 | 1.5744 | 0.0033 | 8.2695 |
| AG(10)(10)trend | 69 | 1.5239 | 2.4667 | 0.0033 | 11.1335 |
| AG(3)(10)perc | 69 | 0.7888 | 1.7237 | 0.0049 | 9.2046 |
| AG(3)(10)trend | 70 | 1.7113 | 4.7780 | 0.0049 | 9.2046 |

Table 10: **Losses after debt crisis**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 39 | 0.5002 | 0.4842 | 0.0005 | 1.6946 |
| AG(10)(5)trend | 39 | 0.6244 | 0.4797 | 0.0005 | 1.6946 |
| AG(3)(5)perc | 39 | 0.4282 | 0.4024 | 0.0005 | 1.8020 |
| AG(3)(5)trend | 39 | 0.5248 | 0.4477 | 0.0005 | 1.8020 |
| HP(10)perc | 46 | 0.1723 | 0.1413 | 0.0211 | 0.5531 |
| HP(10)trend | 47 | 0.1966 | 0.1597 | 0.0058 | 0.7095 |
| HP(3)perc | 43 | 0.1224 | 0.1079 | 0.0089 | 0.4846 |
| HP(3)trend | 45 | 0.1395 | 0.1108 | 0.0025 | 0.4846 |
| ABS | 36 | 0.8658 | 2.7270 | 0.0026 | 16.0377 |
| AG(10)(10)perc | 39 | 1.6642 | 0.8180 | 0.0005 | 4.0388 |
| AG(10)(10)trend | 39 | 1.8217 | 2.8550 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 39 | 0.6273 | 0.9522 | 0.0005 | 4.6050 |
| AG(3)(10)trend | 39 | 1.1286 | 1.4862 | 0.0005 | 5.7084 |

Table 11: **Twin crises - Currency and Debt**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 56 | 0.3983 | 0.4209 | 0.0005 | 1.8448 |
| AG(10)(5)trend | 56 | 0.5286 | 0.5121 | 0.0005 | 2.2125 |
| AG(3)(5)perc | 52 | 0.3849 | 0.4200 | 0.0005 | 1.8020 |
| AG(3)(5)trend | 52 | 0.5198 | 0.4797 | 0.0005 | 1.8020 |
| HP(10)perc | 64 | 0.1334 | 0.1223 | 0.0018 | 0.5170 |
| HP(10)trend | 67 | 0.1561 | 0.1520 | 0.0018 | 0.7095 |
| HP(3)perc | 66 | 0.1172 | 0.2541 | 0.0023 | 2.0370 |
| HP(3)trend | 71 | 0.1032 | 0.0998 | 0.0023 | 0.4846 |
| ABS | 42 | 0.5397 | 1.2529 | 0.0026 | 7.0657 |
| AG(10)(10)perc | 56 | 0.5708 | 0.9698 | 0.0005 | 6.2588 |
| AG(10)(10)trend | 56 | 1.4029 | 2.5465 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 52 | 0.5311 | 0.9354 | 0.0005 | 5.4637 |
| AG(3)(10)trend | 52 | 1.0760 | 1.3452 | 0.0005 | 4.7534 |

Table 12: **Twin crises - Currency and Banking**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 78 | 0.2716 | 0.3726 | 0.0005 | 1.6946 |
| AG(10)(5)trend | 78 | 0.3435 | 0.4417 | 0.0005 | 1.6946 |
| AG(3)(5)perc | 73 | 0.2965 | 0.3360 | 0.0005 | 1.8020 |
| AG(3)(5)trend | 73 | 0.3900 | 0.3884 | 0.0005 | 1.8020 |
| HP(10)perc | 101 | 0.1531 | 0.3014 | 0.0018 | 2.2993 |
| HP(10)trend | 103 | 0.1716 | 0.3123 | 0.0018 | 2.2993 |
| HP(3)perc | 95 | 0.0822 | 0.1108 | 0.0013 | 0.8544 |
| HP(3)trend | 103 | 0.0960 | 0.1342 | 0.0013 | 1.0627 |
| ABS | 56 | 0.6501 | 1.3273 | 0.0001 | 6.8260 |
| AG(10)(10)perc | 78 | 0.3051 | 0.4492 | 0.0005 | 2.1887 |
| AG(10)(10)trend | 78 | 0.8651 | 2.1069 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 73 | 0.3492 | 0.5440 | 0.0005 | 3.7145 |
| AG(3)(10)trend | 73 | 0.7216 | 1.1281 | 0.0005 | 5.7125 |

Table 13: **Twin crises - Debt and Banking**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 36 | 0.5213 | 0.5045 | 0.0005 | 1.6946 |
| AG(10)(5)trend | 36 | 0.6631 | 0.4996 | 0.0005 | 1.6946 |
| AG(3)(5)perc | 35 | 0.4247 | 0.3862 | 0.0005 | 1.8020 |
| AG(3)(5)trend | 35 | 0.5553 | 0.4129 | 0.0005 | 1.8020 |
| HP(10)perc | 32 | 0.2396 | 0.2447 | 0.0093 | 1.2766 |
| HP(10)trend | 34 | 0.2586 | 0.2595 | 0.0058 | 1.3075 |
| HP(3)perc | 32 | 0.1510 | 0.1293 | 0.0000 | 0.4846 |
| HP(3)trend | 33 | 0.1782 | 0.1590 | 0.0000 | 0.7574 |
| ABS | 26 | 1.1814 | 3.1728 | 0.0059 | 16.0377 |
| AG(10)(10)perc | 36 | 0.7952 | 1.1590 | 0.0005 | 5.4650 |
| AG(10)(10)trend | 36 | 1.7638 | 2.6372 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 34 | 0.8204 | 1.7036 | 0.0005 | 9.2046 |
| AG(3)(10)trend | 35 | 1.3295 | 1.9641 | 0.0005 | 9.2046 |

Table 14: **All Twin Crisis**(as percentage of initial GDP)

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| AG(10)(5)perc | 114 | 0.3173 | 0.4052 | 0.0005 | 1.8448 |
| AG(10)(5)trend | 114 | 0.4238 | 0.4946 | 0.0005 | 2.2125 |
| AG(3)(5)perc | 105 | 0.3344 | 0.3755 | 0.0005 | 1.8020 |
| AG(3)(5)trend | 105 | 0.4527 | 0.4386 | 0.0005 | 1.8020 |
| HP(10)perc | 130 | 0.1588 | 0.2902 | 0.0018 | 2.2993 |
| HP(10)trend | 136 | 0.1759 | 0.2996 | 0.0018 | 2.2993 |
| HP(3)perc | 126 | 0.1068 | 0.2071 | 0.0000 | 2.0370 |
| HP(3)trend | 136 | 0.1078 | 0.1423 | 0.0000 | 1.0627 |
| ABS | 78 | 0.9035 | 2.2318 | 0.0001 | 16.0377 |
| AG(10)(10)perc | 114 | 0.4741 | 0.9509 | 0.0005 | 6.2588 |
| AG(10)(10)trend | 114 | 0.9907 | 2.0026 | 0.0005 | 11.1335 |
| AG(3)(10)perc | 104 | 0.5286 | 1.1851 | 0.0005 | 9.2046 |
| AG(3)(10)trend | 105 | 0.9816 | 1.5407 | 0.0005 | 9.2046 |

Table 15: **Severity of crises by Regions - All crises** (Losses as percentage of initial GDP)

| Variable | Nr. | Africa | Nr. | Europe | Nr. | Latin A. | Nr. | Asia | Nr. | North A. |
|---|---|---|---|---|---|---|---|---|---|---|
| AG(10)(5)perc | 71 | 0.2481 | 21 | 0.4674 | 37 | 0.2759 | 32 | 0.5112 | 1 | 0.0091 |
| AG(10)(5)trend | 71 | 0.3253 | 21 | 0.6047 | 37 | 0.3909 | 32 | 0.5751 | 1 | 0.0091 |
| AG(3)(5)perc | 62 | 0.2309 | 26 | 0.4075 | 35 | 0.3083 | 32 | 0.5131 | 1 | 0.0390 |
| AG(3)(5)trend | 62 | 0.3080 | 26 | 0.5250 | 35 | 0.4170 | 32 | 0.6949 | 1 | 0.0390 |
| ABS | 43 | 0.7816 | 17 | 1.2325 | 21 | 0.3113 | 14 | 1.4106 | 0 | 0 |
| AG(10)(10)perc | 71 | 0.4279 | 21 | 0.5354 | 37 | 0.3072 | 32 | 1.0558 | 1 | 0.0091 |
| AG(10)(10)trend | 71 | 0.9220 | 21 | 1.0626 | 37 | 0.7603 | 32 | 1.8413 | 1 | 0.0091 |
| AG(3)(10)perc | 60 | 0.3427 | 26 | 0.5793 | 35 | 0.3789 | 32 | 1.1557 | 1 | 0.0390 |
| AG(3)(10)trend | 61 | 0.6376 | 26 | 1.2732 | 35 | 0.6525 | 32 | 1.6113 | 1 | 0.0390 |

Table 16: **Average severity of crises by income groups** (percentage of initial GDP)

| Variable | Nr. | High Income | Nr. | Middle Income | Nr. | Low Income |
|---|---|---|---|---|---|---|
| AG(10)(5)perc | 21 | 0.2844 | 112 | 0.3801 | 53 | 0.2215 |
| AG(10)(5)trend | 21 | 0.3901 | 112 | 0.4945 | 53 | 0.2946 |
| AG(3)(5)perc | 21 | 0.2389 | 113 | 0.3800 | 48 | 0.2327 |
| AG(3)(5)trend | 21 | 0.4923 | 113 | 0.4915 | 48 | 0.2890 |
| ABS | 10 | 0.4446 | 71 | 0.7927 | 29 | 1.1332 |
| AG(10)(10)perc | 21 | 0.4032 | 112 | 0.6669 | 53 | 0.3403 |
| AG(10)(10)trend | 21 | 1.0673 | 112 | 1.1918 | 53 | 0.7740 |
| AG(3)(10)perc | 21 | 0.4258 | 112 | 0.6814 | 47 | 0.4106 |
| AG(3)(10)trend | 21 | 1.1015 | 113 | 1.0663 | 47 | 0.7485 |

Table 17: Features of the PDF of total losses (more cases)

| | ABS | AG10.10perc | AG10.10trend | AG3.10perc | AG3.10trend |
|---|---|---|---|---|---|
| 99.9 percentile | 5.0e+014 | 2.8e+015 | 5.5e+015 | 5.1e+015 | 1.1e+016 |
| 99 percentile | 2.1e+014 | 1.1e+015 | 2.1e+015 | 1.8e+015 | 3.9e+015 |
| median | 1.1e+013 | 4.4e+013 | 8.1e+013 | 6.6e+013 | 1.3e+014 |
| mean | 2.5e+013 | 1.2e+014 | 2.2e+014 | 1.9e+014 | 4.0e+014 |
| Std. deviation | 4.7e+013 | 2.6e+014 | 5.1e+014 | 4.3e+014 | 9.9e+014 |

Notes:

(1) Number of simulations equal to 500 000. In all cases, the frequency distribution is the Negative Binomial, the severity pdf is a Weibull

(2) Losses are measured in constant 2005 USD and correspond to five-year periods

Table 18: Features of the PDF of total losses (more cases)

| | AG10.5perc | AG10.5trend | AG3.5perc | AG3.5trend |
|---|---|---|---|---|
| 99.9 percentile | 1.5e+015 | 1.9e+015 | 2.3e+015 | 3.6e+015 |
| 99 percentile | 5.9e+014 | 7.7e+014 | 8.6e+014 | 1.4e+015 |
| median | 2.9e+013 | 3.8e+013 | 3.9e+013 | 5.8e+013 |
| mean | 7.1e+013 | 9.3e+013 | 9.9e+013 | 1.5e+014 |
| Std. deviation | 1.4e+014 | 1.8e+014 | 2.1e+014 | 3.2e+014 |

Notes:

(1) Number of simulations equal to 500 000. In all cases, the frequency distribution is the Negative Binomial, the severity pdf is a Weibull

(2) Losses are measured in constant 2005 USD and correspond to five-year periods