FEATURE ARTICLE

Introducing a Framework to Measure Resilience of an Economy[1]

by Francis Lau, Sunny Yung and Ivy Yong of the External Department

There has been much research over the years into developing and refining systems that have the capability of predicting more accurately the likelihood of financial crises. The research has gathered momentum in the wake of the Asian financial crisis of the late 1990s.

The emphasis of such work has centred on the development of advanced "early warning systems" (EWS) using "behaviour patterns" in an economy to judge whether a crisis is about to happen, generally from the movements of particular economic and financial indicators. But there are limitations, and finding a system will not be easy as no two crises are the same.

Now, researchers from the Hong Kong Monetary Authority, are in the preliminary stage of developing a conceptual framework to measure the resilience of an economy. This concept will be useful in complementing the early warning systems. The major difference between the resilience framework and EWS is that it does not aim to predict crises, but rather to assess the current state of health of an economy and hence its ability to withstand financial shocks should they occur.

INTRODUCTION

In the aftermath of the Asian financial crisis (1997-98), international financial institutions, central banks and academics have been involved in a great deal of research into developing forward-looking early warning systems (EWS) for predicting the likelihood of future financial crises. An EWS usually involves the use of a consistent framework to analyse high-frequency macro-prudential indicators. Experience so far suggests there are limitations to the predictive power of most EWS.[2] It is generally acknowledged that predicting future financial crises is not easy, given that no two crises are the same in terms of the factors leading to the crisis, the volatility and dynamics of financial markets, the scale of contagion and the magnitude of the damage inflicted on economies. As markets become more globalised, it will be increasingly difficult to isolate the impact of external events on the domestic economy. In view of these difficulties, there may be merit in developing models that can assess the level of resilience of an economy to withstand external shocks to supplement the EWS.

[1] The authors wish to express their sincere thanks to Professor N. H. Chan and Dr H. Y. Wong, both from the Department of Statistics, Chinese University of Hong Kong, for their suggestions to apply the CART approach and the Mamdani-type fuzzy logic system in the development of the resilience framework. Excellent technical support was provided by Kevin Chow of the Research Department of the HKMA and Lam Yu Fung, Tony Wong and Sam Hui of the Chinese University of Hong Kong.

[2] The early warning systems (EWS) so far developed have a mixed record of predicting capability. For example, while the two IMF core EWS (i.e. the Developing Country Studies Division Model and the Modified Kaminsky, Lizondo and Reinhart Model) correctly predicted that a crisis was impending in Turkey one year before it occurred in February 2001, the models did not issue any warning signals for the January 2002 crisis in Argentina. See IMF, (2002) "*Global Financial Stability Report*", *Washington DC, pp.48-64*.

The Hong Kong Monetary Authority (HKMA), in collaboration with the Chinese University of Hong Kong, has developed a preliminary conceptual framework on resilience indicators to measure the resilience of an economy. In the following sections, we will discuss a range of issues related to the framework on resilience indicators, including the conceptual differences between the resilience framework and EWS; details of the resilience framework; advantages and limitations of the framework; and selected country case studies.

CONCEPTUAL DIFFERENCES BETWEEN THE RESILIENCE FRAMEWORK AND EWS

The major difference between the resilience framework and EWS is that a resilience framework does not aim to predict crises, but rather to assess the current state of health of an economy and hence its ability to withstand financial shocks should one occur. The concept of EWS is based on the premise that an economy and its financial markets would behave differently prior to an imminent financial (banking, currency or debt) crisis. The "abnormal" behaviour has a systemic and recurrent pattern, which is discernible. Therefore, one could judge whether a crisis is about to happen from the movements of particular economic and financial indicators.

The concept of resilience is different. Measuring resilience does not involve anticipating when financial shocks will emerge. In the context of economic and financial systems, resilience can be interpreted as a measure of the ability of a system to remain stable (without undergoing catastrophic changes in its basic functioning) in the event of financial shocks. In other words, the less resilient an economy is, the greater the chance the economy will change from the current state to another state. Batabyal explained that the concept of resilience was based on the hypothesis that different states of a system involve different equilibria.[3] It is believed that if a system is resilient, it should be able to cope with new challenges and sudden qualitative shifts. The resilience concept has been receiving considerable attention in economic-ecological modelling over the past decade, although the concept has not been widely applied to financial market studies.[4] This article is one of the few attempts to actually apply the concept of resilience to financial markets.

In terms of the indicators used, EWS tends to focus on high-frequency market data. Indicators commonly used in EWS include (i) financial market data such as interest rates, exchange rates and equity prices; (ii) monetary aggregates, such as growth in money supply, loan and deposits; (iii) capital flow data, such as foreign direct investment flows, portfolio and other investment flows, imports and exports, and current account balance; and (iv) basic macroeconomic data, such as real output, government budgets and official foreign exchange reserves.

On the other hand, as resilience framework aims at assessing the soundness of the economic and financial systems at a particular point in time, it tends to focus on stock variables, such as the ratio of international reserves to short-term external debt, fiscal reserves or outstanding public debt, and net international investment positions. The system puts less emphasis on data that reflect market stress, such as market pressure on exchange rates and interest rates, as these tend to be highly volatile and contain too much "noise", making it difficult to conduct meaningful analyses.

A RESILIENCE FRAMEWORK

The basic conceptual framework on resilience indicators comprises the assessment of resilience of five key sectors in an economy — external, public, banking, corporate and household. The framework also includes an assessment on the degree of restriction on capital flows moving into and out of an economy, as this affects the resilience of the economy to speculative short-term capital flows.

[3] Levin et al (1998). Resilience in Natural and Socioeconomic Systems, *Environment and Development Economics*, Vol. 3, pp. 222-235.

[4] See Batabyal, A. (1998) The concept of Resilience: Retrospect and Prospect, *Environment and Development Economic*, Vol. 3, pp235-239.

In each of the sectors, three to five key indicators are selected that reflect the level of resilience of the sector. Most of the indicators are developed from the financial soundness indicators (FSI) recommended by the IMF[5], but we have also included new indicators in the framework. For example, we have included a "net international investment position" indicator in the external sector. The other four indicators in the sector are "export growth", "current account balance", "capital and financial account balance" and "short-term external cover". The indicators in the five sectors in our framework are listed in Appendix I. The basic idea of the resilience framework is to classify the resilience level of each of the five sectors at a particular point in time according to the value of observations on a scale of 1 to 5. A resilience score of "5" denotes a state of strongest resilience, while a score of "1" denotes a state of least resilience.

To illustrate the technical process of developing the resilience framework, we will use the external sector as an example. The process can be divided into three major steps:

Step 1: This involves the conversion of the values of data of the respective indicators into probability-weighted "strong" and "weak" signs using the 20%-80% rule. A detailed description of the conversion process is at Box 1. After the conversion, there will be a combination of "strong" and "weak" signs for each observation.[6] For example, the external sector has five indicators, so an observation of the sector will be converted into a combination of five "strong" and "weak" signs.

Box 1: Converting raw data into probability-weighted "strong" and "weak" signs

We first arrange the data series for each of the five indicators in the external sector in ascending order. We then identify the 80th percentile data (i.e. the 80th highest value in a series of 100 data) and the 20th percentile data in the series. For example, the 20th percentile value in the data series of "current account balance as a percentage of GDP" is "-1.9%" while the 80th percentile value is "+2.8%".

We regard a data point with value "+2.8%" or more as a "strong" sign, and hence the probability of it being a "strong" sign is 100% and the probability of it being a "weak" sign is zero. We regard a data point with value "-1.9%" or less as a "weak" sign, and hence the probability of it being a "weak" sign is 100% and the probability of it being a "strong" sign is zero.

For a data point with value between the two percentile values, a probability will be assigned to the data for it to be a "strong" sign, depending on how close is the value from the two percentile values and the distribution of the data series. For example, in the data series of "current account balance as a percentage of GDP", a data with a value of "+0.5%"is assigned a 50% probability of it being regarded as a "strong" sign and a 50% probability of it being regarded as a "weak" sign.

Step 2: We first construct a decision matrix to assign rating scores to all 32 possible combinations of the "strong" and "weak" signs of the five indicators in the external sector. The decision matrix for the external sector is at Appendix II. A rating score of "1" to "5" is assigned to each combination of "strong" and "weak" signs. For example, a combination of five "strong" signs will be assigned a rating score of "5", while a combination of five "weak" signs will be assigned a rating score of "1". For combinations that have one to four "strong" signs will be assigned a rating score between "2" and "4", depending on the number of "strong" signs and whether the "strong" signs are shown in the more important indicators. By determining the rating scores to be assigned to each

[5] For a detailed discussion of financial soundness indicators, see *"Financial Soundness Indicators: Analytical Aspects and Country Practices"*, V. Sundararajan et al, IMF Occasional Paper 212.

[6] An observation comprises the data values of the indicators for a sector at a particular point in time.

combination, the decision matrix construction process allows us to incorporate our professional judgement on the relative importance of various indicators in assessing the resilience level of the sector. Based on the results obtained from step 1 and the rating scores for the possible combinations of "strong" and "weak" signs of the data points as listed out in the decision matrix, we then calculate the resilience score of each observation. A detailed description on the calculation of the resilience scores is at Box 2.

Box 2: Calculating the resilience score of an observation based on the combination of "strong" and "weak" signs

To simplify the case for illustration purposes, let us assume that we have only two indicators (instead of five) in the external sector: "export growth" and "current account balance as % of GDP". The "strong" and "weak" threshold values for "export growth" are ">10%" and "<2%"; and those for "current account balance as % of GDP" are "> 5%" and "<-2%". Suppose we have an observation in which "export growth" is 8% and "current account balance as % of GDP" is 0%. Following the procedures in Box 1, the export growth data of 8% is assigned a 75% probability for it to be regarded as a "strong" sign, and the current account balance data of 0% is assigned a probability of 29% for it to be regarded as a "strong" sign.

	Value	Probability	
		"Strong" Sign	"Weak" Sign
Export Growth	8%	0.75	0.25
Current Account Balance	0%	0.29	0.71

There are four possible combinations of "strong" and "weak" signs for the two data points, and suppose the rating scores to be assigned according to the decision matrix to the four combinations of strong and weak signs are as follows:

	Export Growth	Current Account Balance	Rating Score
1	Strong	Strong	5
2	Strong	Weak	3
3	Weak	Strong	2
4	Weak	Weak	1

The Mamdani-type fuzzy logic system[7] is then applied to the combinations to arrive at an overall resilience score. The process involved is summarised below:

Export Growth	Current Account Balance	Rating Score	Possibility of Triggering
Strong	Strong	5	Min [0.75,0.29] = 0.29
Strong	Weak	3	Min [0.75,0.71] = 0.71
Weak	Strong	2	Min [0.25,0.29] = 0.25
Weak	Weak	1	Min [0.25,0.71] = 0.25

The resilience score is the sum of the probability weighted rating scores of the four combinations, that is,

$(5 \times 0.29 + 3 \times 0.71 + 2 \times 0.25 + 1 \times 0.25) / (0.29 + 0.71 + 0.25 + 0.25) = 2.9$

In this case, the data observation will be assigned a resilience score of "3".

[7] While a detailed description of the Mamdani-type fuzzy logic system is beyond the scope of this paper, readers who are interested can refer to the following papers: (1) *"An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller"*, E. H. Mamdani and S. Assilian (1975), International Journal of Man Machine Studies; and (2) *"Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Systems"*, E. H. Mamdani (1977), IEEE Transactions on Computers.

Step 3 After assigning resilience scores of "1" to "5" to all observations, we can then use the Classification and Regression Tree (CART) approach to generate decision rules through which resilience scores will be assigned to the observations such that the number of observations falling into the five score groups of "1" to "5" will match as much as possible the number of observations we originally classified into the groups in step 2. The final product of the CART process is a decision tree, which will be used for assigning resilience scores to future observations.

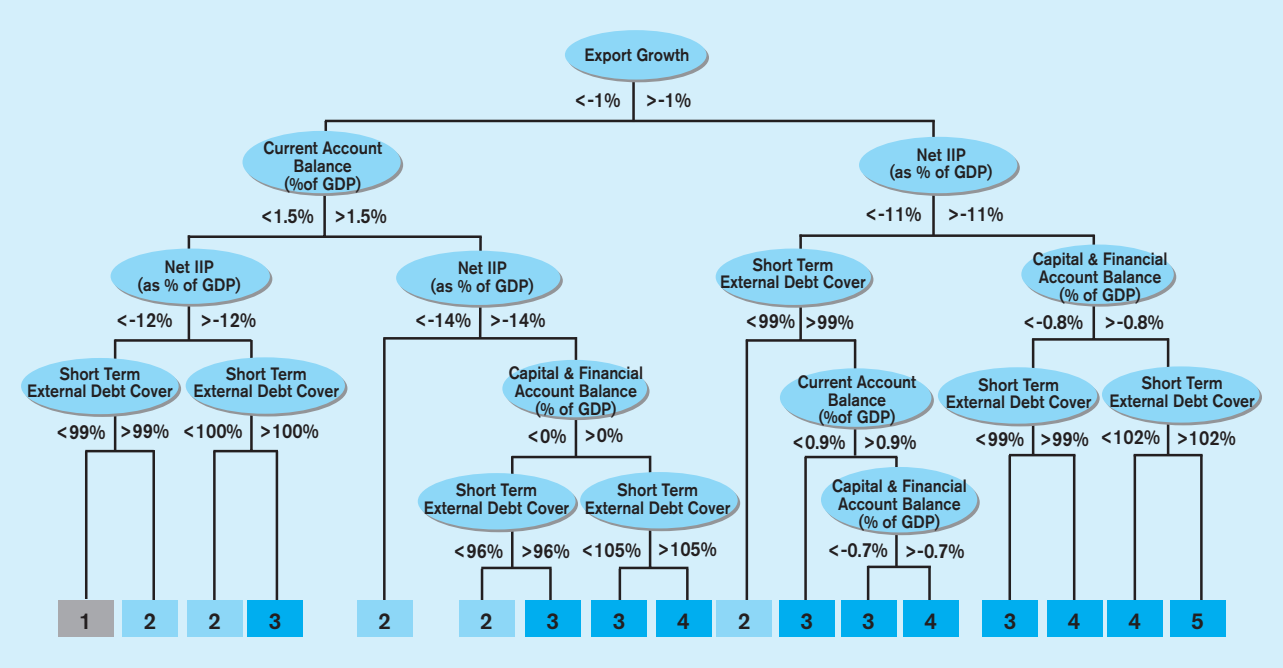
Since the result of assigning scores under the CART approach closely matches that of step 2, the decision tree generated by the CART process is, in effect, analysing and showing the decision process we have used in constructing the decision matrix. By looking at these rules, we can review the logical consistency of the resilience score process. If there are self-conflicting decision rules, we will need to modify the decision matrix to eliminate such inconsistency. The CART approach also has the advantage of facilitating future resilience assessment. We can assign scores to new data as they come in by passing the data through the decision tree, thus saving the trouble of going through the entire score assignment process again from step 1.

OBSERVATIONS FROM THE DECISION TREES

Due to the limitation on data availability, we have only developed the framework to assess the resilience of the external and the fiscal sectors of selected economies. We have calculated the probability-weighted scores of data collected from 28 economies on the five resilience indicators in the external sector and the three indicators in the fiscal sector between 1990 and 2001.[8] We have generated two decision trees for the external sector (Chart 1) and the public sector (Chart 2). The major observations from the two decision trees are highlighted below.

CHART 1

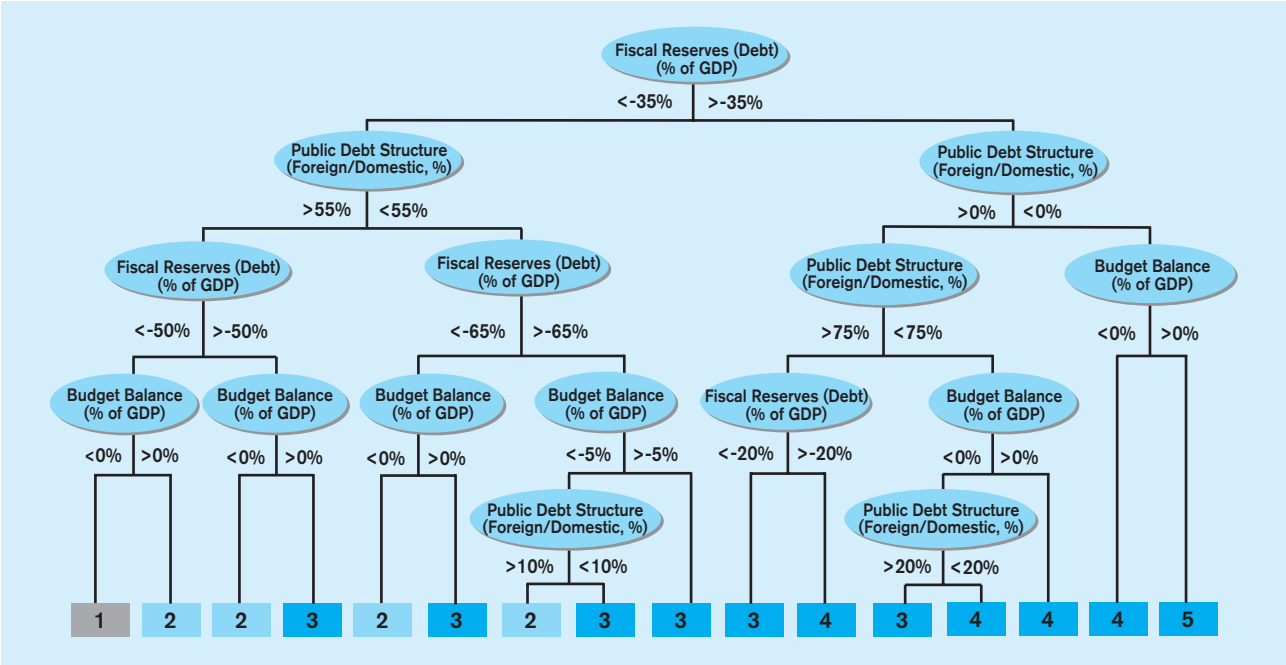
Decision Tree of External Sector for Assigning Resilience Ratings



[8] The 28 economies are Argentina, Australia, Brazil, Canada, Chile, France, Germany, Hong Kong, Hungary, India, Indonesia, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Philippines, Poland, Russia, Singapore, South Africa, Sweden, Switzerland, Thailand, Turkey, UK, and US. We have collected 729 quarterly data for each of the five indicators in the external sector (all together 3,645 data points) and 280 annual data for each of the three indicators in the fiscal sector (all together 840 data points).

CHART 2

Decision Tree of Public Sector for Assigning Resilience Ratings



External Sector

The indicator "Net International Investment Position (IIP)" is an important factor in assessing the resilience of the external sector, as it is an indication of an economy's stock of wealth. While a negative IIP does not necessarily suggest high vulnerability, a strong IIP will suggest a large cushion to absorb financial shocks. "Export growth" is also a significant factor in determining external sector resilience as reflected by the fact that the indicator appears at the top of the decision tree. It provides an indication of the income flow into an economy.

The indicator "Short-Term External Debt Cover" emerged as another important indicator for assessing the resilience of the external sector, as reflected by the number of times it appeared. This indicator is crucial as it reflects an economy's ability to repay short-term external obligations, especially in times of financial shocks.

Public Sector

The indicator "fiscal reserves or debt" is the most important factor in assessing the level of resilience of the public sector, as the indicator not only appears at the top of the decision tree but also at various points on the tree. The indicator "public debt structure" (defined as the ratio of public sector foreign currency debt to public sector domestic debt) is the next most important indicator of public sector resilience. Many governments have used foreign currency debt to finance their fiscal deficits. A large foreign currency debt composition would exert high pressure on the government's foreign reserves if it were asked to repay the debt in a crisis situation.

The indicator "budget balance" appears to be less important because it is common for governments to run budget deficits. Nevertheless, governments that persistently run large budget deficits will see their level of resilience gradually eroded.

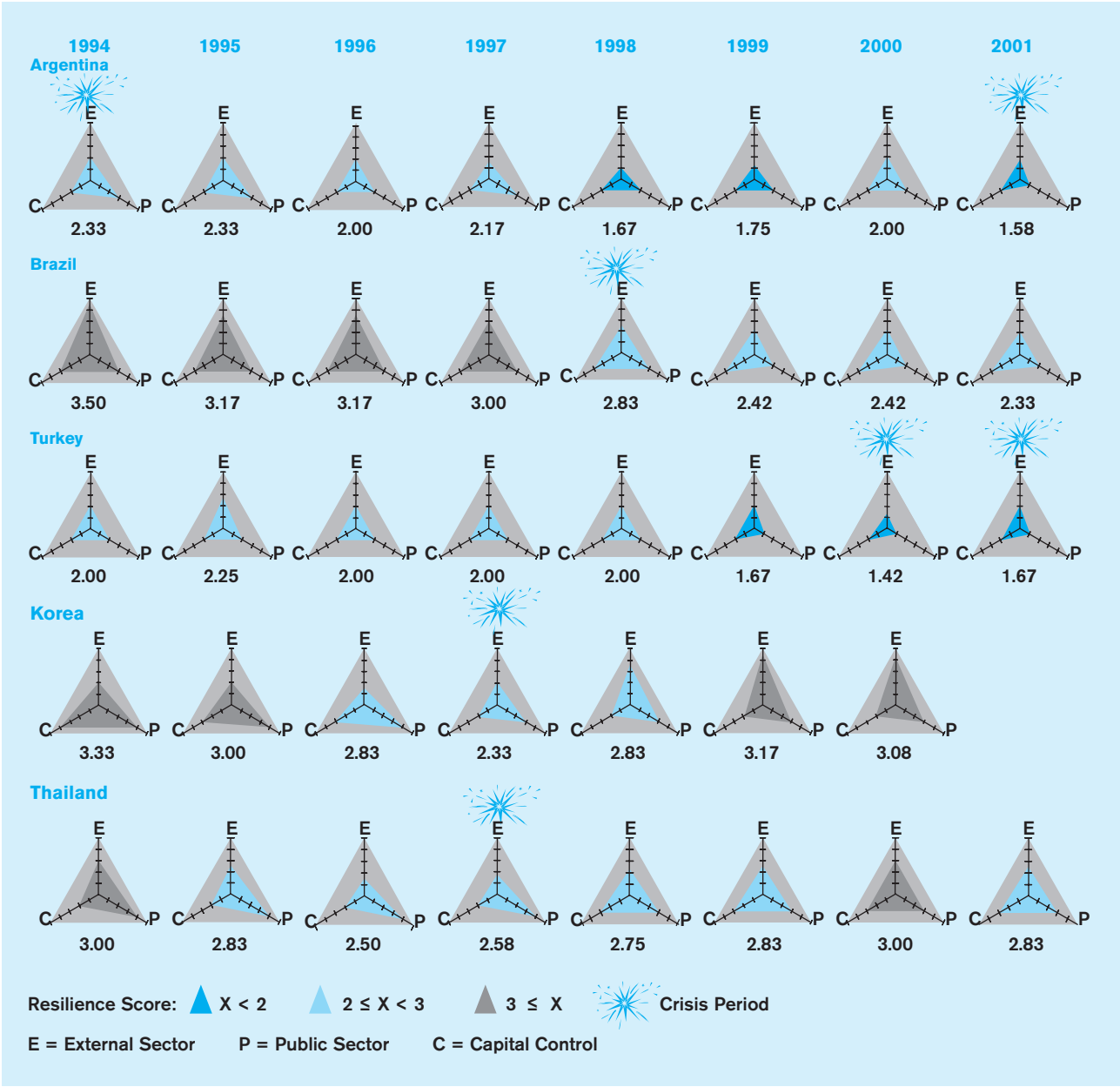
SELECTED COUNTRY CASE STUDIES

We have applied the above resilience framework to assess the resilience level of the external and fiscal sectors of a number of emerging market economies in Asia and Latin America. We have also included the degree of restrictions on foreign exchange transactions and capital mobility as a third dimension to the framework, based on information published in

the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. An overall resilience score was calculated using the arithmetic mean of the resilience score from each of the three dimensions (i.e. the external sector, the fiscal sector and the degree of capital restriction). The initial results are satisfactory. All crisis-hit economies had a very low level of resilience in the years before or during the year when crises hit. For example, the overall resilience scores of Argentina, Mexico and Turkey have been consistently below "3". The outcome indicated that the scores accurately reflected the deteriorating resilience of the country entering a crisis. Similar situations were observed in a number of Asian economies during the Asian financial crisis. The results also indicated improvements in the resilience level of some Asian economies in recent years. The sample results are illustrated in Chart 3.

CHART 3

Country Charts – Resilience Scores



ADVANTAGES AND LIMITATIONS OF THE RESILIENCE FRAMEWORK

Unlike some EWS models that provide users with a set of signals, which may not be easy to interpret, we have distilled the many indicators of the resilience framework into a single score. While this may oversimplify the interpretation, our model has the advantage of being easy to comprehend and interpret because the final resilience score provides a clear indication of the state of health of an economy at a certain point in time, as well as the change in the state of health over time. The breakdown by economic sector can also give a clear picture of the pressure points in the economy. In addition, the standardised framework allows for international comparisons to be made of resilience levels for different economies.

There are, however, a number of caveats for using the resilience framework. First, some information may be lost in the process of translating the data on the various indicators into a single resilience score. Secondly, there may be limited scope for incorporating country-specific factors, and a good balance will need to be struck between the attempt to reflect a true picture of an economy by adding more country-specific factors and to allow international comparability by having a standard set of factors. Thirdly, the CART approach adopted by the resilience framework requires a huge amount of data in order to generate meaningful and robust decision trees.

FUTURE WORK

The development of the resilience framework is still at a very preliminary stage, but our study so far has suggested that this could be a useful framework to complement the EWS. Individual economies can refine the framework to make it more applicable to their own economy by adding in more indicators, especially in the household and corporate sectors, or adjusting the relative weight of indicators. The technical aspects can also be improved to enhance the ability of the framework to assess the resilience of individual economies.

APPENDIX I

RESILIENCE INDICATORS

Sector	Indicators
External	▪ Export Growth[9] ▪ Current Account Balance ▪ Capital and Financial Account Balance ▪ Short-term External Debt Cover[10] ▪ Net International Investment Position (IIP)
Public	▪ Fiscal reserves position or total outstanding fiscal debt (as percentage of GDP) ▪ Budget balance ▪ Public debt structure[11]
Banking	▪ Capital adequacy ratio ▪ Loans to deposit ratio ▪ Ratio of non-performance loans total loans ▪ Domestic credit growth in real terms ▪ Return on assets
Corporate	▪ Debt to equity ratio ▪ Return on assets ▪ Ratio of current assets to current liabilities
Household	▪ Ratio of household indebtedness to disposable income ▪ Ratio of household indebtedness to wealth ▪ Ratio of loan to collateral value (particularly useful for mortgage loan)

[9] In order to minimise seasonal fluctuations in the export growth data, this indicator is calculated by subtracting the average export growth for the most recent four years from the average export growth for the most recent year.

[10] The short-term external debt cover is expressed as foreign exchange reserves divided by stock of short-term external debt.

[11] Public debt structure is expressed as foreign currency denominated debt divided by domestic currency denominated debt.

APPENDIX II

DECISION MATRIX FOR ASSIGNING RATING SCORES TO VARIOUS COMBINATIONS OF "STRONG" AND "WEAK" SIGNS OF THE INDICATORS IN THE EXTERNAL SECTOR

Resilience Indicators					
Export Growth	Current Account Balance	Capital & Financial Account Balance	Short-term External Debt Cover	International Investment Position	Rating Scores Assigned#
W	W	W	W	W	1
W	S	W	W	W	1
W	W	S	W	W	1
W	W	W	S	W	2
W	W	W	W	S	2
W	W	S	W	S	2
W	W	S	S	W	2
W	S	S	W	W	2
W	S	W	S	W	2
W	S	W	W	S	2
S	W	W	W	W	2
S	S	W	W	W	2
S	W	S	W	W	2
W	W	W	S	S	3
S	W	W	W	S	3
S	W	W	S	W	3
S	S	S	W	W	3
W	W	S	S	S	3
W	S	W	S	S	3
W	S	S	W	S	3
W	S	S	S	W	3
S	W	S	S	W	3
S	W	S	W	S	3
S	S	W	S	W	3
S	S	W	W	S	3
S	W	W	S	S	4
W	S	S	S	S	4
S	W	S	S	S	4
S	S	S	W	S	4
S	S	S	S	W	4
S	S	W	S	S	5
S	S	S	S	S	5

Note: "S" represents a "strong" sign and "W" represents a "weak" sign

Rating scores range from "1" (least resilience) to "5" (strongest resilience).