Cambridge Centre for Risk Studies

Cambridge Risk Framework

Asset Bubble Collapse Stress Test Scenario

GLOBAL PROPERTY CRASH STRESS TEST SCENARIO

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1 Executive Summary

Typically, an asset bubble is only recognised as and when it bursts, with prices dropping rapidly and substantially. In this scenario we describe an asset bubble collapse that is caused by inflated global real estate asset prices. It is one of four Financial Catastrophe scenarios completed in this series of stress test scenarios.

Stress tests are shown to be an effective tool for understanding cause and effect relationships and for understanding risk exposure across a spectrum of extreme shocks, such as those proposed in the Cambridge Taxonomy of Threats, encompassing five classes of business risk.[1] A suite of scenarios can be used as a basis for testing against vulnerabilities and improve resilience.

Global Property Crash

Many of the countries around the world are also thought to be in the midst of a looming housing bubble collapse.[2]

The Global Property Crash Scenario describes a property bubble that is triggered in the emerging boom markets of South East Asia and propagates across continents as investors and banks lose faith in global property markets. Following the housing market collapse in India and China the contagion spreads and affects both mortgage and non-mortgage asset prices in Asia Pacific, Scandinavia, Europe and beyond.

The economic impact causes a worldwide recession lasting from one year to eighteen months across the different scenario variants. The overall loss, expressed as lost global Gross Domestic Product (GDP) compared with the projected baseline economic output over a five year period ("GDP@ Risk"), is estimated as being between $13.2 and $19.6 trillion, depending on the variant of the scenario. The Great Financial Crisis of 2007-2011, comparatively, saw a loss of $20 trillion in 2015 dollar estimates.

A context for financial catastrophe

Scenario selection

Our research shows the frequency of market based catastrophes has increased with globalisation. Between 1700 and 1900 the average time between crises was 21 years; since 1960, the interval has shrunk to eight years.[3] Economic interconnectivity plays a key role in the severity and the spread of contagion from bursting asset bubbles.

The Global Property Crash Scenario depicts the collapse of both mortgage and non-mortgage assets triggered in the emerging and BRICs markets before spreading across the world.

Variants of the scenario

In our 'standard' scenario, S1, the real estate and equity markets are shocked by losses of up to 35% and 10% respectively in a cascade across six separate country groupings: Tier 1 – China & emerging markets; Tier 2 – the Commonwealth; Tier 3 – the Nordics; Tier 4 – the United Kingdom; and Tiers 5 and 6 – Europe. Market sentiment is likewise affected, having an impact across all asset classes, particularly share market equities. In S2, the global property crash extends to include: Tier 7 – the United States; Tier 8 – Prudent Europe and Tier 9 – Industrial Asia. In this variant, the real estate and equity markets shocks are increased by 60 and 12% respectively.

The scale of loss inflicted by the Global Property Crash Scenario has been very roughly calibrated to correspond to an event that happens about once a century on average, a 1-in-100 year event.

Two indicators that may give a sense of the likelihood of a catastrophe scenario occurring are its impact on equity returns and GDP growth rates, which are expected to be negative in the throes of a catastrophe. US (UK) equities over the last two hundred years[4] have experienced return rates below -24% (-13%) about once in twenty years, with return rates below

[1] Cambridge Centre for Risk Studies, "A Taxonomy of Threats for Complex Risk Management", 2014

[2] "In come the waves", The Economist Special report, 16 June 2005

[3] Needham, D., "Historical Catalogues of Financial Catastrophes", presentation at the University of Cambridge, 10 July, 2014

[4] Prior to records from FTSE and S&P, we use surrogate stocks such as those from American railroad stock prices and other constructed indexes. We use similar surrogate data for estimating growth rates prior to the availability of standardised data. Our identification of%iles uses a normal curve fitting which is conservative in light of the fat tails associated with equity price distributions.

-36% (-20%) once in every 100 years (1-in-100). In our scenario variants, those return rates are similar regarding the US, with return rates of -20% for S1 and -40% for S2, and much more dramatic for the UK where the scenario return rates are -70% for S1 and -73% for S2. That is, the US data suggest that an impact at the scale of the Global Property Crash Scenario is more likely than a 1-in-100 year event while in the UK it would appear to be much less likely from an historical perspective.

The historical record of economic growth in the US (UK) shows growth rates below -7% (-3%) as 1-in-20 year events, and rates below -13% (-5%) as 1-in-100 year events. In S1 and S2 those rates are calculated as -1% and -4% for the US, and -6.0% and -8.3% for the UK. Again the impact level of a Global Property Crash Scenario seems more likely than a 1-in-100 event in the US and less likely than a 1-in-100 event in the UK.

This is a stress test, not a prediction

This report is one of a series of stress test scenarios that have been developed by the University of Cambridge Centre for Risk Studies to explore management processes for dealing with extreme shocks. It does not predict when a catastrophe may unfold. It does however provide insight into the types of exposure that may be experienced if a similar catastrophe were to occur.

A cascade of bursting property bubbles

The bubble bursts

The trigger for this financial catastrophe is the collapse of investor confidence in the property markets of South East Asia's emerging economies. This triggers a regional shift in investor behaviour which collapses the property markets in China and India.

Financial tsunami across the Pacific

The bursting property bubble in China ripples through international financial and banking systems. It arrives first in Australia, and then travels across to New Zealand and Canada.

Contagion goes global

The next casualty is the Nordic property markets, with economists identifying the bursting bubble as a "global collapse". The UK housing market crashes and property prices plummet across Europe. Within a year of the property collapse the IMF declares a global recession. Quarterly global GDP growth rates reach a low of by -1.5%. Commodity prices fall by over 20%, putting many economies into a deflationary spiral.

Global GDP impact

In macroeconomic terms, the Global Property Crash Scenario induces shocks to inflation, short term interest rates, equity indices, country credit ratings, and GDP growth rates. We estimate the effects of these shocks on the world economy using the Global Economic Model (GEM) of Oxford Economics'. In particular we determine the cumulative loss to global gross domestic product over a 5 year period, dubbed "GDP@Risk". Nations with a relatively higher proportion of government debt, coupled with highly inflated property markets experience the most severe economic consequences.

This scenario attributes more than half of total GDP losses to the US and European economies, and creates a deep global recession lasting up to six quarters. The S1 variant has a global GDP@Risk of US$13.2 trillion, while the S2 variant has a global GDP@Risk of 19.6 trillion.

A caveat is that this analysis via the GEM does not account for extraordinary intervention by national governments to stabilise their real estate, equity, or banking markets. Thus the GDP@Risk figures can be viewed as an assessment of fundamental economic losses that could otherwise be masked by governments, whose actions would postpone or spread economic losses over a longer period without restoring the cumulative lost value.

Financial portfolio impact

We estimate the portfolio impacts of this scenario by modelling the outputs from OEM on portfolio returns, projecting market changes and cash flows while keeping the value of asset allocation fixed. We default all corporate bonds and residential mortgage backed securities (RMBS) given by the 2008 default rates.

Interestingly, the S1 scenario begins to recover after three years, while the S2 variant does not recover over the five year modelling period. The maximum downturn experienced for the conservative portfolio in the S1 variant occurs in Yr1Q4 with a decline of 15.4% . The worst performing equities are UK stocks (FTSE-100), while the best performing equities are German stocks (DAX). The worst performing fixed income bonds are Japanese bonds while US bonds perform the best. The worst performing portfolio structure is the aggressive portfolio with a decline of -22.5% in the S1 variant.

Risk management strategies

Scenarios as stress tests

This scenario is an illustration of the risks posed by social unrest triggered by catastrophic event. The Global Property Crash scenario is just one example of a wide range of scenarios that could occur.

Summary of Effects of Global Property Crash Scenario and Variants				
Scenario Variant	**S1**		**S2**	
Variant Description	Standard Scenario		Scenario Variant	
Affected Property Markets	Tiers 1 - 6		Tiers 1 - 9	
Housing Price Shock	20 – 30%		25 – 60%	
Equity Price Shock	5 – 8%		5 – 12%	
Market Confidence Shock	30 – 50		30 – 70	
Macroeconomic losses				
Global recession severity (Minimum qtrly growth rate global GDP)	-3.5%		-4.7%	
Global recession duration	4 Qtrs		6 Qtrs	
GDP@Risk $Tr (5 year loss of global output)	$13.2 Trillion		$19.6 Trillion	
GDP@Risk % (as % of 5-year baseline GDP)	3.3%		5.0%	
Portfolio Impact				
Performance at period of max downturn				
High Fixed Income	-7%		-7%	
Conservative	-15%		-23%	
Balanced	-19%		-28%	
Aggressive	-23%		-33%	
Asset class performance				
	Yr1Qr4	**Yr3Qr4**	**Yr1Qr4**	**Yr3Qr4**
US Equities (W5000), % Change	-20%	4%	-39%	-36%
UK Equities (FTSE100), % Change	-72%	-43%	-73%	-49%
US Treasuries 2yr Notes, % Change	0%	3%	0%	5%
US Treasuries 10yr Notes, % Change	2%	15%	2%	17%

Table 1: Summary impacts of the Global Property Crash scenario

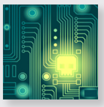
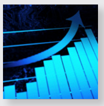
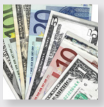
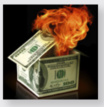
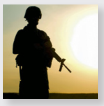
		Trillion US$ GDP@Risk across scenarios		
		S1	S2	X1
	**Millennial Uprising** Social Unrest Risk	1.6	4.6	8.1
	**Dollar Deposed** De-Americanization of the Financial System Risk	1.9	1.6	-1.6
	**Sybil Logic Bomb** Cyber Catastrophe Risk	4.5	7.4	15
	**High Inflation World** Food and Oil Price Spiral Risk	4.9	8	10.9
	**Sao Paolo Influenza Virus** Pandemic Risk	7	10	23
	**Eurozone Meltdown** Sovereign Default Risk	11.2	16.3	23.2
	**Global Property Crash** Asset Bubble Collapse Risk	13.2	19.6	
	**China-Japan Conflict** Geopolitical War Risk	17	27	32
	2007-12 Great Financial Crisis	18		
	Great Financial Crisis at 2014	20		

Table 2: GDP@Risk impact of the Global Property Crash scenario compared with previous Centre for Risk Studies stress test scenarios

2 Financial Catastrophe Stress Test Scenarios

This scenario is an illustration of the risks posed by a plausible but extreme financial market based catastrophe. It represents just one example of such a catastrophe and is not a prediction. It is a "what-if" exercise, designed to provide a stress test for risk management purposes by institutions and investors wishing to assess how their systems would fare under extreme circumstances.

This scenario is one of a series of stress test scenarios developed by the Centre for Risk Studies to explore the management processes for dealing with an extreme shock event. It is one of four financial market catastrophe scenarios being modelled under this work package and includes the following:

- Dollar Deposed: De-Americanisation of the Global Financial System;
- High Inflation World: Food and Oil Price Spiral;
- Eurozone Meltdown: Sovereign Default Crisis.

The scenarios present a framework for understanding how global economic and financial collapse will impact regions, sectors and businesses throughout the networked structure of the economy. These financial stress tests aim to improve organisations' operational risk management plans to form contingencies and strategies for surviving and minimising the impacts from market-based financial catastrophe. In particular, the stress tests allow institutions to manage and build resilience to different forms of risk during periods of financial stress.

These risks include:

- financial and investment risk stemming from a collapse in asset prices across different sectors and regions;
- supply chain risk and the ability of an institution to effectively manage its input requirements through its supply chain, to meet internal production and operational requirements;
- customer demand risk and knowledge for how demand might shift for goods and services during periods of low investment and consumer spending;
- market or segmentation risk and an understanding of how other firms within the same sector will react and perform during periods of financial stress and how this may impact on the business;
- reputational risk and the protection of brand image for reacting appropriately and confidently under crisis conditions.

Each individual scenario may reveal some aspects of potential vulnerability for an organisation, but they are intended to be explored as a suite in order to identify ways of improving overall resilience to unexpected shocks that are complex and have multi-faceted impacts.

Market catastrophe risk and financial contagion

The Great Financial Crisis of 2007-8 not only revealed the extent to which the global financial system is interconnected but how interrelationships between commercial banks, investment banks, central banks, corporations, governments, and households can ultimately lead to systemic instability. As global financial systems become increasingly interconnected, a shock to one part of the system has the potential to send a cascade of defaults throughout the entire network.

In 2008, it was only through government intervention in the form of extensive bailout packages that a widespread collapse of the global financial system was avoided. New models of the global financial system are an essential tool for identifying and assessing potential risks and vulnerabilities that may lead to a systemic financial crisis.

The literature identifies three types of systemic risk: (i) build-up of wide-spread imbalances, (ii) exogenous aggregate shocks and (iii) contagion (Sarlin, 2013). Similarly we work with three analytical methods that help deal with decision support: (i) early-warning systems, (ii) macro stress-testing, and (iii) contagion models. All three methods are actively under research in the Centre for Risk Studies and utilised in the development of these stress test scenarios.

Understanding financial catastrophe threats

This scenario explores the consequences of a financial market catastrophe by examining the notional 1-in-100 possibility for a High Inflation World Scenario and examining how the shock would work through the system.

For a process that truly assesses resilience to market catastrophe, we need to consider how different market-based catastrophes occur and then propagate these shocks through global financial and economic systems. This exercise would ideally include a thorough analysis for each different type of market catastrophe in addition to the four financial catastrophes included in this suite of stress tests.

Such an analysis would also include a range of different severities and characteristics for these scenarios would occur as a result of these different financial and economic crises.

The Cambridge Risk Framework attempts to categorize all potential causes of future shocks into a "Universal Threat Taxonomy." We have reviewed more than a thousand years of history in order to identify the different causes of disruptive events, collating other disaster catalogues and categorization structures, and researching scientific conjecture and counterfactual hypotheses, combined with a final review process. The resulting Cambridge taxonomy catalogues those macro-catastrophe threats with the potential to cause damage and disruption to a modern globalised world. The report *Cambridge System Shock Risk Framework: A taxonomy of threats for macro-catastrophe risk management* (CCRS, 2014) provides a full description of the methodology and taxonomy content.

Within this universal threat framework we have developed a specified taxonomy for financial catastrophes. This can be seen in Figure 1 and includes a list of seven unique financial, market and economic catastrophes. A large economic or financial catastrophe seldom affects just one part of the system.

The historical record shows that multiple market catastrophes tend to occur at the same time and impacts cascade from one crisis to the next. The recent Great Financial Crisis (GFC) is one example of this. The financial crisis started in the US as a sub-prime asset bubble but quickly spread to the banking sector where many major banks were left holding assets worth much less than had originally been estimated. The complicated nature of the various financial derivatives that were being sold made it difficult for traders to understand the true underlying value of the asset that was being purchased. This result was a systemic banking collapse that had worldwide implications that still remains to be solved across the globe.

Throughout history there have been many other examples where multiple forms of financial catastrophe have cascaded from one form of crisis to the next, examples include the 1720 South Sea Bubble; 1825 Latin American Banking Crisis; 1873 Long Depression; 1893 Bearing Bank Crisis; 1929 Wall Street Crash and Depression; 1997 Asian Crisis and the 2008 Global Financial Crisis.

Scenario design

Each scenario is selected as a plausible, but not probable, extreme event that is driven by a number of factors and would cause significant disruption to normal lifestyles and business activities.

They are illustrative of the type of disruption that would occur within a particular category of "threat" or "peril" – that is, a cause of disruption.

In this scenario, we explore the consequences of a "Global Property Crash" when housing asset prices begin a sharp collapse in the world's developing markets, generating a contagion which cascades through the global economy.

The analysis estimates losses to the real economy using the OEM to calculate losses in expected GDP output. We have also estimated how the event would impact investment asset values, using standardized investment portfolios to show the effect on indicative aggregate returns.

Investment managers could apply these asset value changes to their own portfolio structures to see how the scenario would potentially affect their holdings. The impacts of the different variants of this scenario are applied to four financial portfolios: high-quality fixed income, conservative, balanced, and aggressive.

Figure 1: Financial catastrophe "FinCat" taxonomy

Role of Cascades in Amplifying Systemic Risk

Different type of shocks, including a significant asset bubble collapse event, could make the financial system vulnerable to risk. A situation where the highly interconnected nature of the financial systems and the amplification mechanisms causes the entire system to stop performing its necessary duties is generally considered a systemic crisis and the risk associated with the failure of the entire financial system is a systemic risk in contrasts to idiosyncratic risk where only a single institution or asset is affected.

Although any sector of the economy may be subject to systemic risk, it is especially relevant for the financial sector, because it is uniquely dependent on the interplay between confidence and network effects. The failure of a single institution quickly spreads to other banks, even if they have been prudently run. The damage caused by even relatively small events in the markets can be amplified into systemic proportions because of the inherent pro-cyclicality in the financial system, perhaps aided by the perverse incentives of market participants [1].

Channels of contagion

Christian Upper[2] characterizes various channels of contagion in the table below. The key channels of contagion can be categorised into direct and indirect effects. The direct effects mostly relate to bilateral exposure of banks within a certain bilateral contractual agreement. These types of exposures will act as a transmission channel in case of default of a single financial institution. These transmission channels form a complex network of exposures and an interconnected financial system.

Direct Impacts	
Interbank lending	Rochet and Tirole (1996)
Payment system	Bech and Garratt (2006), Galbiati et al. (2011)
Security settlement	Northcott (2002)
FX settlement	Blavarg and Nimander(2002)
Derivative exposures	Markose et al. (2012)
Equity cross-holdings	
Indirect Impacts	
Asset prices	Cifuentes et al. (2005), Fecht (2004)

Table 3: Literature sources of the various contagion channels

Why does interconnectedness matter for financial stability?

In a highly interconnected financial system, where banks are connected to each one another both directly and indirectly, stresses in one part of the system are likely to be transmitted to other parts of the system, resulting in a reduction in the aggregate provision of financial services such as lending to the real economy. The greater the degree of interconnectivity between amongst banks, the greater the likelihood that a default by one bank could trigger contagion to other banks. Banks may also be interconnected through indirect channels: for example, fire sales by a distressed bank may lead to falls in asset prices and associated mark-to-market losses for other banks.

[1] J. Danielsson, *Global financial systems: stability and risk*, 2013

[2] C. Upper, "Simulation methods to assess the danger of contagion in interbank markets." *Journal of Financial Stability* 7.3 (2011): 111-125.

Traditional approaches tend not to incorporate such complex dynamics and interconnectedness. Models and tools within modern macroeconomic theory (e.g. 'sophisticated' DSGE models) are hopeless inadequate to deal with such dynamics with regards to predicting or monitoring banking crises.

Developing a coherent scenario

It is a challenge to develop a scenario that is useful for a wide range of risk management applications. Fully understanding the consequences of a scenario of this type is problematic because of the complexity of the interactions and systems that it will affect.

The economic, financial, and business systems that we are trying to understand in this process are likely to behave in non-intuitive ways, and exhibit surprising characteristics.

During this process we try to obtain insights into the interlinkages through using an extreme scenario.

To develop a coherent stress test we have devised a methodology for understanding the consequences of a scenario, as summarised in Figure 2.

This involves sequential processing of the scenario through several stages and sub-modelling exercises, with iteration processes to align and improve assumptions.

We believe it is important to create a robust and transparent estimation process, and have tried to achieve this through a detailed recording of the assumptions made, and by making use of sensitivity tests regarding the relative importance of one input into another.

In the macroeconomic stages of the modelling, we are conscious that we are attempting to push macroeconomic models, calibrated from normal economic behaviour, outside their comfort zone, and to use them in modelling extreme events. We have worked closely with economists to understand the useful limits of these models and to identify the boundaries of the models functionality.

Uncertainty and precision

Overall the scenario consequence estimation process retains elements of uncertainty. The process entails making a number of assumptions to assess losses and direct impacts. These are then used as inputs within a macroeconomic model, with additional assumptions and the introduction of uncertainty and variation.

The outputs then feed the assessment of portfolio performance, with further assumptions generating additional uncertainty.

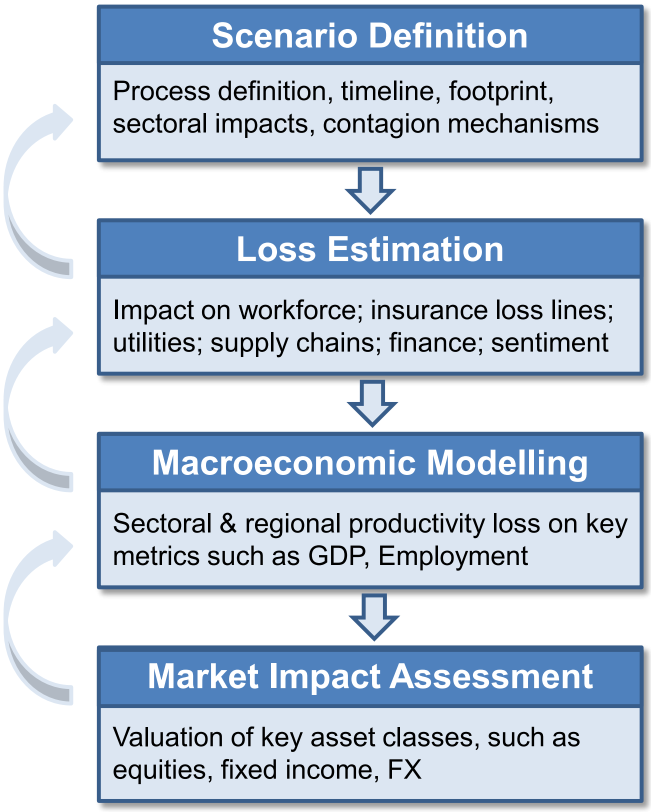


Figure 2: Structural modelling methodology to develop a coherent stress test scenario

Linking all the components into a coherent scenario is problematic to achieve and the process described in this report is one particular approach that has attempted to do this.

It is suboptimal in that the process is imprecise and one of compounded uncertainty at each successive stage and the methodology of various aspects of any particular scenario needs to be understood in this context.

The point, however, of producing the scenario is to understand the consequences in terms of their holistic effects, their relative severities and the patterns of outcome that occur. In fact, the scenario is deterministic and is not designed to provide exceedance probability data points.

An approximation selection process has been adopted on the basis of expert elicitation, to be in the range of the 1-in-100 annual probability of occurrence worldwide, but not rigorously determined.

The scenario production process, limited as it is, does provide interesting insights, and many of the applications of the scenario are achieved through this imperfect approach. The scenario is offered as a stress test, to challenge assumptions of continuing status quo and to enable practitioners to benchmark their risk management procedures.

Use of the scenario by investment managers

The scenario provides a timeline and an estimation of the change of fundamental value in assets in an investment portfolio. These are segmented into broad asset classes and geographical markets to provide indicative directional movements.

These provide insights for investment managers into likely market movements that would occur if an event of this type started to manifest. In real events, market movements can sometimes appear random.

This analysis suggests how the underlying fundamentals are likely to change over time, due to the macroeconomic influences. The spread of asset class and geographical distributions enable investors to consider how different portfolio structures would perform under these conditions and how to develop strategies for portfolio management that will minimize the losses that might occur.

Where there are obvious winners and losers by economic sector, these have been highlighted to provide inputs into optimal hedging strategies and portfolio diversification structures.

This report provides performance projections for a standardized high-quality, fixed income portfolio, under passive management.

This is to enable comparisons over time and between scenarios. We also estimate returns for individual asset classes to help investment managers consider how this scenario might impact their particular portfolio and to consider the intervention strategies over time that would mitigate the impact of this financial catastrophe.

Use of the scenario by policy makers

International agencies like The World Bank, The International Monetary Fund (IMF), The Organisation for Economic Co-operation and Development (OECD) and G7-G8 Group Meetings recognise the serious global implications of market-based catastrophe. Scenario stress testing is a sensible and appropriate tool to improve the awareness and decision-making ability of policy advisors.

This scenario is proposed as an addition to the existing frameworks and procedures that are already being used to understand risk and contagion in the global financial and economic systems.

National governments, central banks and other regulatory authorities including the Prudential Regulation Authority (PRA) in the UK use stress tests to determine whether banks have sufficient capital to withstand the impact of adverse economic developments.

Many banks also carry out stress tests as part of their own internal risk management processes. Such tests are designed as an early detection system to identify vulnerabilities in the banking sector so that corrective action can be taken by regulators. These stress tests focus on a few key risks such as credit risk, market risk and liquidity risk. In many cases, banks are subject to performance reviews against classified versions of these scenarios and they are a mandatory requirement for many national regulatory authorities.

This scenario is a contribution to the design of future versions of these policy-maker scenarios. It offers a view of the economic environment and broader financial disruption that will be caused. It provides inputs into the decision making and resource planning of these authorities, and is offered as context for policy-makers concerned with stemming the impacts of market catastrophe.

Complex risks and macroeconomic impacts

Financial and economic systems are inextricably linked. Thus, financial market catastrophes are of interest because they represent complex risks – they impact the networks of activities that underpin the global economy, disrupting the interrelationships that drive business, and cause losses in unexpected ways and places.

They have multiple consequences, causing severe direct losses, as well as operational challenges to business continuity, cascading effects on the macroeconomy through trading relationships, and on the capital markets and investment portfolios that underpin the financial system.

The stress test is aimed at providing an illustration of the effects of an extreme event, to help a non-specialist audience understand the potential for events of this type to cause disruption and economic loss. It is aimed at informing risk management decisions for a number of different communities of practice.

3 Asset Bubbles as a Financial Catastrophe

The term "economic bubble" describes a situation when the price of an asset rapidly appreciates at a sustained rate, typically over a short space of time, and then bursts, bringing the asset price back down to a level believed to be more representative of its fundamental value. In this definition a bubble cannot be recognised, or at least is not recognised by the market, prior to its collapse. That is, bubbles can only be identified in hindsight along with a post-hoc rationalisation of the bubble as the growth of an unsustainable gap between a larger market value and smaller fundamental value.

Moreover, the size of the bubble is dependent on the timing, namely the time window which defines value before and after the bubble burst. Our subsequent analysis can roughly be described as measuring the size of the bubble burst by looking at value lost over the quarter following the shock.

By definition, bubbles are not sustainable. In general, their lifetimes are defined by three distinct phases: first, the growth of demand and rise in price; second, the "burst", when prices begin to fall; third, the financial fall-out, when investors and businesses that have borrowed to buy assets at an overblown price default.[5] Bubbles may appear to shrink and then peak again. The collapse of a significantly inflated market is regularly followed by financial crisis.

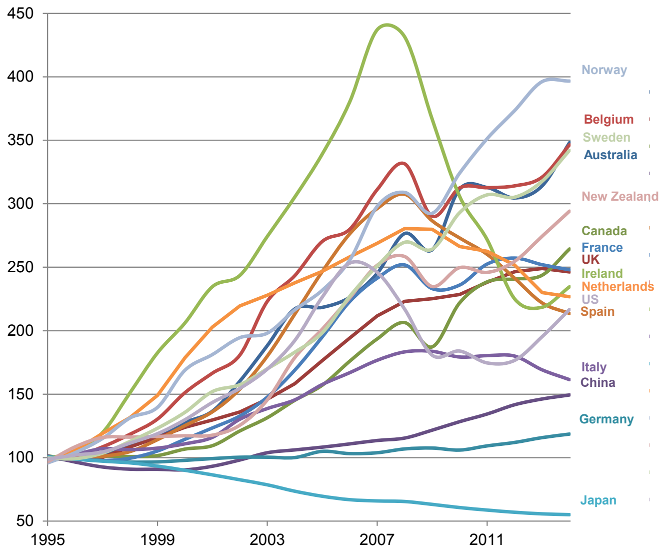


Figure 3: Real house prices index, 1995 – present (Source: Bank of International Settlements, per national sources).

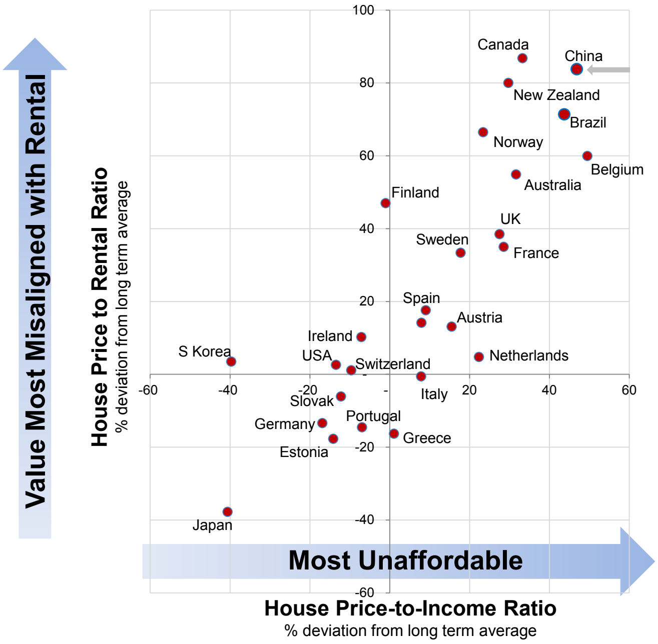


Figure 4: The most inflated property markets, worldwide (Source: IMF Global Housing Watch)

The Great Recession of 2007-2011 was caused, in part, by the bursting of the United States' housing and subprime mortgage bubbles in 2007 which had been growing rapidly for the four years prior and were themselves the product of risky investment strategies carried out by banks and mortgage lenders. The calculated impact of t most recent world financial crisis amounted to $20 trillion in global GDP lost since 2007, in 2010 prices

Historically, bubbles have been hard to identify until after they have begun to collapse. This is due to the acceleration of an asset's market price before its fundamental value can be properly assessed, as it "depends on the expectations of dividends that have yet to be realised."[6] In recent years, however, a perceivable "froth" of property bubbles has been growing in the global economy. At the turn of the century, international housing prices began to rise, namely in the US, Argentina, Australia, the United Kingdom, China, New Zealand, Ireland, Spain, Poland and Croatia, resulting in a global housing boom.[7]

Since 2008-09, the methods taken by central banks to stabilise the banking system after the global credit crunch has perpetuated near-zero interest rates and prompted many stagnating housing markets to reinflate.

[5] F. Allen and D. Gale, (1999) "Bubbles, Crises, and Policy", *Oxford Review of Economic Policy*, Vol. 15 No. 3, 9

[6] Ibid., 14

[7] G. Putland, (2009) "From the subprime to the terrigenous: Recession begins at home", Land Values Research Group

2014 figures from the IMF suggest that property is currently overvalued by 25% in at least nine countries spanning the globe.[8] In 2015, new data from the MSCI Index showed property prices and yields at records last seen before the Great Financial Crisis.[9]

Causes

There is no economic consensus on the definitive causes of asset bubbles. Historical case studies fail to adhere to a regular, standard definition and present an array of reasons for being; bubbles appear to be unique in their causation, duration, and impact. Gadi Barlevy maintains that the appearance of bubbles may suggest that a particular economy "already suffers from certain structural problems."[10]

Keynesian scholarship asserts that bubbles are a natural by-product of "animal spirits", that is: periods of economic instability are caused by "the characteristic of human nature" and "that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic."[11]

The general understanding behind the acceleration of bubble markets involves the "greater fool theory": investors take risks only with the assumption that the assets may later be sold on for an even higher price, to the proverbial "greater fool."

As an example, economists attempting to explain the reasons behind the 1986-1991 Japanese asset price bubble refer to a boom-and-bust economic psychology precipitated by a particular mix of consumer confidence in the wake of the US crash on Black Monday. Widely publicised stories on Japanese take-overs of international companies and new business HQs set up in Tokyo fuelled massive property speculation.

Low interest rates in many countries have contributed to the growth of the current property "froth"; should interest rates increase sharply, property values could begin to drop suddenly. The Federal Reserve's decision to raise US short-term interest rates following a sustained near-zero period could have widespread and negative impact on the global property market.

[8] *The Economist*, "Global property markets: frothy again", August 30 2014

[9] K Allen and A. Nicolaou, "Global property bubble fears mount as prices and yields spike", *Financial Times*, 16 April 2015

[10] *Economic theory and asset bubbles*, Gadi Barlevy, 2007 Economic Perspectives, 57

[11] Keynes, John M. (1936). *The General Theory of Employment, Interest and Money*. London. Macmillan. pp. 161-162.

Historical Case Study

The Subprime Crisis (2007)

After the 2003 recession and the collapse of the dot-com bubble, US central banks re-stimulated the economy by bringing down interest rates to a thirty-year low. Investors began to seek greater returns by pursuing riskier investments. This prompted lenders to do the same; mortgage lenders began to approve high-risk, high-interest subprime property loans to borrowers with weak credit.

The resulting housing boom peaked in 2006 and collapsed through 2007 when foreclosure and default rates began to rise faster than expected. Investors pulled out and subprime lenders and hedge-funds went bankrupt. The downgrading of subprime securities from AAA to junk triggered a selling frenzy which spread rapidly through the global financial system, drying up liquidity.

In December 2007, the United States entered into what is now the "Great Recession", dragging the international economy down with it. The subprime mortgage collapse and resulting liquidity crisis is seen as one of the principle causes of the Great Financial Crisis.

Theory

The frequency of economic bubbles and financial crises has increased with globalisation. Arguably, the first asset bubble to be recorded appeared as a result of cross-cultural trade between Holland and the Ottoman Empire, introducing new and exotic commodities into the marketplace and causing a bidding frenzy over tulip bulbs.

The worldwide effects of the Great Depression of the 1930s and Great Financial Crisis (GFC) since 2009 indicate the potency of stock crises and bubble crashes in the major world economies as they affect the real economy including wider international prospects. The average period of time between crises between 1700 and 1900 was 21 years; since 1960, the interval has shrunk to just eight years.[12]

In a globalised financial system, the economic fallout of bubble collapse can cascade through international markets. Economic interconnectivity is vital to determining the severity and frequency of losses at stake from a bursting asset bubble.

[12] Needham, D., "Historical Catalogues of Financial Catastrophes", presentation at the University of Cambridge, 10 July, 2014

4 Defining the Scenario

The practice of using stress tests to check the health of banks and economic institutions in the wake of the Great Financial Crisis is currently a point of some contention in financial circles. While stress tests have restored confidence in some instances, they have also failed to accurately capture the risk limits of the institutions whose health they seek to diagnose. Recently, the changing economic climate makes so that the results of such stress tests have little longevity and are quickly rendered meaningless.

In this period of general economic recovery there are concerns that current stress tests are either too predictable or too poorly applied and require closer re-examination. In light of this issue, the University of Cambridge Centre for Risk Studies devised a new suite of coherent stress tests designed to reflect four potential, though improbable, global financial crises. This particular scenario explores the consequences of global property crisis triggered by the collapse of the emerging markets housing asset market.

The inflated property markets

After the recession of the early 1990s, housing prices began steadily to rise worldwide, increasing by an average 123% between 1996 and 2007.[13]

Explanations for the growth in property value in this period vary; what may have been a speculative bubble could also be explained by rising household income, housing shortages, and restrictions on land supply occurring at the same time.

For reasons that are not yet understood, certain property markets escaped the major collapse saw house prices in countries such as the United States, Ireland, Spain and the Netherlands collapse after the Great Financial Crisis. Greater hindsight, perhaps, will shed light on why some markets – Sweden, Norway, Belgium and the UK – suffered momentary dips before rebounding, while house prices in emerging markets like China, India, Indonesia, as well as Australia and Canada, continued to rise in spite of the global financial crisis.[14]

These latter national markets comprise the top tier of the graph shown in Figure 4 and continue to grow as a result of near-zero interest rates since 2008 and greater population demands.

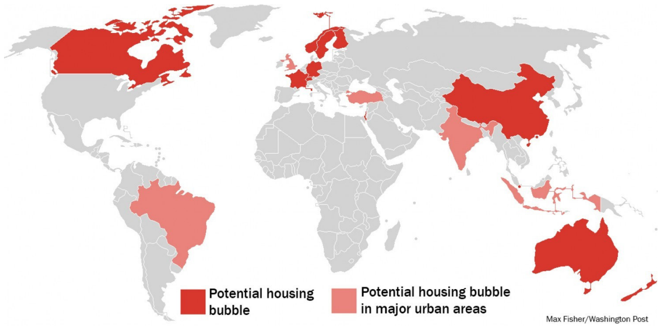


Figure 5: Seventeen countries identified as having potential housing bubbles in 2015. (Source: The Washington Post**)**

Beginning in 1998, China's decision to curtail its nationwide public housing provisions and open the market to bank mortgage loans has stimulated a boom in its domestic property sector which has now become a central pillar of the economy. Within five years, cheap and available credit incentivised widespread investment in land, infrastructure and construction projects. In the space of two years, China used more cement than the US produced "in the entire 20th century"[15]

Australia, Brazil, and China illustrate the global forces pushing up prices of commodity and then real estate following growth in manufacturing output.

As China becomes increasingly identified as the world's largest manufacturer, largely on behalf of the developed economies, its massive demand for raw materials has boosted the export markets of other emerging economies, including Brazil and India, boosting the role of the BIC (Brazil, India and China) as well as Indonesia and Australia in the global economy.

The influx of wealth into these nations has, in turn, fuelled an increase in domestic property values linked to the availability of credit. Australia's own bull market contributed in part to the twenty-year growth in Australia's house prices.[16]

As of 2015, there is a broad division in opinion over whether or not these economies are suffering from speculation-fuelled bubbles, though property prices remain at all-time highs.

[13] P. Soos, "A sore lesson from housing history," *Business Spectator*, 11 June 2013

[14] "Choosing the right pin", *The Economist*, 30 August 2014:

[15] J. Anderlini, "Property sector slowdown adds to China fears", *Financial Times*, 13 May, 2014

[16] D. McWilliams, "China's crisis could be the pin to pop the property bubble in Australia", *Independent.ie*, 29 July, 2015.

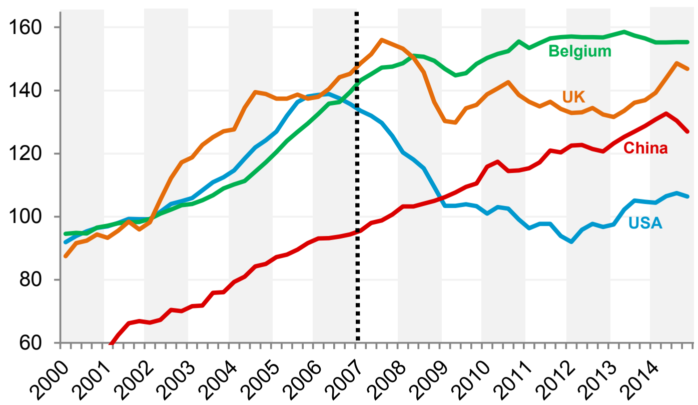


Figure 6: House price-to-rent rates in countries with suspected housing bubbles vs. the United States, before and since the GFC (Source: The Economist**)**

Similarly, the Indian government's 2005 decision to permit 100% foreign direct investment (FDI) construction projects in its growing cities has led to an unprecedented expansion of its credit supply. India's reputation as an emerging "tech giant" made it an attractive target for foreign investors seeking to diversify their portfolios. In 2013, in a bid to protect the value of the rupee, the Reserve Bank of India (RBI) restricted the purchasing of property overseas by national firms.

India's booming population and its high demand for housing would appear to counteract the danger of a speculative real estate bubble and its subsequent collapse, an argument which can also be made for China. The same conditions, however, existed in Japan prior to its severe stock market crash in 1991.

Chinese property prices peaked in 2011, precipitating presumed bursting of the speculative bubble which began there in 1998 but began to rise again in 2012. Property prices continue to rise in all but one of China's 70 largest cities. In early 2015, rental yields in India began to drop drastically compared to the lending rate with some citing this as a sign that the "bubble" is beginning to burst.[17]

Scenario variants

We introduce a set of variants to the global property crash scenario to provide sensitivity analysis so as to gain a better understanding of the greater effects of a global property crash.

Standard scenario S1 is the narrative described in the following section. It depicts the collapse of both mortgage and non-mortgage markets largely contained within six separate country groupings: Tier 1 – BIC (Brazil, China & India) and the emerging markets more generally; Tier 2 – the Commonwealth; Tier 3 – the Nordics; Tier 4 – the United Kingdom; and Tiers 5 and 6 – Europe. In this modelling scenario, the real estate and equity markets are subjected to shocks up to 35% and 10% respectively. The extent of the crash peaks at the end of the first year, while the effects of the shock are felt over the next four years.

Scenario variant S2 is similar to the standard scenario but the impact of the asset bubble collapse extends spatially beyond the above six tiers of countries, to also include: Tier 7 – the United States; Tier 8 – Prudent Europe, and Tier 9 – Industrial Asia. In this variant, the shocks to real estate and equity markets are increased up to 60 and 12% respectively.

Unlike the other financial catastrophes, the global property crash scenario does not have an extreme variant X1, which would have the same spatial extent of shocks similar to S2 but more severe. This is because the severity of this variant is so extreme that it is highly unlikely and does not provide meaningful contribution to the financial and insurance industries.

Tier 1:	China, Hong Kong, India, Brazil, Philippines, Indonesia and Turkey
Tier 2:	Commonwealth
Tier 3:	Nordics
Tier 4:	United Kingdom
Tier 5:	France, Belgium and the Netherlands
Tier 6:	Spain, Portugal, Italy, Granada, Ireland, Austria and Denmark
Tier 7:	United States
Tier 8:	Germany and Switzerland
Tier 9:	Japan and South Korea

Table 4: Tiers or country groupings utilised in the Global Property Crash scenario.

[17] P. Duggal, "Indian Real Estate Bubble is Starting to Burst", *RTN.ASIA*, 17 July, 2015.

5 The Scenario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Housing markets 25% overvalued in emerging economies

Tracking data shows property values vastly outpacing rent rates in booming tech markets Indonesia, Singapore, Malaysia, and beyond

Monday, July 19

BEIJING (1300 UTC) – **Property market investment showed dropping yields rates in the first quarter of the year.**

The South Asian construction boom may be coming to an end as returns shrink for property stakeholders in the BRICs off-shoots.

Last year, gross rental yields were up 6% on those reported in February,

Rumours of the speculative 'bubble' have haunted emerging markets since 2000.

Phase one: the shake-up

Markets begin to show signs that property values in the world's emerging economies are beginning to slip. Rental yields in Indonesia, the Philippines, Thailand, Singapore, and Malaysia drop to 2% compared with the lending rate. The 6% loss in rental returns triggers a change in the behaviour of foreign stakeholders and what begins as a small sell-off by shrewd investors rapidly gains momentum, driving down property values across the region. Before long, prices in the Chinese and Indian property market begin to plummet, indicating a snowballing loss in investment confidence.

In the first quarter of the year, the value of residential sales in the BRICs markets falls by nearly 18% year over year. China's banks and shadow banks, which supply credit to builders and rely on real estate investments as collateral for almost all loans, begin to seize properties as developers default on payments.

The shake-up destabilises the international property market and the most inflated markets are hit first by rapid depreciation.

Phase two: the bubble bursts

The contagion begins to flow through the international financial and banking systems.

As construction grinds to a halt in Brazil, China and India and these economies take a sharp downward turn, the bubble bursts in Australia's exposed and hyper-inflated property market.

This is followed by crashes in New Zealand and Canada, where house prices are more than 40% overvalued.[18]

Economists begin to label the string of market failures a "global collapse" even before the slide begins in the United States. Property prices plummet worldwide over the next two years.

Mortgage equity markets shrink by 50% on average and several large "too big to fail" European banks are thrown into arrears in quick succession due to their exposure to international mortgage markets. Central banks and governments decide to curtail bailout practices due to the speed of the economic wipe-out, allowing investment institutions to fail as a deterrent to risky practices.


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Property crash spreads to Europe

Following the major housing crashes in China, Australia and Canada, property prices are now on the slide in Scandinavia and the UK

Tuesday, April 18

OSLO (1800 CET) – **Norway's latest house price statistics show a 10% slide in a single month. Early indicators follow a stagnant period for house sales in Sweden and the UK, and analysts speculate that the collapse of the property market could be deeper and more extensive than anything yet seen.**

Weak house price indicators are now being seen in some ten countries worldwide, following the sudden drop in property stock in China last autumn.

Buy-to-let schemes are being blamed for inflating house prices in the UK and elsewhere in Europe

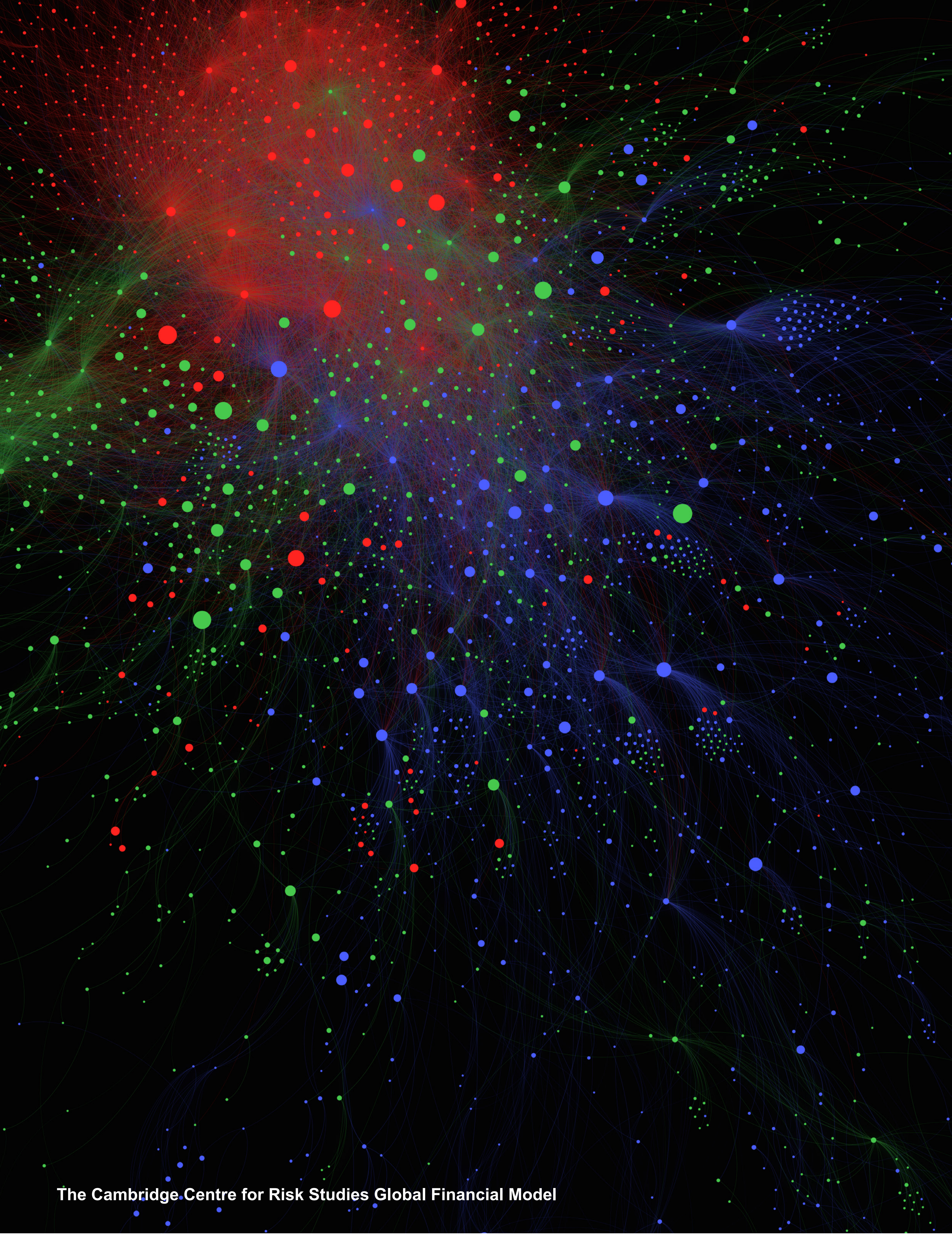
A spokesman for a leading estate agency tried to calm the market on Saturday

Phase three: hitting rock bottom

Within a year of the crash, the IMF declares a global recession, tallying data representing a decline in quarterly GDP growth of up to 1.5%. The global economy returns to a cycle of negative growth with austerity measures showing little effect for several years.

Despite the lowering of interest rates by central banks around the world to stimulate both domestic and global economies, low consumer confidence dampens any exogenous stimulus to increase spending, borrowing or investment. This results in major economies being caught in deflationary spirals for the next three years and which do not recover over the following two years.

[18] H. MacBeth, *When the Bubble Bursts: Surviving the Canadian Real Estate Crash*, Dundum, 2015



The Cambridge Centre for Risk Studies Global Financial Model

6 Modelling Bank-to-Bank Relationships in the Global Financial System

Context

The Cambridge Centre for Risk Studies has developed a global financial system model to investigate the direct and indirect consequences of an exogenous asset price shock, prescribed by this asset bubble scenario, on the global financial system. The financial model includes characterisations of bank balances sheets, bank hierarchical ownership structures, non-controlling equity cross-holdings among different banks, the interbank market, and a cascade mechanism that reflects the propagation of bank failures throughout the system. It provides an estimate of the overall devaluation of the financial system and identifies the banks and countries that are hit hardest by the scenario variants.

This section of the report outlines the data that the financial model draws from and describes the model with a focus on the construction of cross-holding and interbank networks, and the iterative cascade algorithm used to estimate the propagation of bank failures over these networks. The model results for three variants of the asset bubble scenario are also reported.

Data

The underlying data for the model is drawn from Bureau Van Dijk's Bankscope database. Bankscope is a global database containing the latest financial statements and ratings information of more than 30,000 banks.[19] Specifically, balance sheet and cross-holding data are required by the financial model, and a consistent financial criteria of universal data format is used so as to compare banks directly from different regions.

For a given bank, balance sheet data is typically available in either a consolidated or an unconsolidated format. Unconsolidated data is used, where available, to improve the geographic profile of a banking group's assets and liabilities. Key data points required by the model include, mortgage assets (i.e., loans secured by residential or non-residential property), total interbank loans and borrowing, and overall total assets and total equity. The relationship between these data points is illustrated by a simplified balance sheet diagram in Figure 5.

[19] Including, 8,000 European banks, 14,000 North American banks, 1,000 Japanese banks, and 35 supranational banking and financial organisations.

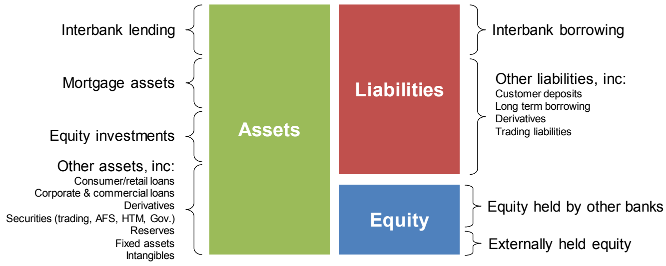


Figure 7: A simple bank balance sheet

A variety of supporting data are also used, including identifier codes, bank specialisation (commercial, investment, central, etc.), filing dates of financial statements, bank status (active, under receivership, dissolved, etc.), and the region in which a bank operates.

Raw data extracted from Bankscope was initially filtered to retain all banks with an active status and a filing date of their most recent statement within the last two years. This data filter yielded 18,447 bank records with overall assets of $210 trillion, overall equity of $17.7 trillion, and overall mortgage assets of $13.3 trillion. 3,513 banks hold a share of these overall mortgage assets.[20]

In addition to the balance sheet data, extensive cross-holding data was also extracted from the database for the filtered selection of banks. Within the database, each bank record contains a list of all reported shareholders and a separate list of subsidiaries/affiliates (i.e., organisations in which a bank holds an equity share), including an indication of thepercentage of shares held in each case. Wherever a reported shareholder/subsidiary happens to be another bank within the database, these ownership links can be considered as cross-holdings within the system of selected banks. The extracted cross-holding data reveal two features. First, bank hierarchical ownership structures can be identified, often resembling tree-like forms stemming from a top-level holding bank. Second, non-controlling ownership linkages between distinct banking groups are elucidated.

[20] Although only 20% of banks in the filtered database are reported as directly holding mortgage assets, all banks have exposure to assets that would devalue in the event of a global property price correction. This is captured in the scenario and model through a correlated, though lesser, shock to bank non-mortgage assets.

Model description

The Cambridge Banking Model

The global financial system model consists of three components: the specification of cross-holding data in a network format; the specification of a plausible interbank market in a network format; and, a contagion mechanism based on an iterative algorithm, which simulates the propagation of banks failures across the cross-holding and interbank networks.

Scenario results

Tier 1:	China, Hong Kong, India, Brazil, Philippines, Indonesia and Turkey
Tier 2:	Commonwealth
Tier 3:	Nordics
Tier 4:	United Kingdom
Tier 5:	France, Belgium and the Netherlands
Tier 6:	Spain, Portugal, Italy, Granada, Ireland, Austria and Denmark
Tier 7:	United States
Tier 8:	Germany and Switzerland
Tier 9:	Japan and South Korea

Table 3: (reprinted from page 14) Tiers or country groupings utilised in the Global Property Crash scenario.

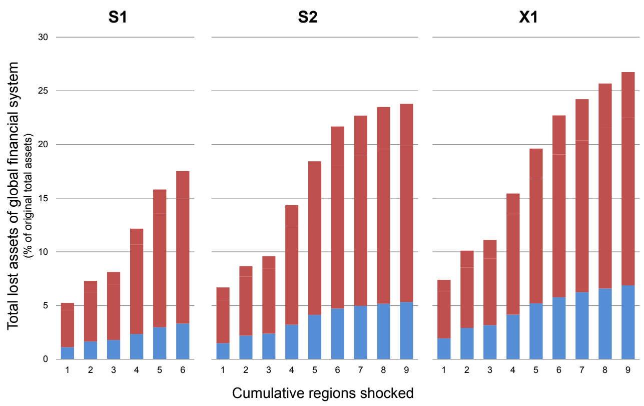


Figure 8: Global financial system model results for the three scenario variants

Table 4 summarises the initial shocks that were applied to bank mortgage and non-mortgage assets in different regions (grouped by region tiers) for the three scenario variants, S1, S2, and X1.

The overall results from the global financial system model are shown in Figure . For example, in scenario variant S1, all banks headquartered in China, Hong Kong, India, Brazil, Philippines, Indonesia, and Turkey receive a mortgage asset shock of 30% and a non-mortgage asset shock of 6%; this is estimated to have a direct devaluation impact of $2.3 trillion (1.1% of the financial system's original $210 trillion of assets). However, the cascading effects following the initial shock estimates a further devaluation of $22 trillion, culminating a total loss in financial system assets of 11.5% (these results are shown in the first stacked bar in Figure 8). Figure 8 also shows how the overall impact of the scenario variants increase as additional tiers of regions are included in the initial shock (with shockpercentages according to Table 5).

Overall, variant S1 involves asset shocks across six tiers of regions, giving a direct devaluation of $6.9 trillion (3.3%) and a total devaluation of $47 trillion (22%). In variant S2, an increase in the shock magnitude in the first six region tiers and additional shocks to a further three tiers of regions are applied. This gives a direct devaluation of $11 trillion (5.3%) and a total devaluation of $58 trillion (28%) in the global financial system assets.

Table 5 illustrates the geographic compositions of the total direct and indirect devaluations estimated for the scenario variants.

For example, in variant S1, although banks in the United States (Tier 7), Germany (Tier 8), and Japan (Tier 9) did not receive an initial shock, they are indirectly impacted by 3.8%, 18.1%, and 2.6% of their domestic bank assets, respectively. Further in S2, after applying direct shocks to these tier groups, the total indirect impacts to these domestic banks' assets are observed to increase by up to 10-fold.

Besides in S1, even though banks in the United Kingdom (Tier 4) are shocked to similar magnitudes as compared to those in India (Tier 1), the British banks suffer 1.5x more total devaluation. The larger extent of indirect devaluations impacted on banks in these developed markets is primarily due to the higher degree of connectivity with other cross-border banks and financial institutions.

In general, the new financial modelling approach described in this section estimates that the Global Property Crash Scenario will wipe out 22% to 31% of asset value in the global financial system.

The failure cascades stemming from initial mortgage and non-mortgage asset shocks are highly systemic and in all scenario variants lead to the default of global systemically important banks (G-SIBs).

The indirect impacts of the scenario are geographically diverse with implications for all major markets, but the performance of individual financial institutions is highly heterogeneous (owing to both variance in connectivity and magnitude of loss absorbing equity buffers).

Table 5 indicates the geographic decompositions of the overall direct and total devaluations estimated for the three scenario variants. For example in variant S1, it is interesting to note that although banks in the United States, Germany, and Japan did not receive an initial shock, they did receive an indirect impact of 3.8%, 18%, and 2.6% of their domestic bank assets, respectively.

Moving to the most extreme variant, X1, we also find banks in Germany have, on average, a huge nine-fold increase from their direct devaluation and their total devaluation. This is due to the degree of connectivity with other banks beyond German borders that received significant shocks.

	Total assets (billion USD)	Direct shock (%)		Total impact (%)	
		S1	S2	S1	S2
CA	41.9	11.8	15.7	42.8	47.4
UK	4.8	7.2	10.5	39.9	44.1
CN	16.3	7.1	9.5	39.2	43.1
BR	14.4	6	8	34.5	37.7
IN	23.1	7.1	9.4	26.4	33.2
DE	3.1	-	2	18.1	22.6
US	2.3	-	1.3	3.8	12.3
JP	210.0	-	1.3	2.6	6.2
World	**23.1**	**3.3**	**5.3**	**22.4**	**27.7**

Table 5: Geographic breakdown of direct shock and total impact

In general, the new modelling approach described in this section estimates that the Global Property Crash Scenario will wipe out 22% to 31% of asset value in the global financial system.

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The indirect impacts of the scenario are geographically diverse with implications for all major markets, but the performance of individual financial institutions is highly heterogeneous (owing to both variance in connectivity and magnitude of loss absorbing equity buffers).

To put these results in context, the Bank of England estimated that the total value of equity bailouts, money creation, collateral swaps, guarantees, and insurance provided by central banks and governments by the end of 2009, in response to the 2008 financial crisis, amounted to about $15 trillion.[21]

In the US alone this support exceeded $10 trillion; roughly a quarter of the value of assets held by US banks in this model. Considering that state support in the wake of the onset of the financial crisis likely stemmed the propagation of contagion across the global financial system, it seems reasonable to speculate that a *laissez-faire* counterfactual of the crisis would have led to global asset devaluations in excess of the reported scenario.

[21] P. Alessandri and A. Haldane, *Banking on the State,* speech given November 2009 at Bank of England.

7 Macroeconomic Analysis

Economic impacts of global property crash

The value of global financial assets is estimated to range between US$250 and $270 trillion (2014) and is predicted to grow to $371 trillion by the end of 2020 (Roxburgh et al., 2011). This is roughly four times the size of annual global GDP output. When crisis occurs in the financial sector, the impacts on the global economy are severe. For example, McKinsey estimates the loss accruing to financial assets in 2008 from the recent global financial crisis (GFC) was around $16 trillion with an additional $30 trillion accruing to the stock of global real estate. Considering losses across all major financial assets, the loss in value caused by the GFC soon approaches $50 trillion, which was equal to total global GDP output in 2008.

The contractual rights to various forms of financial assets are traded on international financial markets. In its simplest form financial assets can be broken into three distinct asset classes these include: equities (stocks), fixed income (bonds), and cash equivalents (money market instruments). In addition to these commonly traded financial asset classes, other types of assets typically include real estate, commodities and other contractual investments. The price of assets traded on financial markets can fluctuate greatly due to a variety of different reasons. Periodic trends of increasing prices caused by speculation can lead to asset bubble risk. During periods of excessive growth in prices, the value of assets tends to rise above the underlying value of the security. When a bubble bursts there is a sharp decline in value to the point where the paper value of the asset becomes underrated. Most financial assets are so closely correlated that when an asset bubble bursts the contagion rapidly spreads across different asset classes, eventually contaminating the entire financial system whilst simultaneously having significant impacts on the real economy.

The purpose of the following section is to model the macroeconomic effects of an asset bubble collapse catastrophe, such as a global property crash. The trigger for this scenario is a sharp decline in the house price index triggered by over-priced real estate values in BIC and emerging markets. The financial shock caused by this readjustment quickly spreads to other markets around the globe.

Historical Case Study

Japanese Asset Bubble Collapse

In 1990, the Japanese stock market crashed and quickly spread to the real estate sector where property prices had been highly inflated for several years. Prior to 1990, Japan's real GDP grew steadily at approximately 5% but, over the decade that followed the collapse, the real growth rate of Japan's GDP rarely exceeded 1%. In comparison, nominal GDP fell from $5.3 to $4.4 trillion over the period from 1995 to 2007. It was not until 12 years after the Japanese asset bubble collapse that GDP recovered to its 1995 level, inciting commentators to label this period in Japan's history as "the lost decade."

The trigger of the collapse can be traced back to an attempt by authorities at the Bank of Japan to deflate speculation and keep inflation in check. They did this by raising the Japanese interbank lending rates and thus ending a period of cheap money. Speculators reassessed long term positions and caused a collapse of the Japanese stock market and the bursting the inflated asset bubble. At the time, many Japanese firms and banks were excessively leveraged; when interest rates were raised, these institutions were burdened not only with higher repayments but an asset base that was worth much less due to the collapse in prices.

In early 2014, the official central bank interest rate was 0.05%, having remained below 1% almost consistently since 1995. Successive efforts by the Japanese government to stimulate the domestic economy through an accumulation of fiscal deficit have left the Japanese economy with the largest government debt in the world, expressed as apercentage of its own GDP (2014: 230%). Unemployment has also had a major impact on the country, increasing from less than 2% before the crisis to a peak of 21% in 1998.

Today, Japan is still searching for solutions to its economic problems of low growth, deflation, rising energy costs and an aging population.

<table>
<tr><th rowspan="2">S/N</th><th rowspan="2">Macroeconomics input variables</th><th colspan="2">Scenario Variants</th><th rowspan="2">Justification for shock</th><th rowspan="2">Scenario-specific key assumptions</th></tr>
<tr><th>S1</th><th>S2</th></tr>
<tr><td>1</td><td colspan="5">House Price Index</td></tr>
<tr><td></td><td>Tier 1: BIC and the emerging markets</td><td>-35%</td><td>-60%</td><td rowspan="9">2008 Financial Crisis:
• US housing bubble burst
• Values of securities tied to US real estate decrease
• More than 20% peak-to-trough decline in US residential home prices[22]
• Contagion spread globally[23] (E.g. peak-to-trough decline: UK-13%; Norway-9%; Australia-5%)</td><td rowspan="9">Country-grouping based onpercentage deviation from long-term average[24]:
• Most unaffordable house price-to-income ratio
• Value of house price most misaligned with rental</td></tr>
<tr><td></td><td>Tier 2: Commonwealth</td><td>-35%</td><td>-60%</td></tr>
<tr><td></td><td>Tier 3: Nordics</td><td>-35%</td><td>-60%</td></tr>
<tr><td></td><td>Tier 4: United Kingdom</td><td>-30%</td><td>-50%</td></tr>
<tr><td></td><td>Tier 5: Europeans</td><td>-30%</td><td>-50%</td></tr>
<tr><td></td><td>Tier 6: Other Europe</td><td>-30%</td><td>-50%</td></tr>
<tr><td></td><td>Tier 7: United States</td><td>-</td><td>-20%</td></tr>
<tr><td></td><td>Tier 8: Prudent Europe</td><td>-</td><td>-20%</td></tr>
<tr><td></td><td>Tier 9: Industrial Asia</td><td>-</td><td>-20%</td></tr>
<tr><td>2</td><td colspan="5">Share Price Index</td></tr>
<tr><td></td><td>Tier 1: BIC and the emerging markets</td><td>-10%</td><td>-12%</td><td rowspan="9">2008 Financial Crisis:
• Record severity of stock market fall
• Contagion spreads across asset classes
• Approx. 50% peak-to-trough decline across major economies (E.g. DJIA-46%; FTSE-40%; SSE-64%)</td><td rowspan="9">Ex-ante analysis:
• Process performed to determine final share price impacts
• Investment sentiment significantly affects the general direction stock market takes</td></tr>
<tr><td></td><td>Tier 2: Commonwealth</td><td>-10%</td><td>-12%</td></tr>
<tr><td></td><td>Tier 3: Nordics</td><td>-10%</td><td>-12%</td></tr>
<tr><td></td><td>Tier 4: United Kingdom</td><td>-8%</td><td>-10%</td></tr>
<tr><td></td><td>Tier 5: Europeans</td><td>-8%</td><td>-10%</td></tr>
<tr><td></td><td>Tier 6: Other Europe</td><td>-8%</td><td>-8%</td></tr>
<tr><td></td><td>Tier 7: United States</td><td>-</td><td>-5%</td></tr>
<tr><td></td><td>Tier 8: Prudent Europe</td><td>-</td><td>-5%</td></tr>
<tr><td></td><td>Tier 9: Industrial Asia</td><td>-</td><td>-5%</td></tr>
<tr><td>3</td><td colspan="5">Confidence Shocks</td></tr>
<tr><td></td><td>Tier 1: BIC and the emerging markets</td><td>-65</td><td>-70</td><td rowspan="9">2008 Financial Crisis:
• US volatility index historical high 2008
• Upward trend of more than 400% increase between 2006 and 2008[25]</td><td rowspan="9">Causal relationship between confidence and macroeconomics:
• Information view (Throop, 1992)[26] including fundamental information regarding to current and future economy states
• Animal spirits (Shiller and Akerlof, 2009)[27], reflecting the “subjective state of mind of consumers</td></tr>
<tr><td></td><td>Tier 2: Commonwealth</td><td>-65</td><td>-70</td></tr>
<tr><td></td><td>Tier 3: Nordics</td><td>-65</td><td>-70</td></tr>
<tr><td></td><td>Tier 4: United Kingdom</td><td>-60</td><td>-60</td></tr>
<tr><td></td><td>Tier 5: Europeans</td><td>-60</td><td>-60</td></tr>
<tr><td></td><td>Tier 6: Other Europe</td><td>-50</td><td>-60</td></tr>
<tr><td></td><td>Tier 7: United States</td><td>-</td><td>-30</td></tr>
<tr><td></td><td>Tier 8: Prudent Europe</td><td>-</td><td>-30</td></tr>
<tr><td></td><td>Tier 9: Industrial Asia</td><td>-</td><td>-30</td></tr>
</table>

Table 6: Catalogue of macroeconomic scenario assumptions made in the modelling process

[22] Data retrieved from US Federal Housing Finance Agency and Haver Analytics

[23] Retrieved from Oxford Economics dataset: Department for Communities for Local Government, UK, Statistisk Sentralbyra, Norway, and Bureau of Statistic, Australia

[24] The most inflated property markets worldwide (Source: IMF Global Housing Watch)

[25] Retrieved from Oxford Economics dataset: Wall Street Journal and Haver Analytics

[26] A. W. Throop, (1992). *Consumer Sentiment: Its Causes and Effects*

[27] R. J. Shiller, G. A. Akerlof, (2009). *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton, NJ: Princeton University Press.

Oxford Economics Global Economic Model

We use the Oxford Economics Global Economic Model (GEM), a quarterly-linked international econometric model, to examine how the global economy reacts to shocks of various types. It is the most widely used international macroeconomic model with clients including the IMF and World Bank.

The model contains a detailed database with historical values of many economic variables and equations that describe the systemic interactions among the most important 47 economies of the world. Forecasts are updated monthly for the 5-year, 10-year and 25-year projections.

The Oxford GEM is best described as an eclectic model, adopting Keynesian principles in the short-term and a monetarist viewpoint in the long-term.

In the short-term, output is determined by the demand side of the economy; and in the long-term, output and employment are determined by supply side factors. The Cobb-Douglas production function links the economy's capacity (potential output) to the labour supply, capital stock and total factor productivity. Monetary policy is endogenised through the Taylor rule, when central banks amend nominal interest rates in response to changes in inflation.

Relative productivity and net foreign assets determine exchange rates and trade is the weighted-average of the growth in total imports of goods (excluding oil) of all remaining countries. Country competitiveness is determined from unit labour cost.

Assumptions and uncertainty

The economic estimates presented in this analysis are subject to the assumptions imposed during the narrative development and how the scenario unfolds over time. The modelling and analysis completed are also subject to several sources of uncertainty.

A best attempt has been made to ensure the macroeconomic interpretation of the narrative is justified on historical grounds and follows sound macroeconomic theory and principles. However, the unusual and unprecedented nature of this particular catastrophe introduces several layers of uncertainty in final model outputs that cannot be completely ruled out.

Macroeconomic modelling of the scenario

The Global Property Crash scenario is triggered by a series of events that start the endogenous wide collapse of inflated property bubbles within the emerging markets.

While China was seen as the one of the fastest growing amongst the emerging economies with its rapidly developing manufacturing base and extremely ambitious infrastructure development, India concurrently maintains the world's largest hub for information technology services.

Other emerging markets like resource-rich Brazil correspondingly accelerate together by providing the raw materials needed for the formers' fast-paced urbanisation and development.

Table 7: Key input variables and their maximum shocks applies to the respective scenario variants

S/N	Input Variable	Scenario Variants			Max. Shock duration applied
		S1	S2	X1	
1	House Price Index	-30%	-60%	N/A	4 Qtrs
2	Share Price Index	-8%	-12%	N/A	8 Qtrs
3	Market Confidence	-50	-70	N/A	4 Qtrs
4	Affected Countries				
	Tier 1: China & Emerging Markets	√	√	√	
	Tier 2: Commonwealth	√	√	√	
	Tier 3: Nordics	√	√	√	
	Tier 4: UK	√	√	√	
	Tier 5: Europeans	√	√	√	
	Tier 6: Other Europe	√	√	√	
	Tier 7: US		√	√	
	Tier 8: Prudent Europe		√	√	
	Tier 9: Industrial Asia		√	√	

Hence, it was not long before emerging market asset bubbles began to inflate as a result of global carry trades[28], where investors borrow heavily from deflation-prone countries with near-zero interest rates (for example, the United States and Japan) to invest in non-deflation-prone economies of the emerging markets. Subsequently, signs of over-heating were observed in Canada and Australia, inflated for similar reasons as the emerging markets bubble expands.

The emerging markets bubble pops as soon as the inflated asset and commodities prices deviate too much from their fundamental value such that they can no longer sustain themselves. The fallout from the collapse sees residential sales in the emerging markets fall by up to 18%, year over year. The contagion spreads from the emerging markets and the shake-up destabilises the international property market, causing rapid asset depreciation in the most inflated markets first.

The domino-effect impacts international financial and banking systems, causing correction shocks to both mortgage (housing) and non-mortgage asset (equity) prices. Following the housing market collapse in the over-inflated emerging markets the contagion spreads and affects both mortgage and non-mortgage asset prices in the Commonwealth, Scandinavia, the UK, Europe, and beyond.

Variable Descriptions

Using the Oxford GEM, two independent variants of this scenario are modelled: S1 and S2. Each variant is modelled to provide sensitivity around the different assumptions being made across the scenario. The severity of the shock applied in each scenario is listed in Table 7, giving changes in the magnitude of the shock and the extent of spatial impact across each of the variants.

Results

The effects of the housing and equity price collapse are not confined by asset class or region. Contagion quickly spreads across continents through cross-border financial integration and affects all asset classes.

Typically, changes in asset prices affect the aggregate demand in the macroeconomic associations through a variety of channels: (1) reduction in household wealth and hence consumption, (2) depreciation of market-value of the capital stocks held, (3) capital flows and (4) psychological effects such as a shock to market confidence.

[28] M. Patterson, "Roubini Says Carry Trades Fueling 'Huge' Asset Bubble", *Bloomberg*, 27 October, 2009

A caveat is that this analysis via GEM does not account for extraordinary intervention by national governments to stabilise their real estate, equity, or banking markets. The macroeconomic indicators of the catastrophe that we track, to follow, can be viewed as economic fundamentals of the shock that could be masked by governments whose actions would dampen economic disruption by spreading its effect over a longer period without, ultimately, restoring the cumulative lost value.

In particular, our GDP@Risk estimates, which represent economic losses that accumulate in the half decade after the shock, may be better viewed as estimating longer term cumulative losses where the time frame of accumulation depends on the action of national governments and their institutions such as central banks.

Due to the model constraint to limited country-specific results, the macroeconomic analysis is reported by representing each country tiers by one major economy that is modelled and reported by the Oxford Economics' GEM.

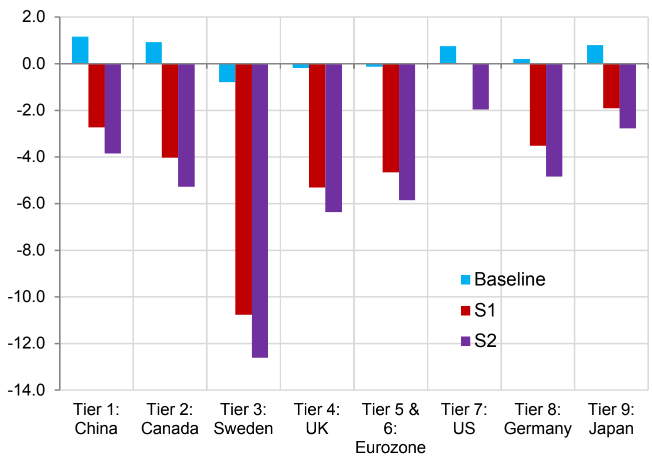

Figure 9: Minimum inflation rates (% year) comparison

Impact on regional inflation rates

The reduction of aggregate demand directly decreases confidence and production levels, contracting credit to create downward pressure on prices leading to a deflationary spiral.

Figure 9 compares the change in inflation rates from baseline across the affected regions and scenario variants. The baseline condition depicts the corresponding inflation rates of each region before the global property crash. Inflation rates fall progressively, resulting in deflation across all countries experiencing deflation in the scenario variant S2.

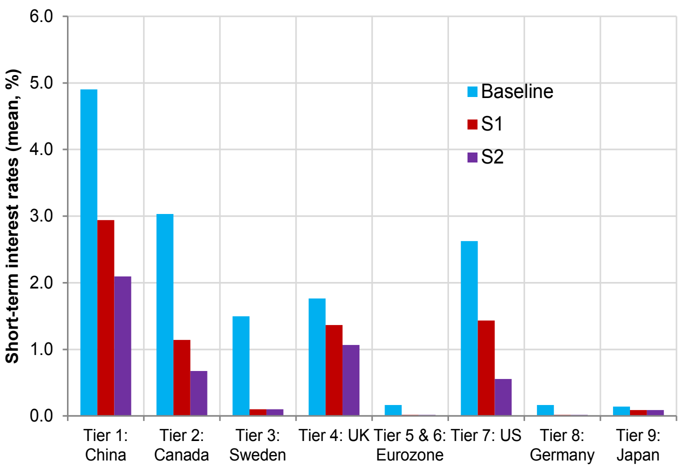

Figure 10: Average short-term interest rates (%) comparison

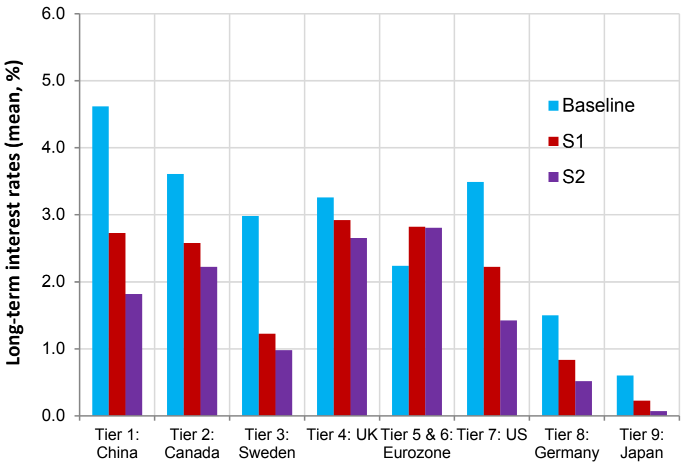

Figure 11: Average long-term interest rates (%) comparison, change from baseline

Impact on interest rates

Figure 10 shows a sharp drop in the interest rate for each of the major economies where interest rates are non-zero (i.e. China, Canada, Sweden, UK, and US), while interest rates in the rest of the world remain near zero throughout the modelling period.

In response to the asset bubble collapse, governments from countries with non-zero interest rates are able to soften the impact by lowering interest rates to encourage borrowing and improve confidence.

Long-term interest rates are usually benchmarked against long-term (e.g. ten years) government bond yields. Contrary to short-term interest rates that are highly correlated with central bank rates, long-term interest rates are tied to many variables, making their projection difficult.

Long-term interest rates consist of both expectations about the future and a risk premium reflecting the uncertainty riskiness of this particular investment. The expectations component is motivated in party by expectations of the inflation rate and future rates of return, which is dependent on future economic growth.

Figure 11 shows a clear reduction in the long-term interest rate for all major economies. The sharp decline in long-term interest rates shows the market has weak long term expectations about future growth. Only the Eurozone experiences an increase in long-term interest rates reflecting the relative safety of the Eurozone as an established market and for attracting global financial capital over the crisis period.

Impact on country credit ratings and government debts

A countries credit rating is an evaluation of its credit worthiness with respect to any foreign currency debt or financial obligation, and is often assessed by a country's ability to repay its debt and the likelihood of sovereign default. While credit ratings are not directly based on mathematical equations, they rely heavily on credit rating agencies' judgement and experience, taking reference from other market indicators.

Table 9 shows the respective credit ratings of the regions affected across all variants of the global property crash.

Table 8: Effect of global property crash on minimum GDP growth rates comparison

Location	Minimum GDP growth rates (% qtr)			Worst Recession Duration (qtrs)	Recession Variants
	Baseline	S1	S2		
Tier 1: China	5.3	-1.6	-2.8	2	S1 and S2
Tier 2: Canada	2.0	-7.6	-9.3	6	S1 and S2
Tier 3: Sweden	1.6	-7.3	-8.2	5	S1 and S2
Tier 4: UK	2.2	-10.1	-12.2	7	S1 and S2
Tier 5 & 6: Eurozone	0.9	-7.1	-8.0	7	S1 and S2
Tier 7: US	2.7	-3.0	-6.0	6	S1 and S2
Tier 8: Germany	1.0	-2.8	-4.1	7	S1 and S2
Tier 9: Japan	-1.2	-2.4	-4.3	7	S1 and S2
World	2.7	-3.5	-4.7	6	S1 and S2

Location	Minimum Credit Rating		
	Baseline	S1	S2
China	AA	BBB	BBB
Canada	AAA	AA	AA
Sweden	AAA	AAA	AAA
United Kingdom	AAA	BB	B
Eurozone	AA	BBB	BBB
United States	AAA	AA	BBB
Germany	AAA	AAA	AAA
Japan	AA	BBB	BB

Table 9: Minimum credit ratings comparison across affected countries and regions

China suffers a downgrade from AA to BBB primarily due to a reduction in foreign direct investment and reduced confidence in the market after the property crash, although its proportion of government debt remains the same.

Other major economies that suffer significant downgrades are: the UK (AAA to B), Eurozone (AA to BBB), the US (AAA to BBB), and Japan (AA to BBB). The downgrades could be attributed to endogenous weak market fundamentals, inflated housing markets, and higher cumulative government debts as a proportion to their GDP (Figure 12).

Countries such as Sweden and Germany both have their credit ratings remain the same throughout the variants, indicating relatively higher credit worthiness and lower overall debt-to-GDP ratios.

Impact on economic growth rates

The technical definition of a recession is two consecutive quarters of negative economic growth. Table 8 represents the minimum GDP growth rates (quarter-on-quarter) across the affected regions.

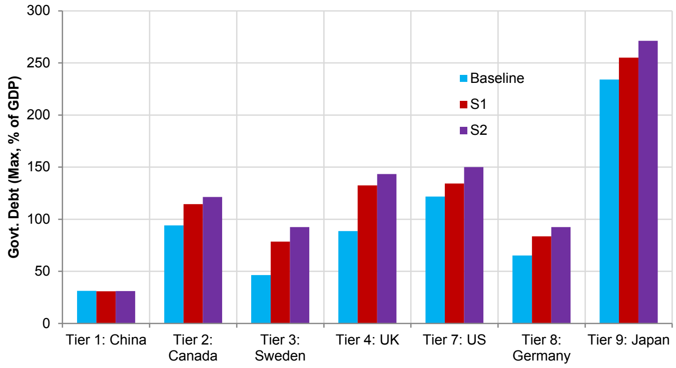

Figure 12: Maximum government debts (% of GDP) comparison, change from baseline

As expected, China is observed to suffer one of the greatest incremental losses, shaving 8% of its quarterly growth rate (from 5.3% to -2.8%) in scenario variant S2.

All other economies suffer significant losses and a global recession develops in this scenario, regardless of the variants. Canada, Sweden, UK and the Eurozone are all particularly affected with growth rates dropping below -8%.

GDP@Risk

The macroeconomic consequences of this scenario are modelled, using the Oxford GEM. The output from the model is a five-year projection of the global economy. The impacts on each scenario variant are compared with the baseline projection of the global economy under the condition of no crises occurring. The difference in economic output over the five-year period between the baseline and each model variant represents the GDP@Risk.

The total GDP loss over five years, beginning in the first quarter of Year 1 during which the shock of the global property crash is applied and sustained through to the last quarter of Year 5, defines the GDP@Risk for this scenario.

Table 10: Global GDP@Risk for the Global Property Crash Scenario variants

	Baseline	S1		S2	
Location	5-yr GDP (US$ Tn)	GDP@Risk (US$ Tn)	GDP@Risk (%)	GDP@Risk (US$ Tn)	GDP@Risk (%)
Tier 1: China	48.4	0.8	1.6%	1.1	2.2%
Tier 2: Canada	9.5	0.4	4.3%	0.6	5.9%
Tier 3: Sweden	2.8	0.1	3.0%	0.1	4.4%
Tier 4: UK	14.0	1.1	8.0%	1.3	9.6%
Tier 5 & 6: Eurozone	67.1	2.9	4.4%	3.7	5.6%
Tier 7: US	88.9	3.0	3.3%	6.1	6.9%
Tier 8: Germany	19.1	0.5	2.8%	0.8	4.1%
Tier 9: Japan	29.3	0.7	2.3%	1.2	4.2%
World	395.0	13.2	3.3%	19.6	5.0%

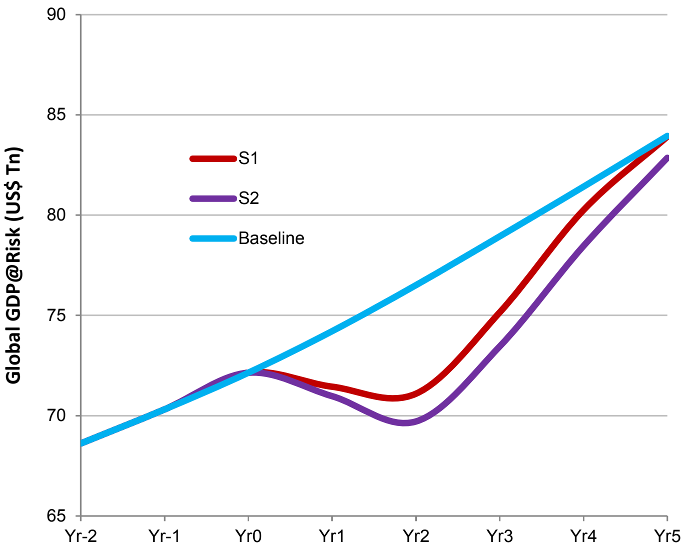

Figure 13: Estimated loss in global output as a result of the Global Property Crash scenario variants

Figure 13 illustrates the dip in global GDP that is modelled to occur as a result of the scenario, across all variants.

Table 10 provides the GDP loss of each of the variants of the scenario, both as the total lost economic output over five years, and as the GDP@Risk.

Economic conclusions

A global property crash of this severity has significant and far-reaching impacts on the global economy: a global recession occurs during the first two years of the shock and, although the financial markets eventually recover, economic output does not recover to the same level as before but suffers a permanent loss.

In this analysis, we have made assumptions regarding how the Global Property Crash would play out: the trigger originates in a few especially vulnerable domestic emerging markets (i.e. highly-inflated real estate markets in China and other emerging economies) and the initial shock then sends tremors through asset markets around the globe.

The shock to the mortgage markets affects the credit ratings of those affected countries whose real estate and equity markets collapse. However, results from the analysis show that some countries' credit ratings are relatively inelastic to moderate changes in global economic output, explained by the favourable government debt to GDP ratio allowing a country to borrow against its earning potential.

Nations with a relatively higher proportion of government debt, coupled with highly inflated property markets, experience the most severe economic consequences.

The result is a global recession with growth rates ranging between -3% and -5% across S1 and S2. The total cost of this scenario to the global economy is estimated between \$13.2 and \$19.6 trillion, of which more than half is attributed to the impact on the US and European economies.

Despite the largest shock applied to the more vulnerable domestic emerging markets (BIC and the emerging economies), Tier 1 - as represented by China in the macroeconomic analysis - illustrates the least economic impact compared to the rest of the country representatives. This observation significantly differs from the global financial modelling analysis presented in the previous chapter, where China was amongst the worst impacted countries while the US is among the least.

A direct comparison cannot be made between both analyses as one measure financial assets (stocks) and the other economic output (flow) and are thus incommensurable. However, this demonstrates that similar shocks to the system bring about very different results in the dynamic stocks and flows of countries.

The permanent global GDP loss indicates that the world economy will never fully return to baseline projections, but is instead reset to a new and lower point from which economic growth eventually resumes at a similar rate.

8 Impact on Investment Portfolio

The macroeconomic effects of the Global Property Crash scenario will cause significant disruption and wipe billions off global capital markets. This section considers the market impact of the scenario and the consequence for investors of capital markets.

The performance of bonds, alternatives and equities in different markets are estimated from the macroeconomic outputs, and compared with a baseline projection of their expected performance that would result from the economic projection in the event the financial catastrophe did not occur.

Valuation fundamentals

Note that this is an estimate of how the fundamentals of asset values are likely to change as a result of these market conditions, as directional indication of valuation. This analysis is not a prediction of daily market behaviour and does not take into account the wide variations and volatility that can occur to asset values due to trading fluctuations, changes in sentiment and the mechanisms of the market.

Passive investor assumption

A fundamental assumption we make in our analysis is that of considering a passive investment strategy. This is a stylised assumption, as we expect an asset manager to react to changing market conditions in order to reduce losses and large fluctuations in returns.

It is however a useful exercise to consider what would happen to a fixed portfolio, in particular because this represents a benchmark against which to compare the performance of dynamic strategies.

Understanding what drives the behaviour of the fixed portfolio at different times gives useful insight towards the design of an optimal investment strategy.

A standardized investment portfolio

We assess the performance of four typical high quality investment portfolios under the Global Property Crash scenario.

We have built a fictional representative portfolio that mirrors features observed in the investment strategies of insurance companies, titled High Fixed Income Portfolio and three others that mirror the investment strategies of pension funds titled Conservative, Balanced and Aggressive.

For example the Conservative Portfolio structure has 55% of investments in sovereign and corporate bonds, of which 95% are rated A or higher (investment grade). Residential Mortgage Backed Securities (RMBS) make up 5 % of the Conservative Portfolio structure.

Investments are spread across the US, UK, Germany and Japan. Equities compose 40% of the Conservative Portfolio. We will assume for simplicity that equity investments correspond to investments in stock indexes. The Wilshire 5000 Index (W5000) , FTSE 100 (FTSE), DAX (DAX) and Nikkei 225 (N225) stocks are used to represent equity investments in the US, UK, Eurozone and Japan, respectively. We assume a maturity of 10 years for long-term bonds, while short-term bonds have a maturity of 2 years in each country.

Details of the High Fixed Income Portfolio are shown on the following page in Table 5, Figure 6, Figure 7 and Figure 8.

Details of the Conservative Portfolio are shown on the following page in Table 12, Figure 17, Figure 18 and Figure 19.

Details of the Balanced Portfolio are shown on the following page in Table 13, Figure 20, Figure 21 and Figure 22.

Details of the Aggressive Income Portfolio are shown on the following page in Table 14, Figure 23, Figure 24 and Figure 25.

High Fixed Income portfolio structure

	USD	GBP	Euro	Yen	Total
Government 2 yr	8%	6%	5%	3%	**22%**
Government 10 yr	8%	7%	6%	2%	**23%**
Corp. Bonds 2yr	4%	4%	4%	2%	**14%**
Corp. Bonds 10yr	6%	7%	3%	2%	**18%**
RMBS 2 yr	2%	1%	1%	1%	**5%**
RMBS 10 yr	1%	1%	1%	1%	**4%**
Equities	2%	3%	3%	2%	**10%**
Cash	4%	0%	0%	0%	**4%**
Total	**35%**	**29%**	**23%**	**13%**	**100%**

Table 11: Composition of the High Fixed Income Portfolio Structure

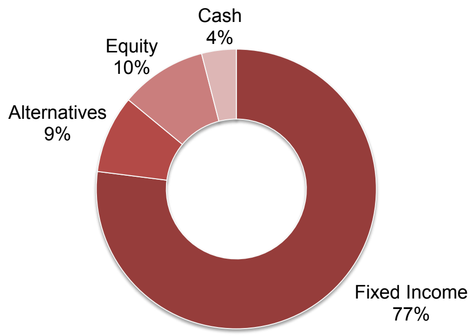

Figure 14: Asset classes in High Fixed Income Portfolio Structure

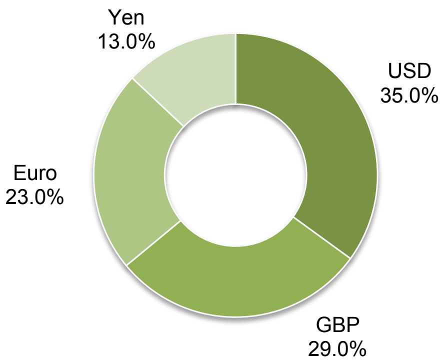

Figure 15: Geographic market spread of High Fixed Income Portfolio Structure

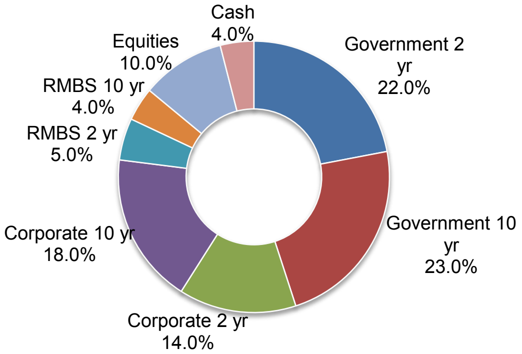

Figure 16: Detailed asset class breakdown of High Fixed Income Portfolio Structure

Conservative portfolio structure

	USD	GBP	Euro	Yen	Total
Government 2 yr	4%	3%	3%	0%	**10%**
Government 10 yr	3%	3%	3%	1%	**10%**
Corp. Bonds 2yr	6%	5%	5%	1.5%	**17.5%**
Corp. Bonds 10yr	6%	5%	5%	1.5%	**17.5%**
RMBS 2 yr	1.5%	0.5%	0.5%	0%	**2.5%**
RMBS 10 yr	1.5%	0.5%	0.5%	0%	**2.5%**
Equities	19%	8%	8%	5%	**40%**
Cash	0%	0%	0%	0%	**0%**
Total	**41%**	**25%**	**25%**	**9%**	**100%**

Table 12: Composition of the Conservative Portfolio Structure

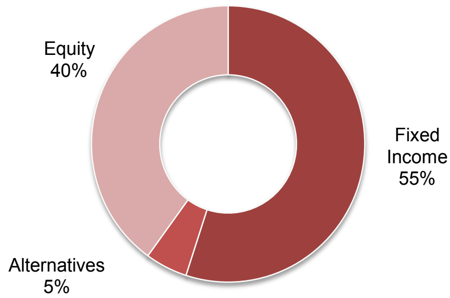

Figure 17: Asset classes in Conservative Portfolio Structure

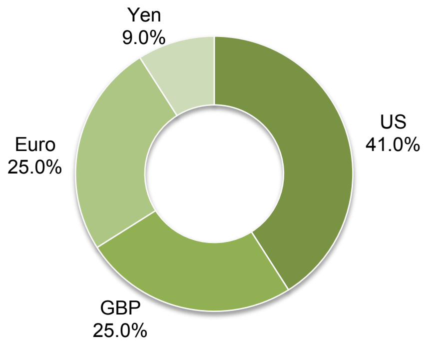

Figure 18: Geographic market spread of Conservative Portfolio Structure

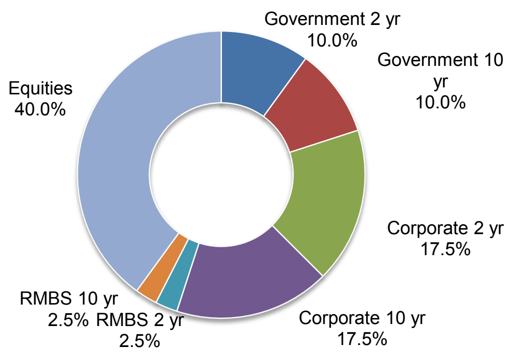

Figure 19: Detailed asset class breakdown of the Conservative Portfolio Structure

Balanced portfolio structure

	USD	GBP	Euro	Yen	Total
Government 2 yr	3%	2%	2%	1%	**8%**
Government 10 yr	3%	3%	3%	1%	**10%**
Corp. Bonds 2yr	4%	3.5%	3.5%	2%	**13%**
Corp. Bonds 10yr	4%	2.5%	2.5%	0%	**9%**
RMBS 2 yr	2.5%	1%	1%	0.5%	**5%**
RMBS 10 yr	2.5%	1%	1%	0.5%	**5%**
Equities	25%	10%	10%	5%	**50%**
Cash	0%	0%	0%	0%	**0%**
Total	**44%**	**23%**	**23%**	**10%**	**100%**

Table 13: Composition of the Balanced Portfolio Structure

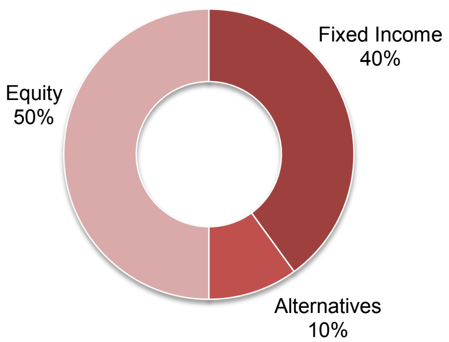

Figure 20: Asset classes in Balanced Portfolio Structure

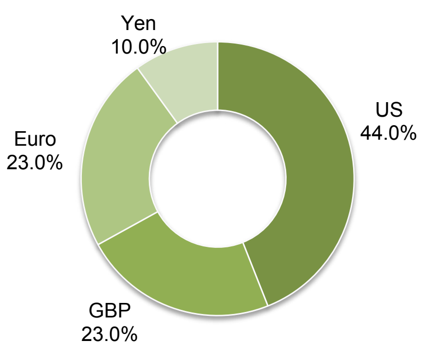

Figure 21: Geographic market spread of Balanced Portfolio Structure

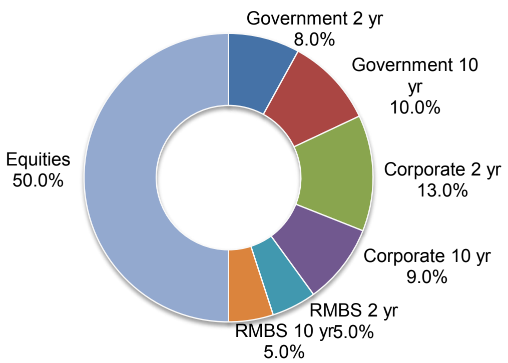

Figure 22: Detailed asset class breakdown of Balanced Portfolio Structure

Aggressive portfolio structure

	USD	GBP	Euro	Yen	Total
Government 2 yr	1.5%	1%	1%	0.5%	**4%**
Government 10 yr	1.5%	1%	1%	0.5%	**4%**
Corp. Bonds 2yr	3%	2.5%	2.5%	0.5%	**8.5%**
Corp. Bonds 10yr	3%	2.5%	2.5%	0.5%	**8.5%**
RMBS 2 yr	3%	2%	2%	0.5%	**7.5%**
RMBS 10 yr	3%	2%	2%	0.5%	**7.5%**
Equities	30%	12%	12%	6%	**60%**
Cash	0%	0%	0%	0%	**0%**
Total	**45%**	**23%**	**23%**	**9%**	**100%**

Table 14: Composition of the Aggressive Portfolio Structure

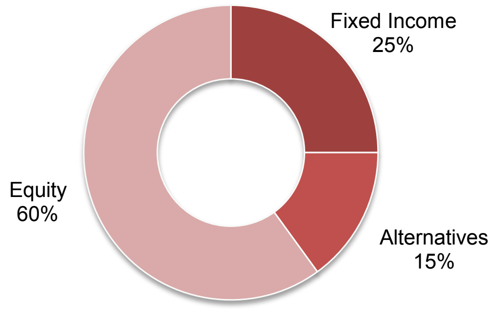

Figure 23: Asset classes in Aggressive Portfolio Structure

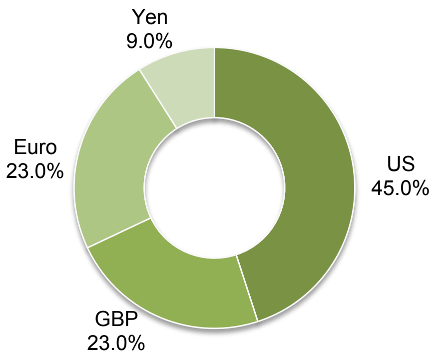

Figure 24: Geographic market spread of Aggressive Portfolio Structure

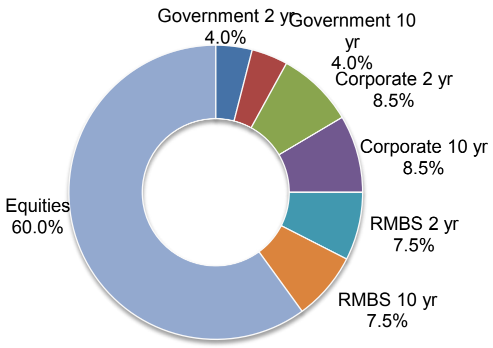

Figure 25: Detailed asset class breakdown of Aggressive Portfolio Structure

Computation of returns

The estimation of portfolio returns is carried out using the following method.

Market price changes or Mark to Market (MtM) are calculated for all government bonds using equation (1) and for corporate bonds and RMBS using equation (2).

(1) $\Delta MtM_{Gov,t} = (D_b)(-\Delta I/100)$

(2) $\Delta MtM_{Corp,t} = (D_b)(-\Delta I/100) + (SD_b)(-\Delta CS/100)$

Where D_b is the bond duration, for which we assumed the following values: D_b =7 for ten years bonds and D_b =1.8 for two years bonds. SD_b represents the spread duration. The change in interest rates, ΔI on government and corporate bonds and the change in credit spreads, ΔCS are taken from the output of the macroeconomic analysis discussed in the previous chapter.

Government bond yields are estimated using a representative quarterly yield while corporate and RMBS yields are estimated using a representative quarterly yield and the period averaged credit spread.

Defaults on corporate bonds are accounted for via a discount factor in the calculations. The 2008 volume-weight corporate default rates from Moody's are shown in Table 9.[1] The 2008 RMBS from S&P are also shown the table.[2] The actual corporate bond and RMBS default rates used were calculated as the weighted average of default rates by credit rating and geographic regions.

Equities market prices are calculated using the change in equity value from the macroeconomic modelling. The equity dividends are estimated using a representative quarterly yield. Exchange rate effects are taken into to account to ensure that all reported portfolio returns are with respect to US dollars.

Bond Credit Rating	Corporate Bonds	RMBS
AAA	0.000%	0.04%
AA	0.816%	0.14%
A	2.370%	0.58%
BBB	1.108%	2.15%
BB	8.097%	6.53%
B	1.287%	15.58%
CCC	11.019%	65.72%

Table 15: Annual default probabilities for corporate bonds and RMBS

[1] Annual Default Study; Corporate Default and Recovery Rates, 1920-2013. Moody's Investor Services. February 28, 2014.

[2] Global Structured Finance Default and Transition Study – 1978-2008. S&P. February 25, 2009.

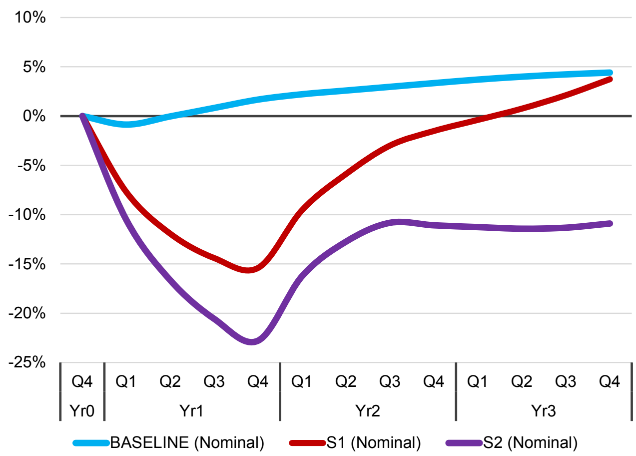

Figure 26: Global Property Crash Scenario Impact by Variant, Conservative Portfolio (nominal %)

Portfolio returns

Results of our analysis are presented in Figure 26, Figure 27, Figure 15 and Figure 16.

Figure 26 shows the scenario impacts by variant for the Conservative portfolio structure. In all variants we observe a significant departure from the baseline (blue line) projections. For the Global Property Crash scenario the economic shocks were applied over a five year horizon with the largest shocks occurring in Yr1. After three years, we see the S1 variant begin to recover, while the S2 variant does not recover. The maximum downturn experienced for the Conservative portfolio in the S1 variant is -15% nominal occurs in Yr1Q4.

Figure 27 shows the scenario variant impacts by portfolio structure. For the Global Property Crash scenario, we see the aggressive portfolio structure underperform compared with the other structures. This implies that investments in heavy equity portfolios will yield the worst returns.

Figure 28 shows market impacts on equity performance by geography for the least extreme variant, S1. Although, all the stocks are performing poorly, the UK (FTSE 100) stock is impacted the most. Interestingly, the US, Euro and Japanese stock indexes starts generating small positive returns towards the end of the three years.

Figure 29 shows the market impact on fixed income performance by geography for the least severe variant, S1. Over the three year analysis window, Japan Fixed Income is impacted the most, yielding the largest negative returns. The US fairs the best, specifically in years two and three. The largest negative impact to a single equity index is greater than 70%, while equities only factor 5% of the fixed income portfolio, the impact from equity markets on a fixed income portfolio is marginal. This confirms the finding that a high fixed income portfolio performs better than a high equity structure.

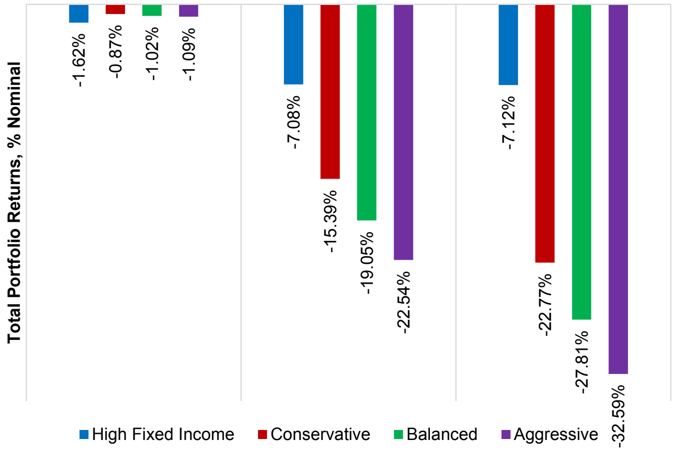

Figure 27: Global Property Crash scenario max downturn by portfolio structure in nominal %

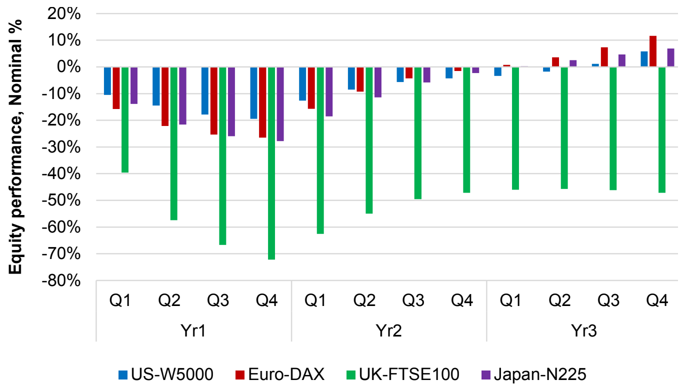

Figure 28: Global Property Crash equity performance by geography in nominal % for S1

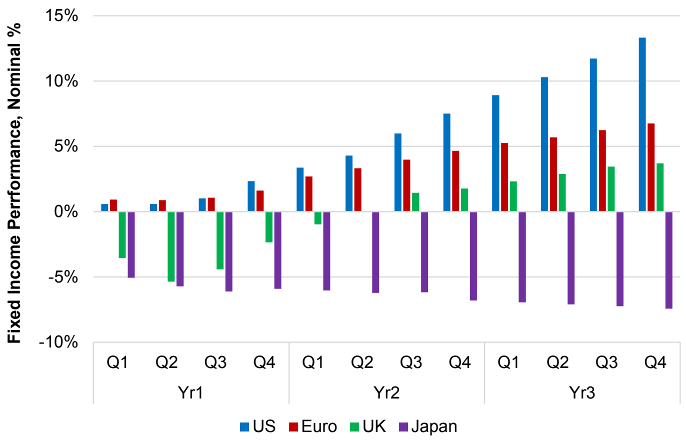

Figure 29: Global Property Crash Fixed Income portfolio performance by geography in nominal % for S1

Correlation Structure

A new market analytics tool called Financial Network Analytics (FNA) is used to monitor market dynamics for each scenario. A daily correlation map was created for a pre-scenario and post-scenario view, see Figure 30 and Figure 31.

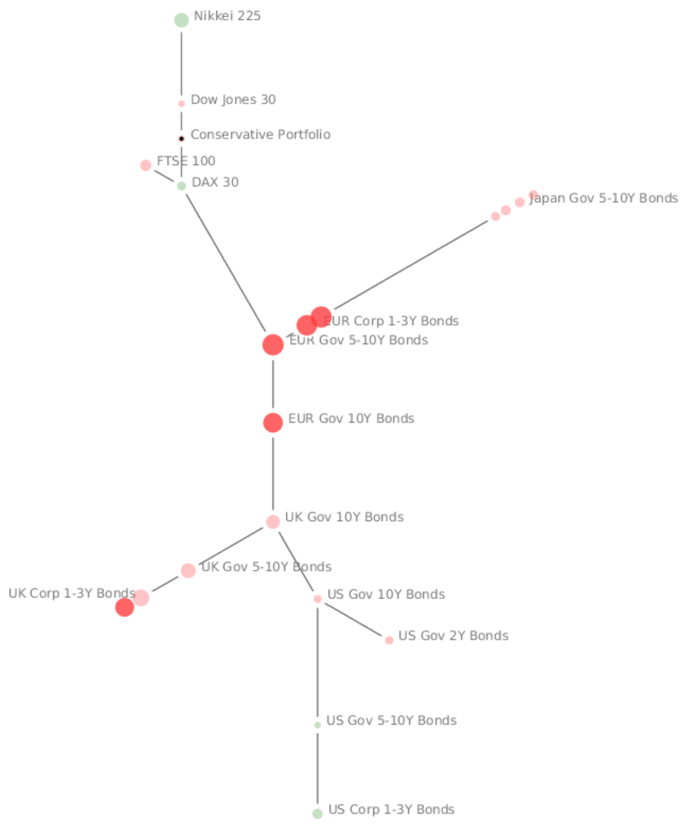

Figure 30: Conservative portfolio before stress test

Figure 31: Conservative portfolio after S2 stress test at Yr1Q2

Assets in the Conservative portfolio are shown as nodes and the correlations are shown as links. Shorter links represent strong correlations. The size of the nodes represent asset returns in relation to the portfolio, the larger the node the larger the return. Nodes that are coloured red represent a negative correlation and thus negative asset returns.

Summary of investment portfolio analysis

The performance four different portfolio structures are now compared using the outputs provided by the Oxford Economics Model. We have estimated the performance of the portfolio under different variants of the Global Property Crash scenario and compared it with the business as usual performance or baseline. The Aggressive portfolio structure performs worst for both scenario variants, with a loss of -23% and -33% respectively. Table 16 summarises the maximum downturn by portfolio structure and scenario variant.

The portfolio analysis assumes a passive investment strategy. Nonetheless, it represents a useful benchmark to compare additional asset management strategies. In particular, it can be used to discuss strategies that improve portfolio performance on a counterfactual basis for each scenario.

An important issue that we have yet to address in our analysis is that of systematically testing the stability of the results with respect to the parameter settings used in the earlier stages of the scenario development. To a certain degree this is taken into account with each of the different scenario variants, but the analysis would also benefit from a more systematic sensitivity analysis for each of the primary variables used in the model.

	Baseline	S1	S2
High Fixed Income	-2%	-7%	-7%
Conservative	-1%	-15%	-23%
Balanced	-1%	-19%	-28%
Aggressive	-1%	-23%	-33%

Table 16: Summary of portfolio performance (max downturn) by structure and scenario variant, nominal %.

REAL USD PERCENTAGE VALUES		Baseline Yr1Q4	Short-Term Impact at Yr1Q4		Baseline Yr3Q4	Long-Term Impact at Yr3Q4	
			S1	S2		S1	S2
US							
Gov Bonds Short	2 yr	-1%	0%	0%	-6%	3%	5%
Gov Bonds Long	10 yr	-1%	2%	2%	-9%	15%	17%
Corp Bonds Short	2 yr	0%	1%	1%	-2%	7%	8%
Corp Bonds Long	10 yr	1%	3%	2%	-4%	21%	22%
RMBS Short	2 yr	0%	1%	1%	-2%	8%	9%
RMBS Long	10 yr	0%	3%	1%	-6%	20%	21%
Equities	W5000	8%	-20%	-39%	15%	4%	-36%
UK							
Gov Bonds Short	2 yr	-5%	-2%	-2%	-9%	10%	12%
Gov Bonds Long	10 yr	-6%	-2%	-2%	-13%	11%	13%
Corp Bonds Short	2 yr	-4%	-1%	-1%	-8%	12%	15%
Corp Bonds Long	10 yr	-5%	-1%	-1%	-11%	14%	16%
RMBS Short	2 yr	-5%	-1%	-1%	-8%	13%	16%
RMBS Long	10 yr	-6%	-1%	-1%	-12%	13%	16%
Equities	FTSE100	5%	-72%	-73%	24%	-43%	-49%
EU (Germany)							
Gov Bonds Short	2 yr	0%	-5%	-5%	-2%	1%	4%
Gov Bonds Long	10 yr	0%	-4%	-4%	-7%	5%	8%
Corp Bonds Short	2 yr	2%	-4%	-4%	2%	4%	7%
Corp Bonds Long	10 yr	3%	-3%	-4%	-1%	11%	13%
RMBS Short	2 yr	-5%	-4%	-4%	-8%	6%	9%
RMBS Long	10 yr	-5%	-3%	-4%	-12%	11%	13%
Equities	DAX	3%	-26%	-46%	12%	18%	-21%
Japan							
Gov Bonds Short	2 yr	-9%	-8%	-8%	-18%	-8%	-7%
Gov Bonds Long	10 yr	-8%	-6%	-7%	-20%	-6%	-4%
Corp Bonds Short	2 yr	-9%	-8%	-8%	-18%	-9%	-7%
Corp Bonds Long	10 yr	-8%	-7%	-7%	-20%	-6%	-5%
RMBS Short	2 yr	-9%	-8%	-8%	-16%	-8%	-7%
RMBS Long	10 yr	-8%	-6%	-7%	-17%	-6%	-4%
Equities	N225	-2%	-29%	-47%	-5%	7%	-25%

Table 17: Global Property Crash summary of asset class performance by scenario variant and geography, in real %.

9 Mitigation and Conclusions

In the Global Property Crash Scenario, reducing or limiting exposure to the property markets of Australia, Belgium, Brazil, Canada, China, New Zealand and Norway is key to weathering the onset of this investment storm. Other countries with high house prices relative to both income and rental rates, such as the UK, are also at risk from joining the cascade of bursting property bubbles.

The wider macroeconomic impact of this event is likely to impact adversely on any nation with relatively high ratios of government debt to gross domestic product. By this measure there is a wide variety of safer countries such as Indonesia, Sweden, South Korea, Turkey, and many in Central and South America, the Middle East and North Africa.

Financial portfolios heavily invested in US and UK bonds tend to perform better and are more stable portfolios invested heavily in property and equity markets.

UK equities experience catastrophic losses over several years; while other geographies are only affected in the first year of the crisis but gradually move from red back to black, with the strongest performance from German stocks (DAX). Japanese bonds are particularly badly affected over a three year period with UK bonds also suffering heavy losses in the first three quarters of the catastrophe. The two main conclusions are not surprising. The first is the relative safety of established markets particularly government bonds, while the second is the imperative to have diverse holdings whether in fixed income, equities or business markets.

An asset bubble burst is typically thought of as a leading event that is followed by collateral damage in the financial markets and relevant sectors of the economy.

Beyond macroeconomic ratios mentioned above, factors that may lead to housing bubbles include an increase in the population or the demographic segment of the population entering the housing market; low interest rates, particularly short-term interest rates that are reflected in the mortgage rate; and more generally, easy access to credit in the form of a lowering underwriting standards.

Such early warning signals can be monitored in real time. Acting on these signals poses a risk in itself since moving too early can be as damaging as moving too late. This is a reminder of why warning signs are inputs to what are only palliative or damage mitigation tools rather than complete solutions to catastrophic threats. Indeed we advocate that recognition of catastrophic events entails recognition of substantial losses, especially in the short term.

Stress tests such as the Global Property Crash Scenario balance magnitude of impact and likelihood of that impact, and facilitate questions such as, “Is my organisation able to withstand a 1-in-100 year catastrophe?” and “What would I do to improve the resilience of my organisation to such a shock?”

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