

**EXECUTIVE
BOARD
MEETING**

SM/20/101
Correction 1

July 22, 2020

To: Members of the Executive Board
From: The Secretary
Subject: **2020 External Sector Report—Chapter 2**

Board Action: The attached corrections to SM/20/101 (7/2/20) have been provided by the staff:

Evident Ambiguity **Pages 6 and Online Annex Page 3**

Factual Errors Not Affecting the Presentation of Staff's Analysis or Views **Pages 8, 14, 15 (Figure 2.7, footnote 1), 24, Online Annex Page 1**

Typographical Errors **Pages 2, 5, 11, 12, 15 (Figure 2.7, Sources), 16, 18, 19**

Questions: Mr. Leigh, RES (ext. 34747)
Mr. Adler, RES (ext. 35648)
Mr. Rabanal, RES (ext. 36784)

EXTERNAL STRESS AND THE INTERNATIONAL INVESTMENT POSITION

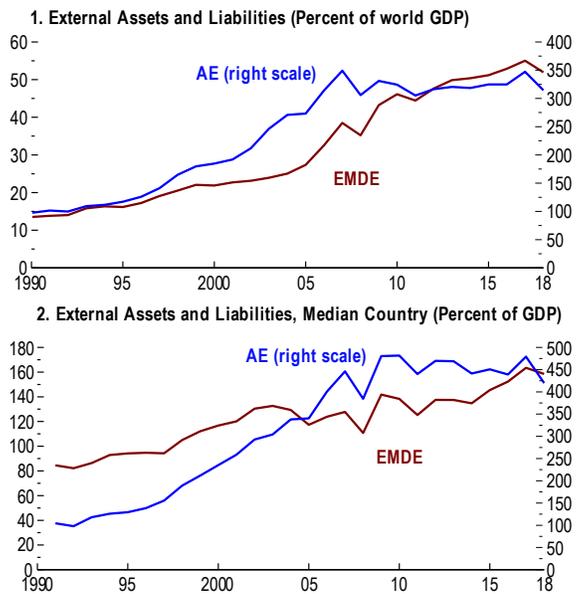
Countries' external assets and liabilities reached historic highs in the years before the Great Lockdown. This chapter examines the relationship between the structure of external assets and liabilities—the components of the international investment position (IIP)—and the risk of external stress events, defined as episodes featuring an external debt default, debt restructuring, or access to IMF support. For a sample of 73 economies over the past three decades, it finds that some components of the IIP relate more strongly to external stress than others do, suggesting that a disaggregated approach can usefully complement the information content of the net IIP for assessing risks. Debt liabilities in foreign currency increase the likelihood of an external stress episode, especially for emerging market and developing economies, while official foreign exchange reserves play a mitigating role. Additional well-studied factors, such as large current account deficits, also come with higher risks. Heightened global risk aversion, as during the Great Lockdown, amplifies these risks. When an external stress episode occurs, countries with greater preexisting external vulnerabilities typically experience larger output losses and sharper current account adjustments. Creditor countries, on average, experience substantial valuation losses during periods of global financial stress, highlighting the risks and costs of excessive external imbalances for both debtor and creditor countries.

Introduction¹

External assets and liabilities more than tripled as a share of GDP from the early 1990s to the years preceding the Great Lockdown (Figure 2.1). This sharp increase, both in gross and net terms, often referred to as the rise of “stock imbalances,” has raised questions regarding its sustainability in debtor economies as well as the associated macroeconomic vulnerabilities when confronted with domestic and global shocks. The initial sharp tightening in global financial conditions and large terms-of-trade fluctuations caused by the outbreak of coronavirus (COVID-19) and the Great Lockdown led to sharp currency and current account movements in many economies—and, while in most cases the exchange rate was allowed to act as a shock absorber, a few countries resorted to foreign exchange intervention—as well as capital flow management measures to support macroeconomic and financial stability.

Figure 2.1. Stock Imbalances, 1990–2018

Gross external assets and liabilities are at record high levels.



Sources: External Wealth of Nations database (Lane and Milesi-Ferretti 2007); and IMF, World Economic Outlook database.

Note: AE = advanced economies; EMDE = emerging market and developing economies.

¹The authors of this chapter are Swarnali Hannan and Pau Rabanal (co-leads) and Luis Cubeddu, with contributions from Suman Basu, Roberto Perrelli, and Weining Xin, and support from Kyun Suk Chang, Deepali Gautam, Jair Rodriguez, and Zijiao Wang.

real effective exchange rate depreciates by about 10 percent and the current account balance rises by more than 2 percent of GDP within the first year of an external stress episode in countries with high preexisting vulnerabilities, with far more limited effects in countries with smaller preexisting vulnerabilities.

- Finally, the chapter also finds that external stress episodes have implications for creditor economies through valuation effects. Although ascertaining the costs for creditors is difficult, the analysis finds that following large global crises, such as the global financial crisis of 2008 and the euro area sovereign debt crisis of 2010—which featured a number of external stress episodes—creditor economies experienced valuation losses that lowered their IIPs. On average, in the decade following the global financial crisis, a 1 percent of GDP rise in the current account surplus has been associated with a 0.5 percent of GDP valuation loss—a systematic relationship that did not necessarily hold before the crisis.

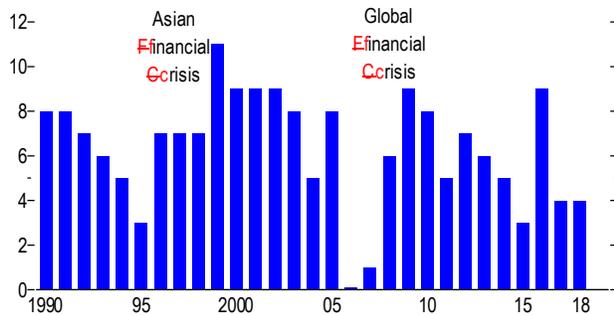
The remainder of the chapter is organized as follows. The first section presents empirical patterns of the main IIP components around external stress episodes. The second section discusses the main results from estimating an external stress probability model, focusing on the IIP and its main components, including how the combination of vulnerabilities increases the likelihood of external stress episodes. The third section computes costs for debtor and creditor economies after external stress episodes materialize, and the final section concludes by summarizing the chapter’s implications for the outlook and risks.

International Investment Position Dynamics before and after External Stress Episodes

To understand the factors that influence external financing risks, the chapter focuses on the determinants of external stress episodes. As in Catão and Milesi-Ferretti (2014), episodes of external stress are defined as years in which an economy experiences sovereign debt

Figure 2.2. External Stress Episodes in Selected Economies, 1990–2018
(Number *a*per year)

External stress episodes are defined as sovereign debt defaults and restructurings, and/or access to IMF arrangements, for 73 advanced and emerging and developing economies.



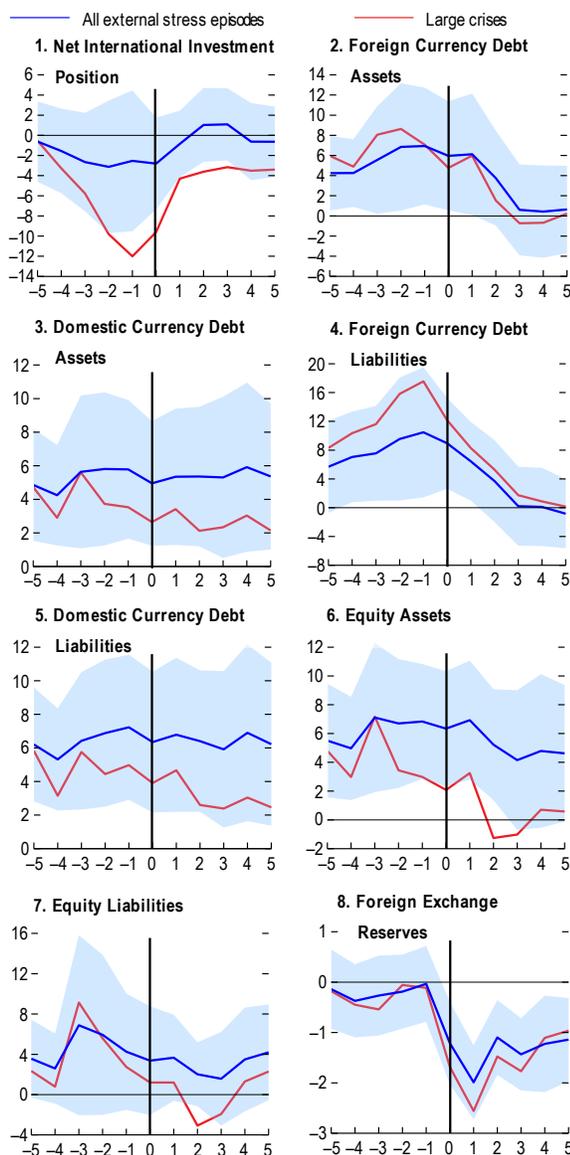
Sources: Das and others (2011); Asonuma and Trebesch (2016); Paris Club; and IMF staff calculations.

default or restructurings or the start of IMF-supported financial assistance. Sovereign debt defaults and restructuring episodes are identified based on an updated version of the data set in Das, Papaioannou, and Trebesch (2011) and Asonuma and Trebesch (2016), and recent Paris Club reports. Using the aforementioned criteria, the chapter identifies 176 cases of external stress (Figure 2.2), most of which involve emerging market and developing economies.⁴ It is important to note that the chapter focuses on episodes of external stress, using the aforementioned definition, and not on fiscal stress or public debt crisis episodes. The latter would include, in addition to sovereign defaults and restructurings and recourse to IMF financing, additional events such as implicit default via high inflation and rising sovereign risk premiums (see Cerovic, Gerling, and Medas 2018).

The first part of the analysis studies the evolution of the main IIP components around external stress episodes. The sample comprises 73 advanced and emerging market economies during 1991–2018. This event-study analysis controls for country and time fixed effects to capture differences in countries' average IIP levels as well as the influence of common shocks (as in Gourinchas and Obstfeld 2012 and Catão and Milesi-Ferretti 2014;

Figure 2.3. Conditional Mean of the International Investment Position and Its Components around External Stress Episodes, 1990–2018 (Percent of GDP)

External stress episodes are usually preceded by a deterioration of the net international investment position and a large buildup of foreign-currency-denominated debt liabilities.



Source: IMF staff calculations.

Note: The methodology for construction of conditional mean estimates is based on Catão and Milesi-Ferretti (2014) and is discussed in Online Annex 2.1. Shaded area corresponds to the 90 percent confidence interval for all external stress episodes.

⁴One difference with Catão and Milesi-Ferretti (2014) is that it focuses on IMF-supported arrangements exceeding 200 percent of quota, while this chapter considers all IMF-supported arrangements, including non-disbursing and precautionary arrangements. Robustness to different definitions of external stress episodes on the inclusion of countries under a Flexible Credit Line is discussed in Online Annex 2.1. All annexes are available at www.imf.org/en/Publications/ESR.

indicates a stress episode in a given country and year, while a value of 0 indicates no stress).⁹ The explanatory variables include the various IIP components and standard macroeconomic variables identified in the empirical literature, such as the current account balance, global risk aversion, the real effective exchange rate gap (measured as deviations of the real exchange rate from the average of the previous five years), a measure of income per capita relative to the United States, the credit gap (constructed in a way analogous to the real exchange rate gap), and the degree of financial development.¹⁰ The financial development index includes measures of market depth, access, and efficiency for each country, and can help explain cross-country differences in the ability to respond to external shocks (see Svirydzenka 2016). The sample is the same as for the event study of stress episode dynamics already mentioned.¹¹

Estimation Results

In line with the event study analysis, a lower net IIP (a larger net debtor position) is associated with higher external stress (see Table 2.1, first column). When further disaggregating the IIP into its main components, the results suggest that both higher foreign and domestic currency external debt liabilities increase the probability of external stress events (see Table 2.1, second column). These results highlight the potential risks and costs of excessive external debt, either public or private. The estimated coefficients for the same external debt category in the IIP are different for assets and liabilities, denoting that gross positions, rather than net positions, provide useful information to assess the likelihood of external stress episodes. In addition, higher levels of foreign exchange reserves lower the occurrence of stress episodes. Private external debt assets do not appear to play a mitigating role. This result could reflect capital flight, which often rises in anticipation of external stress. Meanwhile, equity assets and liabilities are not statistically significant. Among other macroeconomic fundamentals, larger current account deficits are associated with higher external stress. The likelihood of external stress events also increases with global risk aversion, suggesting that global “push” factors also play a role.

There are important differences between the results for the entire sample, which includes both advanced and emerging market economies, and the sample that includes only emerging market and developing economies (Table 2.1, third and fourth columns). Foreign-currency-denominated debt liabilities have a statistically significant relationship with external stress risk for emerging market and developing economies, whereas domestic-currency-denominated debt liabilities do not. Another difference is the relation with private external debt assets denominated in foreign currency, which significantly reduce the probability of a stress episode in emerging market and developing economies. Taken together, these results highlight the importance of assessing currency mismatches in emerging market and developing economies. Equity assets and

⁹Gourinchas and Obstfeld (2012) compare the determinants of various crisis episodes, including sovereign defaults, systemic banking crises, and currency crises. See also Turrini and Zeugner (2019). Box 2.1 presents work by IMF staff on predicting external crises using alternative definitions, including sudden stop episodes with high growth impact and exchange rate market pressure episodes.

¹⁰Several studies have used the Chicago Board Options Exchange Volatility Index (VIX) as a proxy for global risk aversion, with lower values indicating greater tolerance for risk taking and increases in leverage (Rey 2015). Following Obstfeld, Ostry, and Qureshi (2017), the VXO—the precursor of the VIX—is used to maximize data coverage.

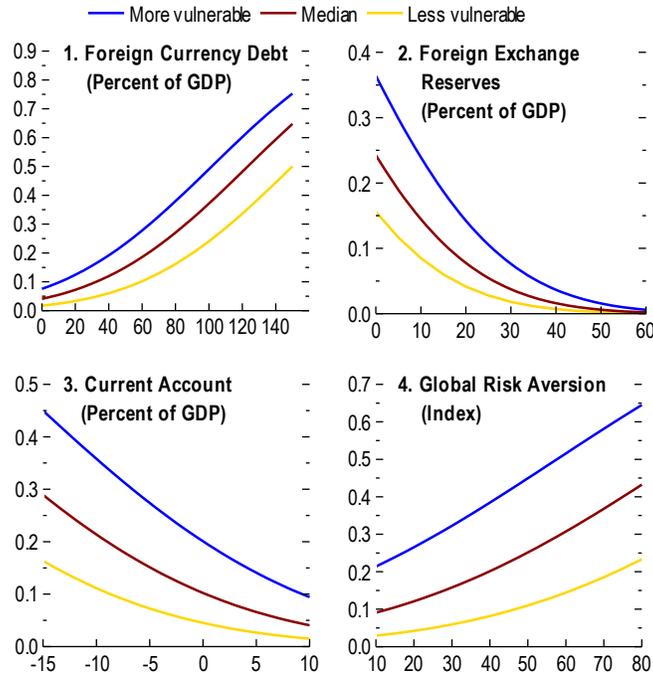
¹¹Data limitations preclude the inclusion of additional countries in the sample.

The results also imply that a combination of two or more external vulnerabilities greatly increases the probability of external stress for emerging market and developing economies (Figure 2.4).¹⁴ The same level for foreign-currency-denominated debt liabilities could signal very different risks of an external stress episode, depending on other vulnerabilities. When foreign currency debt is 40 percent of GDP, the predicted probability ranges from 6–19 percent, depending on whether foreign exchange reserves and the current account balance are at high levels (75th percentile of the sample) or at low levels (25th percentile). Similarly, the vulnerabilities associated with large current account deficits depend on the levels of foreign exchange reserves and foreign-currency-denominated debt. The vulnerabilities associated with a low level of reserves are more severe in economies with a lower current account balance and higher level of foreign-currency-denominated debt.

Finally, the estimated model has important implications for the risks facing emerging market and developing economies today. Global risk aversion increased sharply in the months following the outbreak of COVID-19, with negative implications for countries with preexisting external vulnerabilities. When global risk aversion reaches the peak values seen during the global financial crisis or the Great Lockdown, the predicted external stress episode probability for emerging market and developing economy with an average level of preexisting vulnerabilities rises to about 40 percent—more than double the estimated probability for less vulnerable emerging market and developing

Figure 2.4. Selected Predictors of External Stress in the Emerging Market and Developing Economies Sample
(Model-predicted probabilities)

The combination of external vulnerabilities in multiple dimensions can amplify external financing risks.



Sources: [External Wealth of Nations database \(Lane and Milesi-Ferretti 2007\); Haver Analytics](#); IMF, World Economic Outlook database; [External Wealth of Nations database \(Lane and Milesi-Ferretti 2007\); Haver Analytics](#); and IMF staff calculations.

Note: All panels display the predicted probabilities of an external stress episode, keeping all covariates except foreign currency debt, foreign exchange reserves, the current account, and global risk aversion at their sample mean. More vulnerable countries are defined as those with foreign currency debt at the 75th percentile and foreign exchange reserves and current account balance at the 25th percentile of the sample. Less vulnerable countries are defined as those with foreign currency debt at the 25th percentile and foreign exchange reserves and current account balance at the 75th percentile. Median countries are defined as those with foreign currency debt, foreign exchange reserves, and current account balance at the median.

¹⁴The analysis in Figure 2.4 excludes domestic-currency-denominated debt liabilities given that the estimated coefficient is not statistically significant for emerging markets and developing economies.

economies (see Figure 2.4). These results highlight the importance of preexisting conditions when global risk appetite sours.

External Stress Drivers over Time

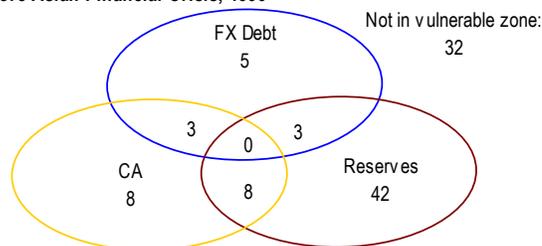
Having discussed which indicators are associated with external stress episodes, this subsection summarizes their configuration among emerging market and developing economies on the eve of three major crises affecting numerous economies: the Asian financial crisis (1998), the global financial crisis (2008), and the Great Lockdown of 2020. The analysis summarizes the configuration of the indicators using Venn diagrams (Figure 2.5). It indicates the proportion of emerging market and developing economies for which the aforementioned country-specific vulnerabilities (related to foreign currency debt, foreign exchange reserves, and current account deficits) are elevated as well as the proportion of those economies for which the indicators are at less vulnerable levels.

Before the Asian financial crisis, external risks were associated mostly with low levels of foreign exchange reserves and, to a lesser extent, large current account deficits. At the onset of the global financial crisis, external risks reflected mainly current account deficits and, to a lesser extent, foreign-currency-denominated debt liabilities. Low levels of reserves had become less of a vulnerability for most emerging market and developing economies at that point. In the years preceding the Great Lockdown, elevated foreign-currency-denominated debt liabilities became a central vulnerability for these economies. At the same time, this vulnerability was, in many cases, mitigated by relatively small current account deficits and relatively high levels of foreign exchange reserves.

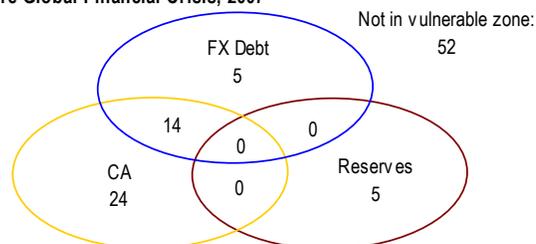
Figure 2.5. Rotating Sources of External Stress in Emerging Market and Developing Economies, 1990–2018
(Percent of sample)

The sources of external vulnerabilities have rotated overtime. Before the Asian financial crisis, countries at risk had low levels of foreign exchange reserves and large current account deficits. In recent years, vulnerabilities have been building through high levels of foreign-currency-denominated debt, but have been mitigated in most countries by a combination of smaller current account deficits and higher levels of foreign exchange reserves.

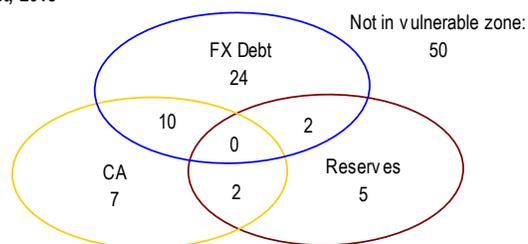
1. Before Asian Financial Crisis, 1996



2. Before Global Financial Crisis, 2007



3. Latest, 2018



Sources: Bénétix, Lane, and Shambaugh (2015); Bénétix and others (2019); and External Wealth of Nations database (Lane and Milesi-Ferretti 2007). External Wealth of Nations database (Lane and Milesi-Ferretti 2007); Bénétix, Lane, and Shambaugh (2015); and Bénétix and others (2019).

Note: CA = current account; FX = foreign exchange. Each Venn diagram reports the proportion of emerging market and developing economies that have a low level of foreign exchange reserves and current account balances (below the 25th percentile) and a high level of foreign exchange debt (above the 75th percentile) for 1996, 2007, and 2018. The current account balance is calculated as a two-year moving average.

to experience larger output losses during an external stress episode (Figure 2.6). The output loss within the first two years for vulnerable economies is about 3.7 percent, well above the 0.5 percent estimated loss for economies identified as “less vulnerable.” The recovery is also slower for vulnerable economies, with an output loss of about 2 percent five years after the external stress episode, while less vulnerable economies experience a recovery in their GDP levels within four years.

The effects on the real effective exchange rate and current account balance also relate to preexisting vulnerabilities. The real effective exchange rate depreciates by about 10 percent and the current account balance rises by more than 2 percent of GDP within the first year of an external stress episode for countries with high preexisting vulnerabilities. For less vulnerable economies, the real effective exchange rate and current account balance movements are much smaller.

Consequences for Creditor Economies

When debtors suffer external stress or a crisis, their creditors experience losses in the form of adverse exchange rate movements, lower asset and bond prices, and other valuation changes, including from debt restructuring and write-offs. This consequence for creditors is particularly visible in the years following the global financial crisis. According to the Laeven and Valencia (2012) banking crisis data set, creditor advanced economies, such as Belgium, Denmark, Germany, Sweden, and Switzerland, suffered a banking crisis in 2008, in part due to these economies’ exposures to distressed assets in debtor economies.¹⁶

The analysis follows an aggregate approach, given data limitations, by studying the evolution of the valuation effects in the net IIP in the aftermath of large crises.¹⁷ Valuation effects are estimated as the difference between the annual change in the net IIP and the financial account flows included in the balance of payments statistics for each country and year.¹⁸

The results indicate sustained valuation losses for countries with persistent current account surpluses in the aftermath of the global financial crisis that were not present in the precrisis period. Figure 2.7 (panels 1 and 2) presents the relationship between the accumulated current account balances of major economies and the estimated accumulated valuation effects,

¹⁶For instance, Hellwig (2018) documents German banking sector losses during the global financial crisis and euro area sovereign debt crisis as a result of exposures to distressed assets in Greece, Portugal, Spain, and the United States. The study’s conclusion is that “the fiscal costs of support to German financial institutions were very large, even in comparison to countries that were epicenters of crises.” Thévenoz (2010) discusses the case of Switzerland during the global financial crisis, including the government rescue of the Union Bank of Switzerland.

¹⁷Ascertaining the costs of each external crisis on each creditor economy would require estimating valuation changes at the security level for bilateral country exposures following each crisis.

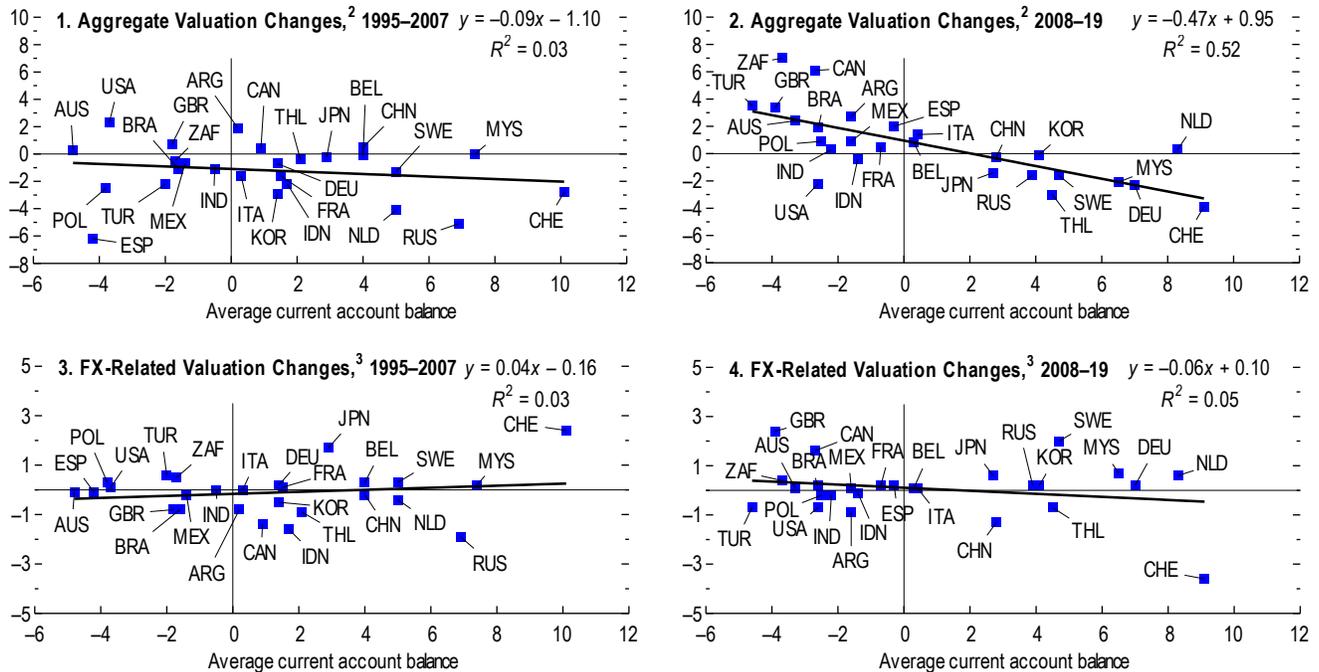
¹⁸See Bergant (2017) or Adler and Garcia-Macia (2018) for details on this approach, which is known as the “residual” approach. A few countries, such as the United States and some euro area countries, publish valuation changes related to exchange rate fluctuations and asset price changes as well as other valuation changes as part of the stock-flow reconciliation tables between the IIP and balance of payments statistics. To increase country and time coverage, the residual approach is applied. Financial centers with large IIP positions are excluded (~~China~~-Hong Kong SAR and Singapore). Saudi Arabia is excluded because of data limitations.

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comparing the periods before and after the global financial crisis.¹⁹ The differences across subperiods are significant. In the precrisis period, there is no systematic pattern: sustained valuation gains or losses were not related to average current account balances.

Figure 2.7. Average Current Account Balances and Net International Investment Position Valuation Changes, 1995–2019¹
(Percent of GDP)

Countries with persistent current account surpluses have experienced sustained valuation losses since the global financial crisis, while this relationship did not hold before the crisis. Valuation effects were not systematically related to exchange rates, but to other asset prices.



Sources: Bénétrix and others (2019); *External Wealth of Nations database* (Lane and Milesi-Ferretti 2007); IMF, Information Notice System; IMF, World Economic Outlook database; *External Wealth of Nations database* (Lane and Milesi-Ferretti 2007); and IMF staff calculations.

Note: Data labels use International Organization for Standardization (ISO) country codes. FX = foreign exchange; NIIIP = net international investment position.

¹Country sample includes all *External Sector Report* economies excluding China, Hong Kong SAR, Saudi Arabia, and Singapore.

²NIIIP valuation change = $\{(\text{change of total asset} - \text{net acquisition of asset}) - (\text{change of total liabilities} - \text{net incurrence of liabilities})\} / \text{GDP}$.

³FX-related NIIIP valuation change = $-(\text{net foreign exchange share in GDP} * \text{percent change in real effective exchange rate})$.

In the post-global-financial-crisis period, which also includes the euro area sovereign debt crisis of 2010, the relationship is negative and statistically significant. Countries with sustained current account surpluses (including Germany, Japan, and Switzerland, among others) experienced sustained valuation losses. The estimated slope coefficient of -0.5 implies that a sustained current account surplus of 2 percent of GDP led, on average, to a valuation loss of 1 percent of GDP a year. The implication of this result is that, in countries with sustained current account surpluses, the net IIP increases by less than would be expected from the cumulative

¹⁹These results are robust when a narrower window around the global financial crisis is considered (such as 2002–07 for the precrisis period and 2008–13 for the postcrisis period). The results are also robust when including the net international investment period in the beginning of each period instead of the average current account balance on the horizontal axis.

current account balances. On the contrary, for the pre-global-financial-crisis period, the coefficient is near zero and not statistically significant.²⁰

The results highlight that the stabilizing role of valuation effects in the net IIP identified by Gourinchas and Rey (2007) and Adler and Garcia-Macia (2018) is especially strong after large systemic crises. On one hand, valuation gains can reflect adverse macroeconomic and financial factors. For example, euro area debtor economies (including Italy and Spain) generally experienced valuation gains following the global financial crisis. Greece and Portugal also experienced large valuation gains during this period that intensified after the euro area sovereign debt crisis.²¹ These valuation gains correspond to losses for investors that had significant exposures to these economies. On the other hand, valuation losses can be the consequence of relatively strong underlying fundamentals. Since 2008 the United States has seen valuation losses despite continuing to run current account deficits. These valuation losses have been driven by (1) an appreciation of the US dollar, which reduces the value of US external assets denominated in foreign currency but does not affect liabilities, which are denominated in US dollars; and (2) better performance of equity valuations compared with peers (which leads to a higher value of US foreign equity liabilities and a lower net IIP).²²

Finally, Figure 2.7 also estimates how much of these valuation effects reflects exchange rate fluctuations. Interestingly, for the two subperiods, there is no systematic relationship between current account balances and valuation changes resulting from exchange rates.²³ This is not to say that exchange rate fluctuations cannot have an impact on countries with large external creditor positions, such as Switzerland. However, when averaged over long periods of time, these valuation effects are not systematically related to the current account balance. This result suggests that factors linked to bond and asset price differentials, debt restructuring, and debt write-offs are driving the valuation effects.

Implications for the Outlook and Policies

This section summarizes possible implications of the chapter's results for economies in today's environment. For debtor economies, the results suggest that the ongoing period of global financial stress has increased the probability of experiencing external stress with either a debt

²⁰The ratio of valuation changes to nominal GDP is estimated by converting both measures to US dollars, following the literature (see Devereux and Sunderland 2010; Bergant 2017; and Adler and Garcia-Macia 2018). The choice of the numeraire can affect the estimates. However, the results are quite similar when computing the ratio of valuation changes to nominal GDP when both measures are converted to domestic currency, in particular for economies with sustained current account surpluses.

²¹Greece and Portugal are not shown in Figure 2.7 because they are not economies reported in the *External Sector Report*. Ireland, in contrast, suffered valuation losses, although these estimates are imprecise, given that Ireland's IIP data are influenced by measurement issues related to the significant presence of multinational companies.

²²Gourinchas, Rey, and Govillot (2010) argues that this phenomenon implies that the United States acts as a world insurer by transferring wealth to the rest of the world in crisis periods (via valuation losses). Given this role, Gourinchas, Rey, and Govillot (2010) argue that the United States should earn an insurance premium in the form of higher rates of return on its external assets compared with its external liabilities (an "exorbitant privilege") during tranquil times. Curcuro, Dvorak, and Warnock (2010) challenge this view and does not find evidence of a higher rate of return of US external assets over US external liabilities. See also Lane and Milesi-Ferretti (2008).

²³The valuation changes due to exchange rate fluctuations are estimated using data on net foreign asset positions in foreign currency from the Bénétrix and others (2019) data set.

Box 2.1. Drivers of Various Types of External Crisis¹

This box investigates the robustness of the chapter’s findings on the drivers of external stress events or crises to alternative definitions. It also considers additional potential explanatory factors. The following events complement the external stress episodes studied in the chapter. These episodes feature capital outflows, exchange rate depreciation, and tighter financial constraints²:

- *Sudden stops with growth impact (SSGIs)*: During these episodes, a large decline in net private capital inflows tightens financial constraints sufficiently to generate unusually large recessions or lead to recourse to IMF financial support (following the work of Dornbusch, Goldfajn, and Valdés 1995 and Mendoza 2002, among others).
- *Exchange market pressure events (EMPEs)*: During these episodes, the currency sharply depreciates or reserves suddenly decline (as in Kaminsky and Reinhart 1999). Such events may imply different growth outcomes, depending on whether gains in export competitiveness are offset by the tightening of financial constraints due to foreign-currency-denominated debt.

The starting point of the analysis uses signal extraction methods to predict external crises given their potential for superior out-of-sample performance, as documented in Berg, Borensztein, and Pattillo (2005). This technique calculates a threshold for each variable separately, which enhances performance by reducing the impact of outliers and missing data but does not allow for variable interactions or more complex nonlinearities. Having established a benchmark, the performance of machine-learning techniques—which offer the potential to uncover novel nonlinearities and complex interactions among many variables—is explored.³

About 80 predictive indicators that cover various external crisis generations identified by the academic literature are explored (Table 2.1.1). Variable selection broadly follows the literature on generations of external crises, capturing a range of factors, including (1) policy regimes, such as the exchange rate regime and capital account openness; (2) imbalances and mismatches, including the current account, balance sheet indicators, and private and public buffers; (3) asset price booms and busts, such as medium-term growth and acceleration of stock prices, house prices, and the real effective exchange rate; (4) global liquidity and contagion, such as US interest rates, spreads, volatility, and banking linkages to other countries experiencing recent crises; and (5) political shocks.

¹The authors of this box are Suman Basu (IMF), Roberto Perrelli (IMF), and Weining Xin (University of Southern California), based on Basu, Perrelli, and Xin (forthcoming).

²SSGIs occur when the net private capital inflow as a percentage of GDP is at least 2 percentage points lower than in the two previous years with large multilateral support. EMPEs are defined as episodes where the weighted average of the annual percentage depreciation in the nominal exchange rate and the annual decline in reserves as a percentage of the previous year’s GDP is below the 15th percentile of the worldwide pooled sample, with large multilateral support.

³Tree-based machine-learning models are an extension of the signal extraction technique: after the sample is split according to the threshold for one variable, subsamples continue to be split according to thresholds of other variables, generating an entire tree of threshold splits. The random forest model averages over a large number of randomly generated trees, whereas the RUSBoost model constructs new trees to capture the information left out of previously constructed trees. Machine-learning techniques discipline the construction of trees so that the maximization of in-sample model fit does not worsen out-of-sample performance. See Basu, Perrelli, and Xin (forthcoming).

Box 2.1 (continued)

The main results are that stock vulnerabilities are generally reliable predictors of external crises, whereas the ranking of indicators and the importance of interactions vary across crisis categories and country groupings. This may indicate that stock variables, being predetermined, are econometrically more sound. Figure 2.1.1 reports, for each type of crisis, the top indicators explaining in-sample variation for the prediction technique with the lowest sum of the percentages of false alarms and missed crises⁴:

- SSGIs in emerging market economies are well predicted by signal extraction methods. The most important predictors are debt liabilities and the asset price and credit bubbles they finance. The predictors include global factors (including the TED spread [the difference between the three-month US Treasury bill rate and the three-month London interbank offered rate LIBOR-based in US dollars], the incidence of financial crisis in advanced economies, and interbank liabilities to banks in these advanced economies), medium-term bubbles (stock prices, house prices, ~~and the~~ real effective exchange rate), and external debt measures (scheduled amortization, ~~and~~ cross-border interbank debt).
- EMPEs in emerging market economies, by contrast, are better predicted by machine learning techniques, implying that interactions between variables help sort through the more heterogeneous category of events. The best predictors come from several crisis generations models. External variables, such as reserve adequacy metrics, are complemented by measures of equity outflows that generate depreciations. In addition, fiscal vulnerabilities (EMBI sovereign spread, change in public debt) and competitiveness indicators (cumulative inflation) are highly important.
- EMPEs in advanced economies are well predicted by signal extraction techniques, and the most important predictors are indicators of external debt (private external debt, amortization, and the foreign currency and external shares of public debt).
- EMPEs in low-income countries are sometimes better predicted by signal extraction techniques and sometimes by machine learning, depending on whether foreign currency share data are included. If included, net open foreign currency share measures are important; other important predictors include indicators of first-generation currency crises (cumulative inflation, fiscal vulnerabilities, exchange rate regime), banking system health (share of non-investment-grade debt, capital-to-assets ratio), and—for countries where it is available—stock market overvaluation (price-to-earnings ratio). When foreign currency share data are not available, machine-learning methods deliver superior performance, and, in addition to the above variables, global factors (TED spread, US term premium) are identified as important.

⁴The sample is not balanced, so missing variables are imputed using the machine-learning-based surrogate technique, which involves substituting available variables for variables that are not available. Both signal extraction and machine learning models are estimated with data from 1990 onward. The results are presented for the model that performs best with out-of-sample testing between 2008–17. The variable importance ranking is subject to the following caveats: (1) in machine learning, there may be slight differences in variable importance in different runs owing to random seed effects; (2) using different subsets of variables can alter the ranking between signal extraction and machine learning; and (3) in-sample and out-of-sample variable importance rankings may vary.

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Online Annex 2.1. Additional Details on Empirical Analysis

Data Sources

The chapter studies episodes of external stress for a group of 73 advanced and emerging market and developing economies (see Annex Table 2.1.1). Given data constraints, especially regarding the foreign currency composition of external debt, the period considered is 1991–2018.

Annex Table 2.1.1. List of ~~Countries~~ Economies

Countries Economies	Countries Economies
Argentina	Kazakhstan
Australia	Korea
Austria	Latvia
Bangladesh	Lithuania
Belarus	Malaysia
Belgium	Mexico
Bosnia and Herzegovina	Morocco
Brazil	Netherlands
Canada	New Zealand
Chile	Nigeria
China	North Macedonia
Colombia	Norway
Croatia	Oman
Czech Republic	Pakistan
Denmark	Peru
Dominican Republic	Philippines
Egypt	Poland
El Salvador	Portugal
Estonia	Romania
Finland	Russia
France	Singapore
Georgia	Slovak Republic
Germany	Slovenia
Greece	South Africa
Guatemala	Spain
Hong Kong SAR	Sri Lanka
Hungary	Sweden
Iceland	Switzerland
India	Thailand
Indonesia	Tunisia
Ireland	Turkey
Israel	Ukraine
Italy	United Kingdom
Jamaica	United States
Japan	Uruguay
Jordan	Venezuela
	Vietnam

plotted in Figure 2.3, thus capture how much the movement of the variable is associated with the external stress episode.

Probit Estimates: Results and Robustness

Estimation Results

A pooled probit model is used to study the likelihood of external stress episodes. The setup is similar to Catão and Milesi-Ferretti (2014). The independent variables can be placed in three groups: (1) IIP components for each country, (2) macroeconomic variables for each country, such as the current account balance, the real exchange rate gap (measured as deviations of the real exchange rate from the average of the previous five years), the credit gap (also measured as deviations from the credit-to-GDP ratio from the average of the previous five years), the level of financial development and income per capita relative to the United States (including in the form of an interaction term), and (3) a global risk variable (captured by the VXO, an indicator similar to the Chicago Board Options Exchange Volatility Index [VIX] but with longer time series). The first two categories are lagged by one year to control for endogeneity.

Robustness

The main findings are robust to alternative specifications of the probit baseline regression, which involves (1) changes in country sample (to exclude oil exporters), (2) changes in the definition of stress episodes (to exclude consecutive years; ~~and IMF Flexible Credit Line~~ different types of IMF arrangements; and to include Spain's European Stability Mechanism program), (3) inclusion of additional controls (to consider the exchange rate regime, capital account openness, and terms-of-trade changes), (4) alternative estimation techniques (logit model), and (5) winsorizing all the independent variables to account for outliers (1 percent from both tails). The results are also robust when only large crises (same as the baseline definition, but with IMF loans greater than 200 percent of quota) are considered (Catão and Milesi-Ferretti, 2014). In addition, the results are robust to excluding large financial centers such as Iceland and Ireland from the sample. In fact, the exclusion of Iceland makes the coefficients for foreign-currency-denominated debt liabilities stronger than that of the entire sample. All these results are generally robust both for the full sample as well as the emerging markets and developing economies sample.

The baseline regressions do not address what is referred to as “potential postcrisis” bias in the literature (Bussiere and Fratzscher 2006) related to the distinction between tranquil periods (economic fundamentals are sound and sustainable) and stress/poststress periods (economic variables go through an adjustment process before reaching a sustainable level). To address these concerns, many studies have adopted various methodologies for approximations, each with important advantages and disadvantages. When incorporating these considerations using various