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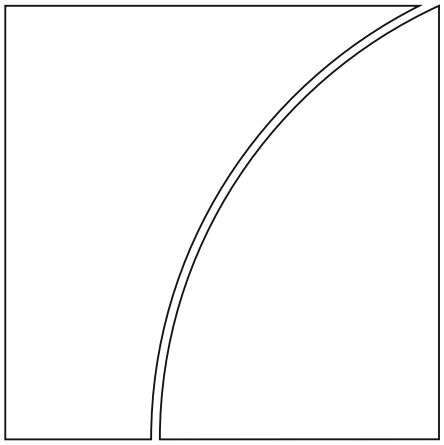

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A disaster under-(re)insurance puzzle: Home bias in disaster risk-bearing

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A disaster under-(re)insurance puzzle: Home bias in disaster risk-bearing

Hiro Ito and Robert N McCauley[1]

Abstract

The losses from the 2011 earthquakes in Japan remained in Japan, while reinsurance spread the losses from that year's New Zealand earthquake to the rest of the world. This paper finds that the Japanese case is more typical: losses from natural disasters are shared internationally to a generally very limited extent. This finding of home bias in disaster risk-bearing poses a puzzle of international risk-sharing. We decompose international risk-sharing into the portion of losses insured and the portion of insurance that is internationally re-insured. We find that the failure of international risk-sharing begins at home with low participation in insurance. Regression analysis points to economic development and institutional/legal quality as important determinants of insurance participation. We propose a new method to measure international reinsurance payments with balance of payments data. This method identifies for the first time the cross-border flow of reinsurance payments to 88 economies that experienced insured disasters in the 1985–2017 period. Regression analysis of these data points to small size and de facto financial integration as positively related to the reinsurance share, as one might expect. However, we also find that more internationally wealthy economies reinsure less, suggesting that net foreign assets substitute for international sharing of disaster risk. For advanced economies, a lack of international risk-sharing is correlated with a lack of fiscal space. Thus, the governments under more pressure to provide ex post government insurance through the budget have less room to manoeuvre to do so. At high levels of public debt, a lack of ex ante insurance can turn disaster risk into financial risk.

JEL classification: F32, G15, G22, Q54

Keywords: international risk-sharing; earthquake insurance; reinsurance

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Contents

1. Introduction

The magnitude 9.0 Great East Japan Earthquake and tsunamis in March 2011 wreaked havoc on Japan's economy and roiled financial markets. The direct cost of the earthquake is estimated to have been $225 billion, 4% of Japan's GDP, or over 1% of national wealth and about 6% of Japan's net international investment position.[2] Technically, this earthquake numbered among the strongest ever recorded, but it could have done much more damage had it struck a more populated region.

Ex ante risk-sharing was surprisingly small, leaving the government as the ex post insurer. Only 16% of the direct cost was covered by earthquake insurance. Instead, the central government's budget bore the burden of the uninsured cost.[3] Despite special taxes, its debt rose substantially.

The international bearing of the $18 billion of losses (10.7% of GDP) from the New Zealand earthquake that year offers a striking contrast. There, government-provided insurance is a "de facto compulsory" (Nguyen and Noy (2017)) add-on to fire insurance policies that mortgage lenders require. As a result, over 90% of households participate and 70% of losses were insured. We estimate that 60% of insured losses were in turn re-insured, so that almost half of the losses were borne by the rest of the world.

The New Zealand result is closer to an ideal type of international risk-sharing. In theory, disaster insurance improves welfare if it is priced not too much above the actuarily expected loss (Ehrlich and Becker (1972); Borensztein et al (2017)). In particular, investors in places where earthquakes do not happen should be willing to shoulder much of the risk of earthquakes around the Pacific at a price, leaving both parties better off. In a world of perfect risk-sharing, Japan should keep less than 10% of its earthquake risk (since its economy is less than a tenth of the global economy)[4] and pass on 90% to the rest of the world. In 2011, however, reinsurance paid not for nine-tenths, but much less than one-tenth, of Japan's losses.

We find that Japan's case is more normal than New Zealand's. This is, to our knowledge, a new finding. On average, no more than 4.8% on a dollar-weighted basis or 4.9% on an unweighted basis of disaster losses in 1980–2017 were shared internationally. This is based on a novel estimation method based on balance of payments data that admittedly misses many small disasters.

This finding of home bias in disaster risk-bearing poses a puzzle of international risk-sharing. To make progress, we decompose international risk-sharing into two components and separately analyse them.

As an identity, the ratio of reinsured losses to total losses is the product of the portion of losses insured and the portion of insurance that is internationally re-insured (equation 1). This decomposition is useful in that comprehensive industry

[2] This is an insurance-type estimate of the direct losses. It does not include the cost of shutting down Japan's nuclear power generators for years and the consequent cost of fuel imports.

[3] The state where disaster risk is not highly insured because individuals anticipate to receive financial assistance from the government or aid from the private sector is known as "charity hazard" (Raschky and Weck-Hannemann (2007)).

[4] If Japan's GNP or the theoretically most appropriate share of global wealth rather than GDP are used to set the benchmark, then the warranted reinsured share would be lower.

data (eg Munich Re's NatCatSERVICE database) can be brought to bear on the first ratio. Our laborious estimation of the reinsurance rate is then performed for a smaller sample.

(1) International risk-sharing
= [insured losses/total losses] x [reinsured losses/insured losses]

The failure of international risk-sharing begins at home with low insurance coverage. Regression analysis of industry data points to economic development and institutional/legal quality as important determinants of insurance participation.

We develop a novel methodology to measure the reinsurance rate for major disasters. We start with data on insurance losses from disasters reported by industry sources, as compiled in Munich Re. After identifying the quarter of each disaster, we inspect IMF-collated balance of payments to identify reinsurance payments. This inspection is laborious owing to accounting diversity (explained in Appendix 2).

Despite the limitations of these data, they unambiguously point to surprisingly little of the insured losses being reinsured. Why? Regression analysis points to small economic size and de facto financial integration as positively related to the reinsurance share, as expected. However, we also find that more internationally wealthy economies reinsure less, suggesting that net foreign assets substitute for international sharing of disaster risk.

This third finding is new and arguably more surprising in view of the institutional nature of the decision to reinsure, as opposed to the household or firm-level decision to insure. The reinsurance market brings together professionals who are described as practicing Bayesians by Jarzabkowski et al (2015), at least less subject to the heuristic biases that may limit household or business participation in insurance (see below). Where insurance markets are oligopolistic and insurers end up well-capitalised, we are told that it is not easy to sell re-insurance. But this account is not altogether satisfactory.

That said, it turns out that the low insurance coverage of disasters – the failure at home – makes the failure of international risk-sharing inevitable. If only a tenth of California households sign up for the earthquake insurance that state law requires insurers to offer (Marshall (2017)), then no amount of reinsurance purchased by the California state agency can achieve international risk-sharing of more than a tenth!

We conjecture that government compulsion or creditor/insurer requirement may be a necessary condition to take participation insurance against infrequent disasters up to high rates. This may hold particularly for earthquake insurance. Japan's participation rate in such insurance has been low ever since compulsion was ended years ago. As noted, the less intrusive California legal requirement that every home-owner insurance policy offer earthquake insurance leaves the participation rate low (Marshall (2017)).

High participation evidently would not suffice to lead to appropriate extent of reinsurance, however. Where public agencies have taken on the insurance role, their design and bureaucratic incentives seem to play an important role in explaining the extent of risk re-insured.

We contribute to the literature in our analysis of both insurance coverage and the reinsurance rate. To our knowledge, we are the first to attempt to measure the extent of international sharing of disaster risks. Oddly enough, industry data bases do not include measures of the extent of reinsurance. It is well-known in the insurance

literature that insurance participation and coverage varies across countries, time and hazards, but to our knowledge we are the first to econometrically analyse coverage by disaster type.[5]

Somewhat related work is the estimation of the macroeconomic cost of disasters. Noy (2009) assesses the macroeconomic cost of disasters and Borensztein et al (2017) measure the permanent loss in the level of GDP that results from natural disasters in a sample of mostly small, tropical countries. Building on Noy (2009), von Peter et al (2012) distinguish the macroeconomic impact of insured and uninsured losses. Their design presumes but does not explain heterogeneity in the extent of insurance. We analyse a waterfall: how much is insured, and how much of that is internationally reinsured.

Methodologically, we should note that this empirical exercise is conducted in a highly exogenous setting, which is rare in empirical international macroeconomics. The shock that hits is a natural disaster, whose incidence is not affected by the ex ante risk-sharing. As a result the problem of endogeneity in the estimation model does not arise.

The rest of the paper is organised as follows. Section 2 lays out our central finding of low international risk-sharing. Section 3 then decomposes the reinsurance as a ratio of losses into the insurance coverage and the share of insurance reinsured, arguing that the domestic failure of coverage dominates the overall failure of international risk-sharing. Section 4 reports regression analysis of the insurance coverage; Section 5 reports regression analysis of the re-insurance ratio. Section 6 concludes with policy implications, drawing attention to the accumulating risks of a lack of reinsurance given already high levels of government debt. We also will raise important questions for future research pertaining to the international sharing of natural disaster risks.

2. The limited extent of international risk-sharing

An ideal, textbook view of the international sharing of disaster risk posits full insurance in which all risks are insured and then re-insured internationally to the extent necessary to spread the risk-bearing evenly across countries. This view would imply nearly 100% international disaster risk-bearing for small economies, and about 80% and higher such risk bearing for large countries. Large economies' size allows them to retain some of the risk of their own disasters, even as the risks are spread evenly across the globe.

(2) international risk-sharing gap = s* - i*r,

where ***s**** is one minus country *j*'s share of global GDP, ***i*** is the insured losses/total losses, and ***r*** is the reinsured losses/insured losses.

Admittedly, this ideal neglects pervasive features of insurance, including deductibles and co-pays. It is still useful as a benchmark, and indeed the deviations observed from it cannot be ascribed to such features.

[5] Kunreuther and Michel-Kerjan (2014) review the many explanations for low insurance coverage..

In this ideal world, once a disaster struck, the rest of the world would remit 80% or more of the losses. The disaster-hit country would have experienced a loss in some portion of its domestic capital stock, but a nearly equal improvement would soon be felt in its international financial accounts. Its net international investment position would rise by the amount of the reinsurance receipts. This improvement would offset any deterioration of the trade or services accounts occasioned by the damage and reconstruction (see Appendix 3).

We measure international risk-sharing through institutional means, that is, through insurance and re-insurance companies, not through a country's international portfolio. In principle, international assets and liabilities could provide de facto insurance to a significant extent. We doubt it, however. The outstanding securities known as catastrophe bonds are small in aggregate and are mostly issued by insurers to lay off risk, rather than eg by governments. Equity holdings by non-residents could in principle share disaster risk with the rest of the world. But home bias suggests that domestic residents sustain the bulk of any losses. Exchange rate depreciation after a disaster would increase domestic wealth in countries that are long foreign currency assets and short domestic currency assets (Bénétrix et al (2015)). But in the large cases that we have examined, depreciation does not occur with any consistency. Indeed, in Japan, the yen tends to appreciate in the wake of an earthquake. Such appreciation goes in the opposite direction from insurance, reducing both external net assets and domestic stock market wealth (on the foreign earnings translation effect).

How does the real world compare to this ideal type? Consistent with Equation 2 above, we require data on the size of the economy, the share of losses that was insured in each disaster, and the share of insured losses that were re-insured.

For total losses and the portion insured, we rely on a proprietary database called the NatCatSERVICE database. This is compiled by Munich Re, a leading global insurance and reinsurance group (see Appendix 1 for all data definitions and sources). To cross-check these data, we analyse the so-called EM-DAT database compiled by the Centre for Research on the Epidemiology Disasters (CRED) based at the Catholic University of Louvain in Belgium.

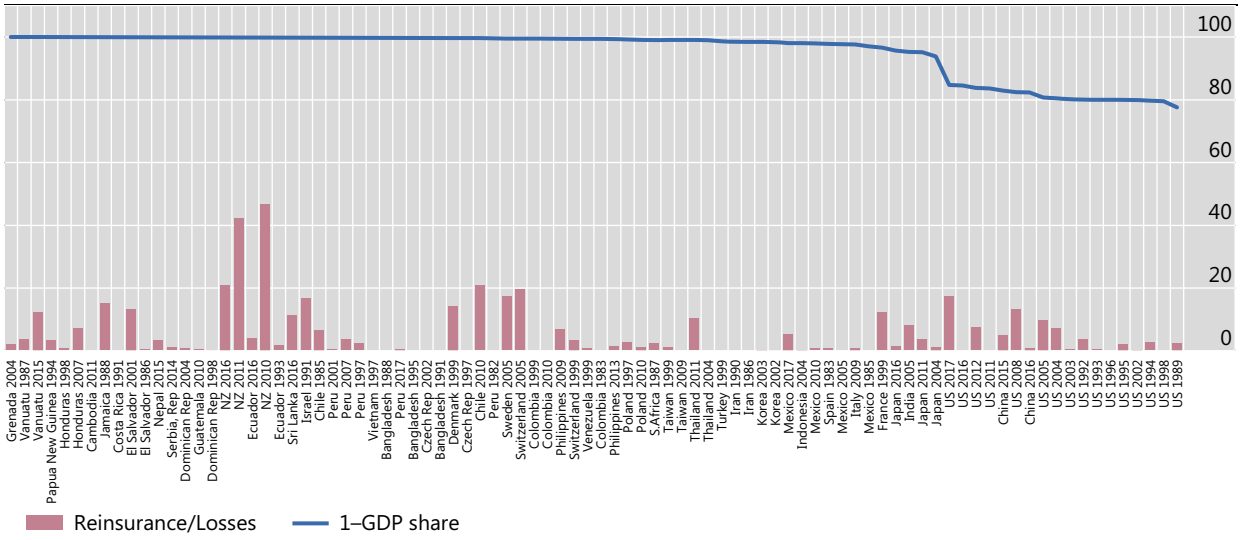
For the share of insured losses that was paid by international reinsurance, we turn to the balance of payments. Whereas any industry source would be unlikely to distinguish between the residence of re-insurers, our balance of payments measure only captures cross-border flows of re-insurance payments. For full details of their balance of payments treatment, see Appendix 2; what follows offers a minimal description of our method.

Under recently adopted balance of payments accounting, large payments on re-insurance are registered as a *capital account transfer*. The capital account is the new name and place for stock-flow discrepancies, such as debt forgiveness. (Most of what used to be called the capital account is now termed the financial account.) Debt forgiveness was thought to be a one-off adjustment to the stocks of debt that did not fit with current account transfers of a recurring nature, like workers' remittances or inter-governmental aid. Similarly, while reinsurance payments associated with normal levels of claims continue to appear in current account transfers, reinsurance associated with major disasters now are treated as a stock-flow discrepancy. After all, it was reasoned, major disasters make calls on stocks of reserves rather than just the flow of premia.

Shortfall of reinsurance coverage of disaster losses relative to a CAPM-type ideal distribution of risk

In per cent

Graph 1



Sources: IMF, *Economic Outlook Database*; Authors' estimations.

This new accounting treatment facilitates our measurement of reinsurance through the balance of payments. Capital account transfers are sparse, so the appearance of inflows on this account in the quarter or quarters after a natural disaster provides a strong indication of a flow of reinsurance payments. Thus, we use the flows of capital account transfers in the quarters after a disaster to measure reinsurance payments.

Unfortunately, statisticians in many jurisdictions have not shifted major reinsurance payments from current account transfers to capital account transfers. As a result, we use *changes* in the current account transfers to measure reinsurance receipts for such jurisdictions. These data are of lower quality because the baseline of current receipts is not zero, and re-insurance receipts must be estimated as differences from this baseline.

Using the NatCatSERVICE data and this measure of international reinsurance flows in the balance of payments, we can juxtapose textbook international risk-sharing and the reality of disaster insurance. Graph 1 plots the fraction of economic losses that were re-insured against our text book norm of practically 100% risk-sharing for small countries, falling to around 80% for the United States. Thus Graph 1 orders the disasters from smallest to largest countries hit. We observe that the international sharing of economic losses varied enormously, but is generally low.

New Zealand is an outlier on the high side, with almost 50% reinsurance of losses from the 2010 and 2011 earthquakes. Coverage of the de facto compulsory earthquake insurance and private add-ons are high, as is the propensity of the government earthquake agency to lay the risk off in the international re-insurance market. Nguyen and Noy (2017) describe the 2010–11 Canterbury Earthquake as "one of the most insured large disasters in history". We can take this description one step further and say that it was possibly the most reinsured large disaster in history.

In this near textbook case, reinsurance buoyed New Zealand's external wealth as external assets largely replaced the destroyed domestic capital stock. New Zealand's reinsurance receipts did wonders for its big net external debtor position. Its net international liability of 62.5% of GDP as of the first quarter of 2011 represented an improvement compared to the previous quarter by 8.5 percentage points, three quarters from the jump in international reinsurance claims (see Appendix 3). Of course, the sudden improvement in New Zealand's external accounts was just the counterpart of losses to the domestic capital stock and the reinsurance receipt would fund extraordinary imports arising from reconstruction activity. But going forward, New Zealand had to pay up to lay off its earthquake risks as its premia payments in the services account about tripled (see Appendix 4 for a typology of other effects of disasters on the balance of payments).

Elsewhere international sharing of disaster losses is conspicuously small. On average, international re-insurance paid only 4.9% of total losses (Table 1, first row). Looking across the unweighted mean, the mean weighted by GDP or dollar losses, and median, the reinsurance share tends to be higher for advanced economies (second versus third rows).

Summary statistics on three ratios

Table 1

	Group	N	# of Countries	Mean	Weighted Mean (GDP)[1]	Weighted Mean (Losses)[2]	Median	S.D.	Min	Max
Reinsurance as a share of total losses (%)	FULL	88	43	4.9	4.8	7.5	1.3	8.2	0.0	46.7
	AE	29	9	8.7	5.1	8.0	3.5	11.9	0.0	46.7
	EME	59	34	3.1	2.9	5.4	0.8	4.7	0.0	20.8
Insured losses as a share of total losses (%) (large sample)	FULL	138	60	18.4	32.5	27.7	10.7	19.5	0.1	80.8
	AE	44	13	33.2	39.7	34.6	33.6	23.9	0.3	80.8
	EME	94	47	11.5	6.7	9.9	6.3	12.0	0.1	50.0
Insured losses as a small share of total losses (%)[3] (small sample)	*FULL*	88	43	24.1	37.4	35.0	19.7	20.2	0.1	80.8
	AE	29	9	42.9	41.9	39.4	46.9	19.6	3.3	80.8
	EME	59	34	14.9	9.7	16.6	10.8	12.7	0.1	50.0
Reinsurance as a share of insured losses (%)	FULL	88	43	18.8	14.5	20.6	10.7	22.8	0.0	99.4
	AE	29	9	18.4	12.1	19.2	9.2	20.9	0.0	79.8
	EME	59	34	19.0	29.1	26.7	10.8	23.9	0.0	99.4

Notes: AE stands for "advanced economies" which are traditional OECD countries (whose IMF code is less than 200). EME stands for "emerging market economies". [1] The "weighted mean (GDP)" is the mean of the relevant ratios weighted by the GDP of the disaster economy in US dollars. [2] The "weighted mean (Losses)" is the mean of the relevant ratios weighted by the total economic losses of the disaster economy in US dollars. [3] The sample includes only the observations for which there are corresponding reinsurance data. This layer sample is used for the regression on the insured losses as a share of total losses.

Little shared with the rest of the world were the losses from the Great East Japan Earthquake: only 3.6% of the losses were passed on to global re-insurers. This figure seems low for a high-income country prone to earthquakes, and it arises both from low coverage and low re-insurance. Japan used to have a mandatory earthquake insurance along with fire insurance, much as New Zealand does today. However, in 1979, after an earthquake had led to higher rates, fire insurance policy-holders were

allowed not to purchase earthquake insurance.[6] Moreover, the government earthquake agency, which bears most earthquake risk, does not reinsure its exposure at all.

A big California earthquake would expose little international risk-bearing. A reasonable estimate would be less than 10% (see above) despite the California earthquake agency's purchase of reinsurance. While this seems like a far cry from appropriate international risk-sharing, it would mark an improvement over the experience with the Northridge earthquake in 1994 (third bar from the right in Graph 1). Then we see almost no reinsurance receipts in the US balance of payments.

Taking it all together, the balance of payments of disaster-hit economies support the inference that international risk-sharing of disaster losses is low. What are the proximate sources of this failure of international risk-sharing? To this question Section 3 turns.

3. Decomposition of international risk-sharing of disasters

This section demonstrates that the very limited international sharing of disaster risk owes more to failures of insurance coverage than to failures of international reinsurance. We exploit the decomposition in Equation 2 to partition the overall shortfall of international risk-sharing from out ideal type, as shown in Graph 1.

Starting with Equation 2, we add and subtract s*i (in parentheses), the warranted insurance of observed ratio of insured losses to total losses. Then we gather terms in the last (bolded) expression:

(3) international risk-sharing gap = $s^* - i^*r = s^* + (-s^*i + s^*i) - i^*r$
$= s^*(1-i) + i(s^*-r)$.

The last expression decomposes the international risk-sharing gap into two components (or failures). These are the part for which the lack of insurance coverage is responsible, and the part for which the lack of warranted reinsurance is responsible. In particular, s*(1-i) is the contribution from the underinsurance of disaster risk (1-i), on the assumption of the presence of warranted reinsurance, s*. If one imagines two social planners successively setting the two ratios in Equation 1, we first measure the shortfall of the first planner on the assumption that the second acts appropriately. The second term captures the lack of appropriate reinsurance (s*- r) in interaction with the observed level of insurance coverage, i. How much international risk-sharing is the second planner missing out on, given the choice of the first planner?

To see how this works, consider the prospect of a California earthquake. Assume that 16% of home insurance includes earthquake coverage (neglecting deductibles, see Marshall (2017)) and that 50% of any insured losses are reinsured abroad.[7] In the US case, the warranted reinsurance rate is about 80% (=s*), so that an observed international risk-sharing of 8% (= i^*r = 16% x 50%) implies a gap of 72%

[6] The earthquake insurance participation rate has recovered from its lows but is still around 30% as of 2016.

[7] It is not clear from the CEA's financial statements what fraction of reinsurance is bought from firms in the United States and what fraction is bought from firms outside the United States.

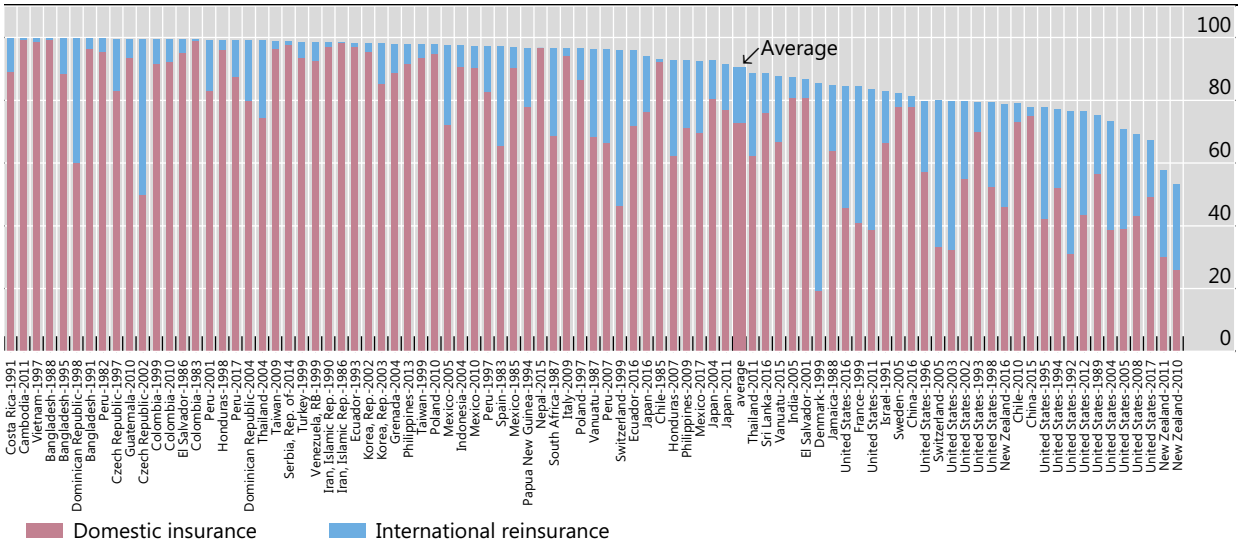
(= $s^* - i^*r$ = 80% – 8%). This gap is then decomposed into the difference between full insurance and observed insurance, ie 84% (= (1-i) = 1 – 16%), times the warranted reinsurance rate of 80% (= s^*(1-i)), or 67.2%. This leaves only 4.8% (= 72% – 67.2%) of the 72% to be ascribed to a lack of warranted reinsurance: 16% * (80% – 50%) (= i(s*-r)). The proximate source of the lack of international risk-sharing is overwhelmingly on the ground in California.[8]

Graph 2 shows the decomposition of the international risk-sharing gap from Graph 1 into the two components, in accord with Equation (3) above. In our sample, the overall lack of coverage accounts for much more of the gap than the lack of international reinsurance. On average, lack of insurance coverage accounts for 72.9% of the gap of 90.5%, while the lack of international reinsurance accounts for only 17.6%. The predominance of the lack of insurance coverage is no less in evidence if dollar losses, dollar insurance and dollar reinsurance are summed.

Decomposition of the shortfall into insurance cover and reinsurance

In per cent

Graph 2



Based on equation (3) above.

Sources: NatCatSERVICE data; IMF, *Balance of Payments and International Investment Position*; Authors' calculations.

The case of Japan, where two insurance systems co-exist, provides a nice natural experiment on the relative importance of reinsurance and insurance coverage. One system is run by the Ministry of Finance, and it pools and redistributes the risk from insurance that private casualty insurers market. The risk is ultimately shared among the Japan Earthquake Reinsurance Company (JER), a quasi-governmental corporation, private insurers and the government. Neither the JER nor the government reinsures with firms abroad, and it appears that the private insurers do not do so either.[9]

[8] By contrast, fire insurance covering half to two-thirds of the loss and over half the insurance supplied by non-US firms resulted in about a third of the cost of the 1906 San Francisco earthquake being paid by non-US, mostly British insurers. See Odell and Weidenmier (2004).

[9] A small amount of reserves is re-reinsured (ie, retroceded) by private insurers and a (or the only) private reinsurance corporation called *Toa Reinsurance*.

The other system is based on cooperatives supervised by the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Health, Labour and Welfare. Judging from the largest cooperative, JA Kyosai, these cooperatives are heavy users of international re-insurance. What if the two systems reinsured to an equal extent – say the Ministry of Finance led system reinsured 58% of its losses, as did JA Kyosai?

Overall, the Japan's insured losses amounted to only 16% of total losses in 2011. If that were true of residential insurance,[10] then the MoF system covered 9% of residential losses and the cooperatives, 7%. (The near-equality of these exposures reflected the fact that the earthquake hit a largely rural part of Japan; the MoF system would cover a larger share of a more urban hit.) A 58% reinsurance rate for the cooperatives and zero for the MoF system left international sharing of overall residential losses at about 4%.

A substantial reform of the MoF system would be entailed in its laying off a significant portion of its risk to international reinsurers. It should be remembered that one of the tasks of the MoF is to sell Japanese government bonds (JGBs). A shift to international reinsurance would most likely result in more insurance reserves held in bonds in the rest of the world, and less in JGBs. All that said, had the MoF system also re-insured 58%, then about 9% of residential losses would have been spread to the rest of the world (Appendices 5 and 6 for more details).

The upshot of this natural experiment is simply a particular instance of the theme of this section: the bulk of the failure of international risk-sharing in Japan as elsewhere arises from a lack of insurance coverage in the first place. A big reform of the MoF system so that it reinsured to the same extent as the biggest cooperative would move the needle from 4% to 9%. But this increment in international risk-sharing would still leave a yawning gap in comparison to our ideal of international risk-sharing.

4. Regression analysis of insurance coverage

Thus far we have established that a wide variation in the coverage of disaster insurance and the extent reinsurance combine to yield remarkably little international sharing of disaster risk. What factors explain these variations? This section analyses the determinants of insurance coverage, and the next section those of the reinsurance of that coverage.

Our empirical analysis of the determinants of (primary) insurance coverage reveals that countries with higher levels of economic, institutional, and financial development tend to cover a larger share of disaster losses. The coverage of earthquakes is smaller compared to that of floods or storms; these three are the only disasters that we analyse.

These findings arise from our regression of the share of estimated insured losses in total economic losses on a set of candidate variables. Theoretical rationales for the choice of variables and the expected signs for their estimates follow.

At a high level of economic development, economic agents are more likely to buy insurance against risks including natural disasters. Here, the rationale is that

[10] That is, if the proportion of insured losses were the same in residential and in commercial real estate.

disaster insurance is a superior good; people in relatively prosperous economies can better afford to hedge against risks. We measure the level of economic development using per capita income in purchasing power parity terms and expect it to be a positive contributor.

While income level can be regarded as a demand factor, it also taps the supply side. Cantor and Packer (1996) found that the level of income is the most important determinant of sovereign ratings. Higher rated sovereigns provide bonds of quality and duration that are useful to insurance firms

The extent of development in terms of legal systems and institutions also contributes to insurance coverage. On the demand side, trust in institutions spurs demand. On the supply side, legal and institutional development contributes to the smooth enforcement of contracts and thereby creating and executing complex financial products including insurance against disasters (Levine et al (2000)). An economy with more developed legal systems or institutions should tend to insure more of its disaster risk.

Similarly, an economy equipped with a well-developed financial system provides a wider variety of financial instruments to hedge against risk and to invest insurance reserves. Hence, a deep and liquid financial market should yield more ways to cover the risk of disasters, which we test by using private credit as a share of GDP.

As discussed below in Section 6, when the risk of a disaster is not well covered by insurance, the government may end up playing the role of the ex post insurer – ie the government funds reconstruction efforts and compensation out of its budget. Conversely, if the general public expects that the government would eventually behave this way, incentives for signing up for costly disaster insurance can weaken – "charity hazard." Hence, the size of government interventions in markets, measured as the ten year average of government consumption as a share of GDP, can negatively affect the extent of disaster insurance coverage.

Lastly, evidence that decisions from recent experience underweight the likelihood of rare events (Hertwig et al (2004)) might suggest that insurance coverage would tend to be low for earthquakes. We include a dummy that takes the value of one when the country of concern experiences earthquakes in a year.

In the estimation, there is a risk of endogeneity from bidirectional causality. To mitigate this risk, we lag the right-hand-side variables except for the earthquake dummy.

When we test the candidate variables individually, we find each of them is significantly correlated with the insurance coverage with predicted signs, except for the variable for government consumption (Columns (1) through (5) in Table 2). These findings suggest that an economy with a higher level of economic, financial, or legal development tends to insure more of its disaster risk while earthquake coverage tends to be smaller.

When we test these variables altogether, financial development and legal and institutional development stand out as robust contributors (Columns (6) and (7)). Government consumption now enters the estimation as a negative contributor, but its effect is insignificant. These results suggest that not only economies with highly developed financial markets, but also those with highly developed legal systems and institutions tend to cover more of the risk of economic losses driven by disasters.

Determinants of insurance coverage

Dependent variable: Insured losses/total damage

Table 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	WR (weighted by losses in US$)	WR (weighted by losses in US$)
Per capita income (PPP), t-1	9.149					3.795		14.587	13.405
	(1.383)***					(2.692)		(3.741)***	(1.590)***
Private credit/GDP, t-1		0.192				0.084	0.115	0.035	
		(0.027)***				(0.041)**	(0.037)***	(0.041)	
Legal/institutional development, t-1			0.432			0.181	0.237	–0.034	
			(0.063)***			(0.114)	(0.083)***	(0.140)	
Govt consumption				1.245		–0.276		–0.972	
(% of GDP), 10 yr avg				(0.378)***		(0.422)		(0.681)	
Dummy for earthquakes					–6.657	–6.191	–5.284	–15.674	–16.377
					(3.416)*	(3.242)*	(3.174)*	(3.193)***	(2.556)***
N	137	129	122	125	138	111	115	111	137
Adj. R2	0.24	0.28	0.28	0.07	0.02	0.33	0.33	0.52	0.52

Notes: The dependent variable is the estimated insured losses as a share of total losses. The simple OLS technique is applied to columns (1) through (7). For columns (8) and (9), weighted regressions are implemented with the weights being the estimated economic loss in US dollars. * indicates significance at the 0.10 level. *** indicates significance at the .01 level.

Source: Munich Re NatCatSERVICE data; authors' calculations.

The sample of this exercise includes a heterogenous group of disaster economies. Especially, the size of economic losses can vary significantly across the disasters. The economic loss of Japan's 2011 earthquake/tsunami disaster exceeded $210 billion and that of the US Katrina disaster reached $160 billion, which are the two largest disasters in our sample (their shares in GDP were "only" 3.5% and 1.6%, respectively). In contrast, the economic loss of the storm Dominica experienced in 2007 was $20 million (though its share in GDP was almost 5%). This heterogeneity in economic losses leads us to run the regression with the observations weighted by of economic losses in US dollars (Columns (8) and (9)). We find that it is the level of economic development that matters for the extent of disaster insurance coverage.

Let us put our estimation results in perspective. The economic loss arising from the devastating flood in Thailand in 2011 amounted to $43 billion or 11.6% of its GDP. According to the NatCatSERVICE database, 37% of its loss was covered by insurance. As of 2010, the year prior to the disaster, the country's per capita income level was $13,460 (in PPP). Our estimation results reported in Column (9) of Table 2 indicate that, if Thailand's per capita income had been the same level as that of New Zealand, ie $31,901, the insurance coverage of the 2011 disaster would have been 11.6 percentage points higher than it actually was.

As another example, the average per capita income of the advanced economies (AEs) as of one year before the occurrence of a disaster is $37,476 (in PPP) whereas that of the emerging market economies (EMEs) is $6,894 (in PPP). The difference in the per capita income level between the two country groups would suggest that, on average, the insurance coverage ratio should differ between the two groups by 22.7

percentage points. This figure is close to the difference in the mean insurance coverage ratio between the two country groups, 21.7%.

5. Regression analysis of reinsurance rate

We now analyse the determinants of reinsurance coverage as a share of total insured losses. Our findings indicate that net international investment position, the size of international reserves, the share of the economy in the world economy, and the level of de facto financial openness affect the extent of reinsurance coverage.

In particular, we regress the share of reinsurance coverage in total insured losses on a set of candidate determinants. These include variables used to explain the insurance ratio and new variables that bear on the choice of re-insurance.

In this estimation, we continue to think that government consumption and the dummy for earthquake affect the share of reinsurance coverage in total insured losses. In addition to these variables, we test other variables tapping into international wealth and liquidity, size and openness which may affect the extent of reinsurance coverage.

Whether the economy of concern is a net creditor or debtor could affect the extent of reinsurance coverage. New Zealand, a net debtor country (with net international liabilities surpassing 60% of its GDP), faces a more constrained external budget constraint, which could bind more tightly when a catastrophe hits the country. Prudence thus might strongly recommend that such a net debtor share disaster risks internationally. By contrast, a net creditor like Japan does not face such a constraint. It could liquidate external assets if necessary and need not actively pursue international risk-sharing through market-oriented reinsurance scheme. Hence, the better net international investment position an economy has, the less incentive it has to reinsure internationally, suggesting a negative sign of the estimated coefficient.

Holding ample international reserves can provide buffer against economic disruption caused by a disaster. In fact, researchers have empirically identified some such precautionary motive for holding international reserves (Aizenman and Marion (2003); Aizenman and Lee (2007); Cheung and Ito (2008, 2009)), though the motive is usually construed to be to forestall or to prepare for financial crises. Hence, in a country that holds ample international reserves, firms may feel less incentive to reinsure the risk of natural disasters, suggesting a negative relationship, between the amount of international reserves held and the extent of reinsurance coverage.

At the same time, a country with ample foreign exchange reserves can afford to purchase international reinsurance for the risk of natural disasters. This suggests the correlation between the amount of international reserves holding and the extent of reinsurance coverage might be positive (ie a complementary relationship).

Larger economies may be able to depend on reinsurance opportunities domestically, and thus face less need for international reinsurance (eg the US, Russia, and Australia). Furthermore, theory suggests that the smaller a country's output share in the world is, the more its portfolio should comprise foreign assets to diversify fully internationally. The bottom line is that the portfolio should include enough overseas assets that throw off returns that are weakly or negatively correlated with the domestic assets to leave only as much domestic risk as characterises the global portfolio (consistent with the capital asset pricing model (CAPM)). Hence, we test the

effect of the size of the economy in two ways. First, we examine if the physical size of the economy of concern matters or not by including the natural log of the land of the economy (originally in square kilometres). Second, we test the effect of the output share in the world economy, which we capture with the GDP world share (in PPP). For both variables, we expect negative correlations with the reinsurance coverage ratio.

Despite its benefit, international risk-sharing can materialise only when an economy is open to cross-border financial transactions. Constraints can be legal or behavioural. In fact, many studies have evidenced that financial liberalisation leads to a decline in the extent of home bias (Baele et al (2007); Mondria and Wu (2010); and Sørensen et al (2007)). Hence, we can expect that greater financial openness would lead to a greater use of international reinsurance. To capture the possible positive impact of financial openness, we use a de facto measure of financial openness using the dataset developed by Lane and Milesi-Ferretti (2001, 2007, and 2017).

Net international investment position, and de facto financial openness enter the estimation significantly with the predicted signs whether individually or jointly. International reserves are found to have a complementary relationship with international reinsurance (Table 3). When the estimation is weighted based on the US dollar value of economic losses, GDP shares enter the estimation with a significantly negative sign.

Determinants of reinsurance coverage

Dependent variable: Reinsured losses/Insured loss — Table 3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	WR (Loss in US$)	WR (Loss in US$)
Govt consumption (% of GDP), 10 yr avg	0.072							0.728		–0.865	
	(0.104)							(0.596)		(0.885)	
Dummy for earthquakes		1.115						9.332	9.660	13.334	
		(0.552)**						(5.327)*	(4.892)*	(5.194)**	
NIIP/GDP, t-1			–0.104					–0.148	–0.138	–0.213	–0.147
			(0.051)**					(0.064)**	(0.053)**	(0.064)***	(0.048)***
Intl' reserves, t-1				0.560				0.705	0.710	0.503	0.321
				(0.240)**				(0.261)***	(0.230)***	(0.215)**	(0.194)*
Land in log					–2.120			–2.121		–1.545	
					(1.175)*			(2.244)		(3.602)	
GDP share, t-1						–0.556		0.171		0.118	–0.723
						(0.326)*		(0.611)		(0.797)	(0.274)***
De facto financial openness, t-1							0.199	0.184	0.227	0.182	0.110
							(0.079)**	(0.093)*	(0.076)***	(0.072)**	(0.058)*
N	80	79	88	88	84	88	85	75	81	75	81
Adj. R2	–0.01	0.04	0.03	0.03	0.05	0.02	0.06	0.24	0.22	0.31	0.26

Notes: The dependent variable is the estimated reinsured losses as a share of insured losses. The simple OLS technique is applied to columns (1) through (9). For columns (10) and (11) weighted regressions are implemented with the weights being the estimated economic loss in US dollars.

* indicates significance at the 0.10 level. ** indicates significance at the .05 level. *** indicates significance at the .01 level.

The disaster economy with more positive net international investment positions (one year prior to the occurrence of the disaster) is less likely to reinsure internationally. A more positive net investment positions mean more external assets to cash in and to repatriate when the disaster economy needs to fund reconstruction efforts, which would substitute for international reinsurance. Larger economies (not in terms of their physical size but of their share in the world economy) are less likely to reinsure internationally. Economies with more open financial markets tend to cover more disaster risks with international reinsurance. The extent of covering disaster risks with international reinsurance is higher for economics with larger holdings of international reserves.

One more factor may affect the reinsurance participation rate. That is the profitability of (property) insurance industry. If the primary insurance firms are profitable, they may be able to cope with an influx of insurance claims at the time of a disaster by using their internal funds (which can accumulate over time if the market is not highly competitive). In other words, the more competitive environment the primary insurance firms are in, and the less profitable they are, the more willing they may be to buy reinsurance because they may not have sufficient internal funds to handle a large volume of insurance claims.

Unfortunately, there are no cross-country data that measure the level of profitability of insurance industry over time. However, the the World Bank's Global Financial Development Database has several variables that measure the profitability of the banking industry. If the profitability of banking industry is highly correlated with that of insurance industry, the variables for the profitability of banking industry can proxy for the profitability of insurance industry.

We test the effect of net interest margin and lending-deposit spread, for both of which higher values could represent higher levels of profitability.[11] Hence, the sign of the estimates of these variables is expected to be negative; higher profitability may discourage countries to sign up for reinsurance.

Neither of these variables enters the estimation significantly, though their signs are negative (not reported).[12] Hence, perhaps because we have bad proxies for the profitability of insurance, we do not find evidence that profitability affects the participation rate for international reinsurance.

Graph 3 illustrates, for selected disasters, the contributions of these factors to the ratio of reinsurance over insured losses based on the estimation model of Column (11) in Table 3. For the US and Japan, the observed reinsurance coverage ratios are more or less on par with the predicted levels. For these two economies, large size (GDP share) reduces the reinsurance coverage ratio. In contrast to the US, however, Japan is a net creditor country, which also helps lower the ratio. For all the countries except for the US, international reserves holding contributes positively to higher reinsurance coverage. The estimation model underpredicts for New Zealand and Chile and overpredicts for Indonesia and Thailand.

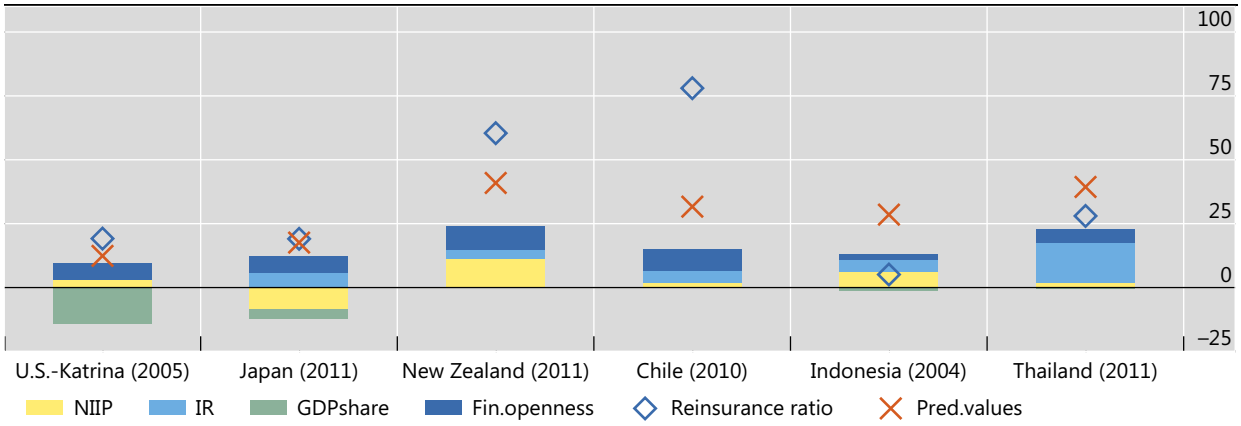
[11] See Appendix 1 for the definitions of the variables.

[12] The estimation results are available from the authors upon request. We also tested the effect of returns on assets (ROA); returns on equity (ROE); overhead cost; and cost-to-income ratio. Signs of the estimates of ROA and ROE are expected to be negative; signs of the estimates of overhead cost and cost-to-income ratio are expected to be positive since higher values of these variables suggest lower levels of profitability.

Contributions of the factors to reinsurance coverage

In per cent

Graph 3



The effect of the estimated constant is omitted from presentation.

Source: Authors' calculations.

6. Government as de facto ex post insurer

This paper's finding that the losses from natural disasters are not much shared internationally nor much insured at all raises the question of the role of the government. This role breaks down into the government as explicit insurer or backstop to the insurer, the government as implicit backstop for public agencies or authorities, and the government as ex post de facto insurer. For emerging market countries, foreign governments can play this last role as donors.[13]

Some governments provide explicit insurance. Under the MoF system, the Japanese government is liable for 95% of insured earthquake losses over about $2 billion (224 billion yen). France's "catastrophe naturelle" scheme depends on an inter-ministerial decree that pays out state funds raised through a flat-rate levy on fire insurance policies (Muir-Wood (2016, pp 149, 311)). The US National Flood Insurance Program, with over a million policies and over $1 trillion in coverage, has a $30 billion credit line with the US Treasury. When it exhausted it in 2017, the US Congress granted it debt relief for $16 billion so that it could pay claims from Hurricanes Harvey, Irma, and Maria (Horn and Brown (2018)).

National and state agencies or authorities raise the question of what happens if claims overwhelm reserves. This question arises, for instance, with the New Zealand agency and even the California earthquake authority. A rating report for the California Earthquake Authority's bonds (Butler and Grimes (2018, pp 1, 2)) notes its position: "the state of California, the insurance industry in California and policyholders in California all have an interest in the CEA's continuance as an organization"; but "the CEA is not a state agency and has no connection to the state budget". The CEA's last

[13] The capital and current account transfers can reflect grants in aid as well as reinsurance payments.

resort is to pay claims on a pro rata basis, with political implications that may be readily imagined.

Observers detect a trend toward a larger after-the-fact US government role in response to natural disasters. In addition to flood insurance, ad hoc US federal disaster relief funding has risen from single-digit shares of losses in the 1950s to 80% in more recent years (Kunreuther and Michel-Kerjan (2014)); also Cummins et al (2010)). Much of such funding rebuilds (uninsured) public infrastructure and provides temporary housing. However, the federal government crossed an important threshold in 2006 when it gave grants of up to $150,000 (without an income test) to over 100,000 uninsured homeowners after Hurricane Katrina (Muir-Wood (2016, p 146)). Such payments, of course, undermine the incentive to insure (ie poses charity hazard).

As in the United States, the high budgetary cost of the 2011 Japanese earthquake may be seen as the culmination of an historical evolution. The government reinsurance scheme was started in 1966 after 1964's Niigata earthquake. After another earthquake, the government in 1979 raised the premia but made participation optional rather than compulsory. By the time that the 2011 earthquake hit, low coverage of losses helps to explain why the central government ended up spending more than the earthquake's estimated direct economic losses at 4% of GDP.[14]

In the case of New Zealand, the government earthquake agency's explicit public policy purpose is to limit the demand for an extraordinary budget response to disaster (New Zealand Treasury (2015)). The New Zealand system dates to 1944. The precedent for a compulsory scheme was the Churchill government's 1940 levy on insurance policies to fund a state insurance scheme for war damage during the Blitz. The New Zealand government transposed the enemy from German bombers to earthquakes, of which two had hit in 1942 (Muir-Woods (2016, p 130)). The accumulated surplus from 1945 to 2010 was paid out after the 2011 earthquake, and the premium was then tripled in line with reinsurance rates. Questions remain regarding its long-run adequacy and the New Zealand Treasury (2015) proposed review of its adequacy every five years. It was raised by a third in 2017 to 0.2% of insured value.

Government ex ante interventions to offer insurance thus face a dilemma. If insurance rates are set to be affordable, participation rates are higher, and compulsory participation may be politically feasible. But if rates are too low, the scheme will lose money and reinsurance will be problematic.[15] If rates are set higher and even somewhat related to risks, then only a minority will participate in a voluntary scheme, as in Japan and California. The political pressure for ex post government aid may increase.

If uninsured losses from natural catastrophes have become contingent government liabilities, then they compete for limited fiscal space in advanced economies. Space is limited because public debt has reached record levels in these economies. Its median value has increased by over 30 percentage points of GDP since

[14] And it is expected that spending will be higher (World Bank (2014, p 289)). The main offset is a 2.1% surcharge on individual income taxes to run for 25 years.

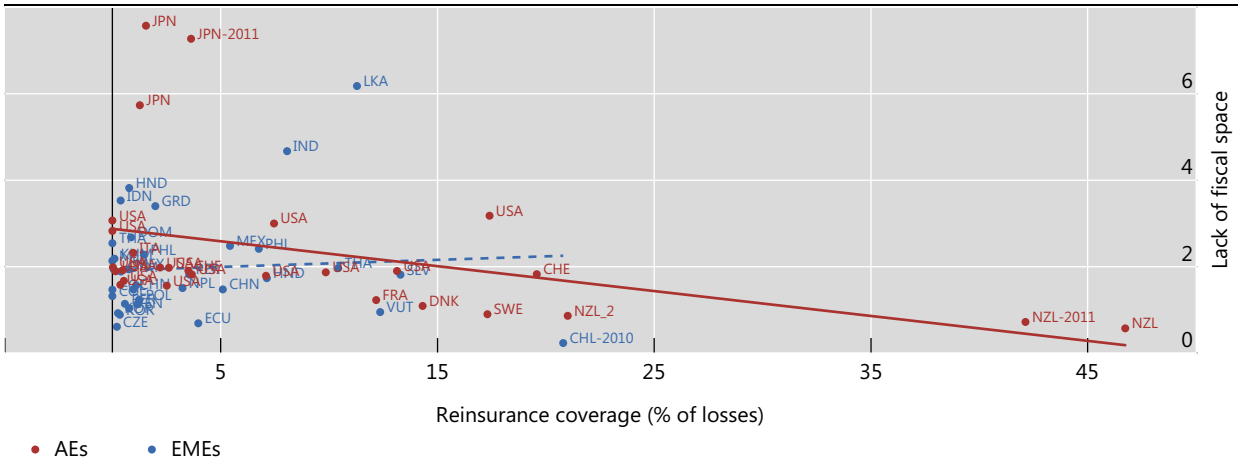
[15] The US National Flood Insurance Program has begun to buy reinsurance (Horn and Brown (2018). The larger the program, the more will uneconomic legacy pricing and out of date risk maps be exposed.

2007 and now stands at about 100%. Fiscal space is in any case easily overstated (BIS (2016, Box V.B)).

For advanced economies, a lack of international risk-sharing is perversely correlated with a lack of fiscal space. This is evident in Graph 4. It plots our measure of internationally reinsured losses as a share of losses against the ratio of government debt to average revenues (Aizenmann and Jinjarak (2011)). A high value indicates that a government has little fiscal space. Graph 4 shows that for advanced economies those with little international risk-sharing have little fiscal room to manoeuvre.

International risk-sharing and lack of fiscal space in AEs

Graph 4



Fiscal space proxied by lagged government debt/five-year average revenue.

Source: Authors' calculations.

Interpreting this relationship is not straightforward. Perhaps the best way to think about it is that international risk-sharing and fiscal space both result from policies that in turn reflect the role of the government. To be sure, the immediate impact of a disaster can be to use and to reduce fiscal space, so we lag the budget/debt observations.

Whatever the interpretation, in advanced economies, a lack of ex ante insurance leaves the government subject to pressure to provide ex post government insurance through the budget. Yet precisely such governments have the less fiscal room to manoeuvre.

Thus, at high levels of debt, the realisation of the contingent liability from a disaster could pose a risk to financial stability. How big a disaster loss can be absorbed by a given government's budget before investors, including domestic ones, come to doubt government bonds?

7. Conclusion

We find that the risk of disasters is shared internationally to a surprisingly limited extent. In the cases for which we have been able to identify reinsurance payments in the balance of payments, the mean portion of economic losses received offset by reinsurance is less than 5%. And, on a value-weighted basis, the degree of

international risk-sharing is still only 7.5%. These findings are far below a textbook norm of full international risk-sharing, which makes allowance for larger countries shouldering more of their disaster risk. Even qualifying this ideal for standard features of insurance contracts like deductibles and co-insurance leaves such international risk-sharing low.

This result depends to a remarkably little extent on the precise measurement of reinsurance receipts. This is because the lack of insurance coverage is the overwhelming factor in the shortfall of reinsured loss from the textbook level. The contrast of international risk-sharing of the losses from the 2011 earthquakes in Japan and New Zealand arises mostly from the coverage of insurance.

Regression analysis ascribes cross-disaster variation in insurance coverage and reinsurance as a share of insured losses to different factors. Our results point to economic and financial development and institutional/legal quality as important determinants of insurance participation. The reinsurance share is related to small size, as theory would suggest, while higher levels of international reserves holding are also found to be positive contributors. As a form of international financial integration, the international reinsurance share is also positively related to overall de facto international financial integration (as measured by the ratio of international assets and liabilities to GDP). In addition, we also find that more internationally wealthy economies reinsure less, suggesting that net foreign assets substitute for international sharing of disaster risk.

The lack of international risk-sharing against the background of low insurance coverage poses profound questions about the role of government. The practical alternative to ex ante insurance, however organised, seems to be demand for government spending to serve as ex post insurance. Indeed, the trend in both Japan and the United States looks to be toward greater spending in relation to disaster losses over time.

The difficulty is the empirical observation that those advanced economies which enjoy less international risk-sharing also enjoy less fiscal space. Thus, the realisation of a disaster risks ratcheting up already high public debt levels. In this manner, disaster risk can morph into financial risk.

Future work on this subject should take better account than we have of the implications of multinational firms on both the supply and demand side in the insurance market. On the supply side, a subsidiary of a multinational insurer that suffers a loss that was not reinsured may mark down its reserves and equity, so that the loss goes through the direct investment accounts. On the demand side, a multinational automobile firm, for instance, may insure centrally against disaster-related losses and business interruptions in its multi-country value chain and funnel insurance receipts to its subsidiaries. Again, internationally shared risks might show up in the direct investment accounts. Firms' balance sheets can span national borders, leaving national balance of payments statistics less informative (Avdjiev et al).

Appendix 1: Data and sources

Insured losses from disasters – Data extracted from the NatCatSERVICE database.

Estimated economic losses – Data extracted from the NatCatSERVICE database.

Current transfers, credit – the IMF *Balance of Payments*.

Capital account, credit – the IMF *Balance of Payments*.

Estimated reinsurance payments – Current or capital transfers from the IMF *Balance of Payments*. For more details, refer to Appendix 2.

Reinsured losses as a share of economic losses – Estimated reinsurance payments divided by estimated economic losses.

Insured losses as a share of economic losses – Insured losses from disasters divided by *estimated economic losses*.

Reinsured losses as a share of insured losses – Estimated reinsurance payments divided by *insured losses*.

Per capita income – Gross domestic product per capita in current international dollars (purchasing power parity), extracted from the IMF *World Economic Outlook* database.

Private credit as a share of GDP – "Private credit by deposit money banks and other financial institutions to GDP (%)", extracted from the World Bank's *Financial Structure and Development* database.

Legal/Institutional development – The first principal component of law and order (*LAO*), bureaucratic quality (*BQ*), and anti-corruption measures (*CORRUPT*), all of which are extracted from International Country Risk Guide (ICRG). Higher values of these variables indicate better conditions.

Government consumption – General government final consumption expenditure as a share of GDP, obtained from the *World Development Indicators*. We calculate the average from t-10 through t-1.

Dummy for earthquakes – The value of one is assigned if the country-year includes an occurrence of an earthquake.

Net international investment position – Total external assets minus total external liabilities divided by GDP. The data on total external assets and total external liabilities are extracted from the nations' external wealth dataset developed by Lane and Milesi-Ferretti (2001, 2007, 2017).

International Reserves – Total international reserves minus gold divided by GDP.

GDP shares – "Gross domestic product based on purchasing-power-parity (PPP) share of world total" from the IMF's *World Economic Outlook*.

De facto financial openness – The sum of total external assets and total external liabilities divided by GDP. The data on total external assets and liabilities are obtained from the dataset on international investment positions developed by Lane and Milesi-Ferretti (2001, 2007, and 2017). However, the ratio of the sum of total external assets and liabilities to GDP can be very high, especially for economies with global financial centers (eg Hong Kong SAR, Ireland, and Singapore). Therefore, we winsorize this ratio at the 10th and 90th percentiles (with both percentiles being calculated from a

sample excluding all the financial-centre economies), and normalize the ratio using the following formula:[19]

(Z) $$X\_n_{it} = \frac{X_{it} - X_{i,\,min}}{X_{i,\,max} - X_{i,\,min}}$$

Where X_i is the sum of total external assets and total external liabilities $X_{i,\,max}$ and $X_{i,\,min}$ are the global maximum and minimum of the winsorized variable X_i, respectively.

Net interest margin – Accounting value of bank's net interest revenue as a share of its average interest-bearing (total earning) assets from the Global Financial Development database.

Lending-deposit spread – Difference between lending rate and deposit rate. Lending rate is the rate charged by banks on loans to the private sector and deposit interest rate is the rate offered by commercial banks on three-month deposits from the GFD database.

Overhead cost – Operating expenses of a bank as a share of the value of all assets held. Total assets include total earning assets, cash and due from banks, foreclosed real estate, fixed assets, goodwill, other intangibles, current tax assets, deferred tax assets, discontinued operations and other assets from the GFD database.

Returns on assets – Commercial banks' after-tax net income to yearly averaged total assets from the GFD database.

Returns on equity – Commercial banks' after-tax net income to yearly averaged equity from the GFD database.

Cost-to-income ratio (%) – Operating expenses of a bank as a share of sum of net-interest revenue and other operating income from the GFD database.

Fiscal space – The ratio of gross public debt to the five-year average of tax revenues. Both variables are retrieved from the IMF's WEO. A lower value of this variable indicates more fiscal space.

[19] The definition of financial centres follows that of Lane and Milesi-Ferretti (2017). They are the Bahamas, Bahrain, Belgium, Cyprus, Hong Kong SAR, Ireland, Luxembourg, the Netherlands, Panama, San Marino, Singapore, Switzerland, and the United Kingdom.

Appendix 2: Balance of payments measure of re-insurance

To examine how the risk of natural, or man-made, disaster is shared internationally, we need to know how to identify cross-border financial flows that arise from such sharing. In principle, such insurance flows are captured by the balance of payments.

One might guess that the answer lies in the current account. The residents of the country buying insurance would show a service import as they paid premia to reinsurers in the rest of the world. Correspondingly, they would show a current account receipt when a disaster hit and insurers in the rest of world paid for losses. If this were one's hunch, then one would have readily grasped the balance of payments accounting for disaster insurance until ten years ago.

Now, after changes in the accounting treatment and somewhat less intuitively, there is an asymmetry. Premium payments show up as service imports, as before. But, in principle, the claims paid after big disasters now show up in the capital account. Thus, big casualty losses no longer give a temporary boost to the current account.

Nevertheless and somewhat reassuringly, in *stock* terms well-insured big disasters still improve the net international investment position (NIIP) of the economy suffering the disaster. In effect on impact, international insurance replaces the destroyed domestic capital stock with financial claims on the rest of the world.

With this preview, let us now walk through the balance of payments accounting. Households and corporations in a disaster-prone economy insure themselves against catastrophes through earthquake, storm or flooding insurance. Typically, resident companies, including affiliates of multinational insurers, provide the immediate insurance and collect the premia (top left arrow in Graph A2-1). In turn, these local insurance companies may also reinsure with global reinsurance companies to cover a share of the risks or risks above a certain threshold (bottom left arrow). Once the disaster hits, local insurance companies make payments to policy holders (top right arrow). And these local insurers in turn file claims to receive payments from reinsurance companies (bottom right arrow), When reinsurance is provided by firms headquartered and mostly owned abroad, the risk is diversified internationally.

The balance of payments flows are shown by the two bottom arrows in Graph A2-1. Premia for reinsurance are a current account outflow, ie a service import (bottom left). And an insurance claim filed by a local insurance company on a reinsurer abroad appears as an inflow since it involves a financial claim on the rest of the world.[16]

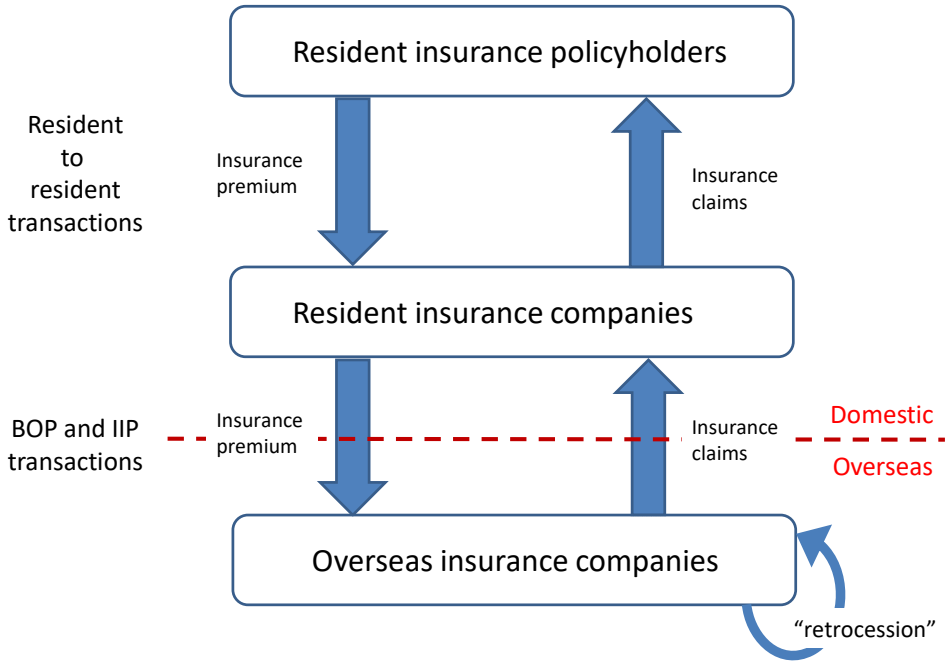
Formerly, claims for insurance payments from overseas reinsurers appeared as unilateral transfers in the current account alongside workers' remittances, as transfers of claims on income from abroad to the home country. In that case, a current account transfer inflow is recorded – the transaction appears in row (A) in the simplified balance of payments shown in Table A2-1 (and also as arrow (A) in Graph A2-2). Given the double-entry balance of payments book-keeping, corresponding to this inflow on the current account is an outflow in the financial account – the acquisition of the claim

[16] Some reinsurance companies insure each other (or through other financial institutions) for potential peak risks. This kind of financial transaction is called "retrocession."

on the insurance company abroad: row (C) in Table A2-1 (and also as arrow (C) in Graph A2-2.[17]

Insurance transactions between residents and cross-border

Graph A2-1



Such treatment of reinsurance payments in the International Monetary Fund's (IMF's) Balance of Payments Manual 1 (BPM1) through 5 changed with BPM6. It relocated big reinsurance transfers from the current to the capital account. When the scale of the disaster and the resultant losses of insurance companies are great, it was decided that treating insurance claims on overseas reinsurers as unilateral current transfers is not appropriate. BPM6, introduced in 2009, reclassified certain disaster-related insurance receipts from international reinsurers as capital transfers in the *capital account* (row (B) in Table 1 and arrow (B) in Graph A2-2) instead of unilateral transfers in the *current account* (row (A)).[18] Statistical authorities of the government decide whether to apply the capital transfers rule based on the scale of the disaster.

17 It is analogous to the accounting for a home country export to a foreign country in that the exporter receives a claim on the importer. Due to the double entry nature of the balance of payments, a corresponding outlfow to this reinsurance receipt occurs in the financial account, recorded as an increase of "trade credit" in the "other investment" category of the international asset. See below.

18 Recall that the "capital account" here does not mean the capital account in the sense of the BPM5. In the BPM6, the former capital account is called the "financial account," though many researchers still use the name "capital account" to refer to the financial account (Table 1). BPM6's new capital account comprises capital transfers and the acquisition or disposal of non-produced, non-financial assets (which used to be reported as part of the current account in BPM5) – row (B) in Table 1. For most countries, transactions in the capital account are much smaller than those in the financial account, and are often negligible.

Balance of payments and earthquake reinsurance payments — Table A2-1

Current Account

Exports (goods + services + income receipts) – Imports (goods + service + income payments)

(A) Current transfer, credit – Current transfer, debit

Capital Account

(B) Capital transfer, credit – Capital transfer, debit

Gross disposals of non-produced, non-financial assets – Gross acquisitions of non-produced, non-financial assets

Financial Account *(= formally called "capital account")*

Direct investment

Net acquisitions of financial assets – Net incurrence of liabilities

Portfolio investment

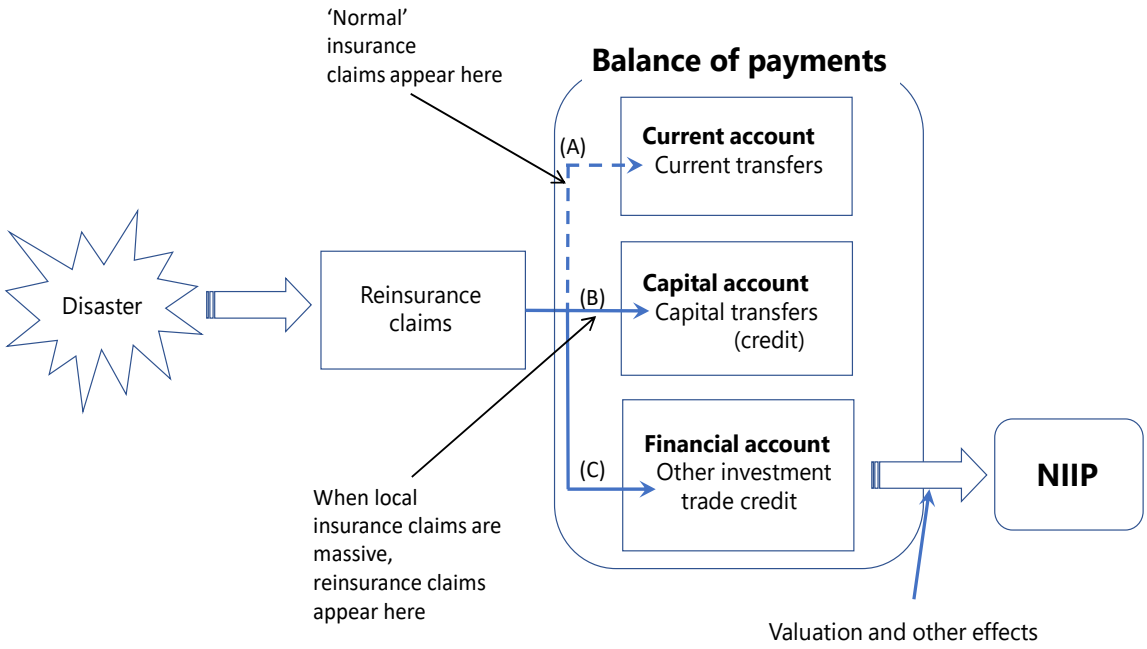
Net acquisitions of financial assets – Net incurrence of liabilities

Other investment

(C) Net acquisitions of financial assets – Net incurrence of liabilities

Reserve assets

BOP-IIP accounting for disaster insurance transactions — Graph A2-2



The rationale behind the new rule draws on both the source and use of the transfer. First, the unilateral transfers (ie inflows) that spike for the disaster-hit economy are usually paid for by insurance companies out of reserves, not out of

income arising from "current" production. Second, since the insurance payments are used to replace destroyed capital, including such insurance payments as a current (income) transfer was judged not appropriate. The change also had knock-on effects on domestic GDP/GNP accounting that were seen as desirable.

After BPM6's introduction, the US Bureau of Economic Analysis (BEA) adopted this rule in 2009 (Flatness, et al (2009); USBEA (2009)).[19] New Zealand adopted the rule in June 2011, following the Canterbury earthquakes of 2010 and 2011 (Statistics New Zealand (2011)), as did Japan in 2011 after the Great East Japan Earthquake in March 2011 (Japan Cabinet Office (Yoshino and Koori) (2011)). Presumably, other countries that adopt the BPM6 will treat insurance payments in the same manner as these countries.[20]

With this balance of payments accounting in hand, we can locate reinsurance payments in the international accounts of countries that have suffered big disasters in recent years. Graph A2-3 illustrates the capital account credit of Chile, Japan, New Zealand, and the United States. The spikes in the graphs correspond to disasters that hit these countries: the Maule earthquake in Chile in 2010, the Great East Japan Earthquake in 2011, the Canterbury Earthquakes in New Zealand in 2010 and 2011, and the September 11 attack in 2001 and Hurricane Katrina in 2005 in the United States. These spikes in the capital account credit indicate that these countries' insurance companies filed massive claims on overseas reinsurers after they experienced the catastrophe.[21] As an additional note, recall that the financial account is now the home for what we used to call capital flows. As a result, the value of capital account transactions is often negligible and generally their appearance is infrequent (except countries that often receive debt forgiveness). Thus, observing the capital account is a way to identify cross-border insurance transactions arising from a disaster in the next section.[22]

Whether accounted current or capital transfers in the balance of payments, reinsurance payments boost the net international investment position of the disaster-hit economy. That is, owing to the double-entry nature of the balance of payments, reinsurance claims appear once as a transfer receipt and again in the financial account as an outflow from a rise in trade credit (or receivable) in the "other investment" category of international asset (row (C) in Table A2-1 and arrow (C) in Graph A2-2). This claim represents a gain in the disaster-hit economy's external wealth. Of course, it no more than partially offsets the loss of the domestic capital stock owing to the

[19] After the September 11th terrorist attack in 2001, the US BEA changed the way it treats insurance losses and reinsurance claims starting with the 2003 Comprehensive Revision of the National Income and Product Accounts that year (USBEA (2003a,b)). This change intended to smooth large swings in measured insurance services that can arise from catastrophes such as earthquakes (eg, Northridge, 1994), hurricanes (Hurricane Andrew, 1992), and terrorist attacks (September 11, 2001). See USBEA (2003a,b) for more details.

[20] Regular reinsurance payments unrelated to large-scale disasters continue to be recorded as unilateral transfers in the current account (arrow (A) in Graph 2).

[21] The balance of payments can be affected in several other channels in the aftermath of a disaster. We summarise the impact of a catastrophic disaster on the balance of payments in Appendix 4.

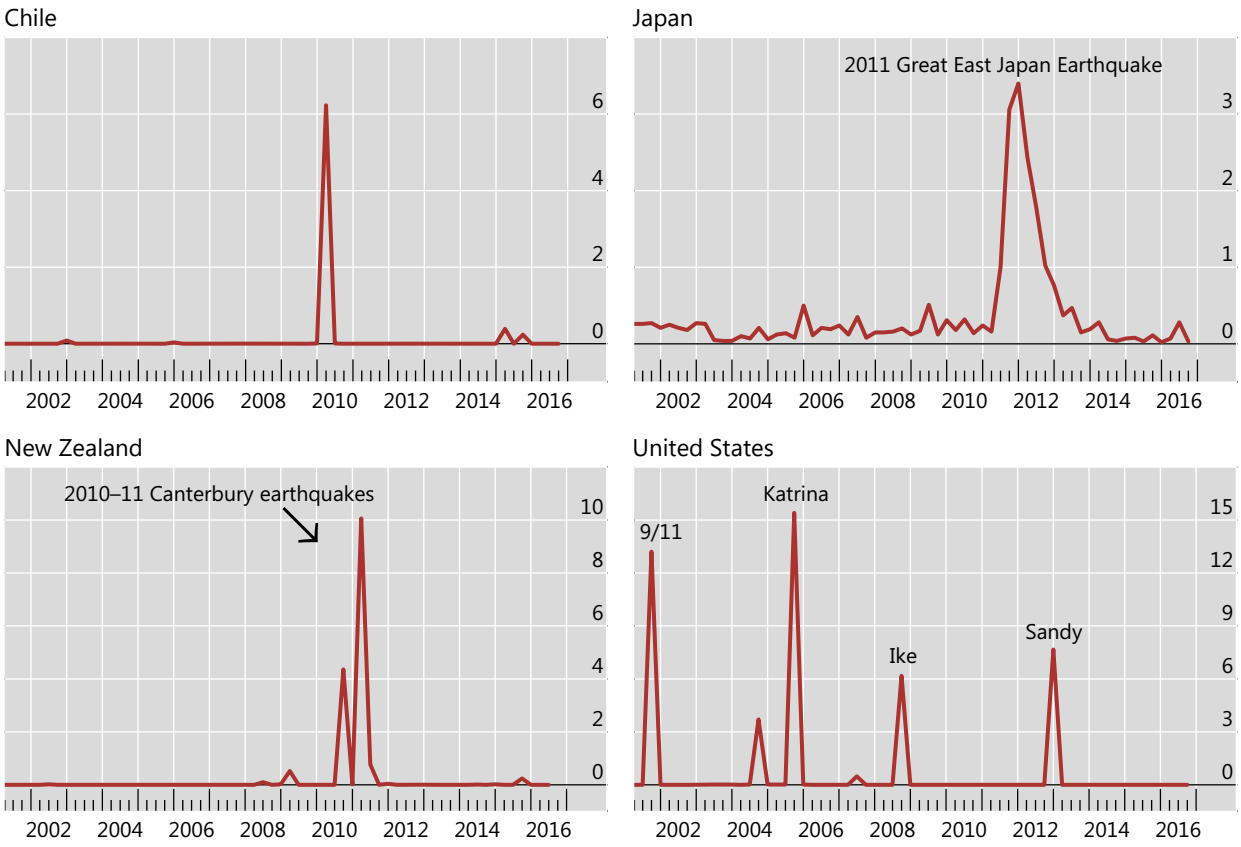
[22] However, not all the countries that experience disasters but do not receive debt forgiveness present capital account profiles like those in Graph 3, in which the spikes correspond to disasters, for various reasons. Disaster economies, especially those of developing countries often receive grants in the immediate aftermath of the disasters, which are generally reported as capital account transfers.

disaster. In practice, the impact of disaster reinsurance payments on the net international investment position is not as discernible as that on the capital account (eg, Graph A2-3) because many other factors, disaster-related and otherwise, affect the financial account.[23]

Capital accounts of Chile, Japan, New Zealand, and the United States

In billions of USD

Graph A2.3



Source: IMF, *International Financial Statistics*.

[23] As Appendix 4 shows, disasters affect the overall balance of payments in manifold ways. If they affect the current or capital account, they affect the financial account as well. Furthermore, in addition to the financial account, valuation changes arising from exchange rate and other asset price movements affect the NIIP (Benetrix et al (2015), Tille (2003)). Appendix 3 summarises the link between disasters and valuation effects.

Appendix 3: Disasters, valuation effects and the NIIP

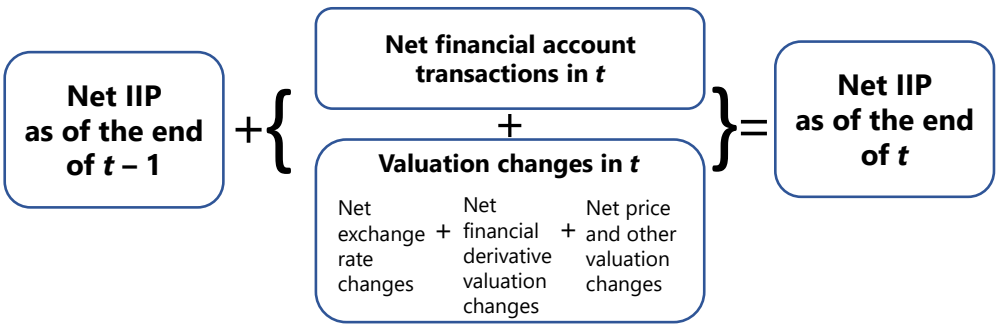
The financial account records capital flows that affect the net international investment position. However, in addition to the financial account, the valuation effect of exchange rate and other asset price changes affect the net international investment positions (Benetrix, 2015, Tille, 2003) as shown in Graph A3-1. The prices of assets issued by the domestic country and held by non-residents as well as the exchange rate movements vis-à-vis the U.S. dollar exert evaluation effects on the values of both external assets and liabilities, affecting the net international investment position.

As priori, there are grounds for expecting the exchange rate to appreciate in the event of a big disaster. This rise in the relative price of nontraded goods would divert aggregate supply from tradeable goods to construction and other nontradeables. This presumption is strengthened if reinsurers in the rest of the world have to transfer substantial amounts funds into the domestic currency.

This prior view tends to be strongly held in Japanese financial circles. The particular form is that domestic casualty insurers can be expected to liquidate foreign securities and to repatriate the proceeds. Even if such liquidations occur, the exchange rate effect would be attenuated by the substantial foreign exchange hedge ratio applied by Japanese insurers to such investment (Borio et al (2017)).

The valuation effect of such domestic currency appreciation on the NIIP could be perversely to lower the international wealth of the disaster-hit economy. As demonstrated by Tille (2003) for the United States and by Bénétrix et al (2015) more generally, advanced economies tend to have a net liability position in domestic currency and a net asset position in foreign currencies. This means that the appreciation of the domestic currency lowers the domestic value of the net foreign currency assets, and worsens the NIIP. This would run counter to the effect of the receipt of the reinsurance payments in raising the NIIP.

Reconciliation of NIIP, financial account, and valuation effects — Graph A3-1



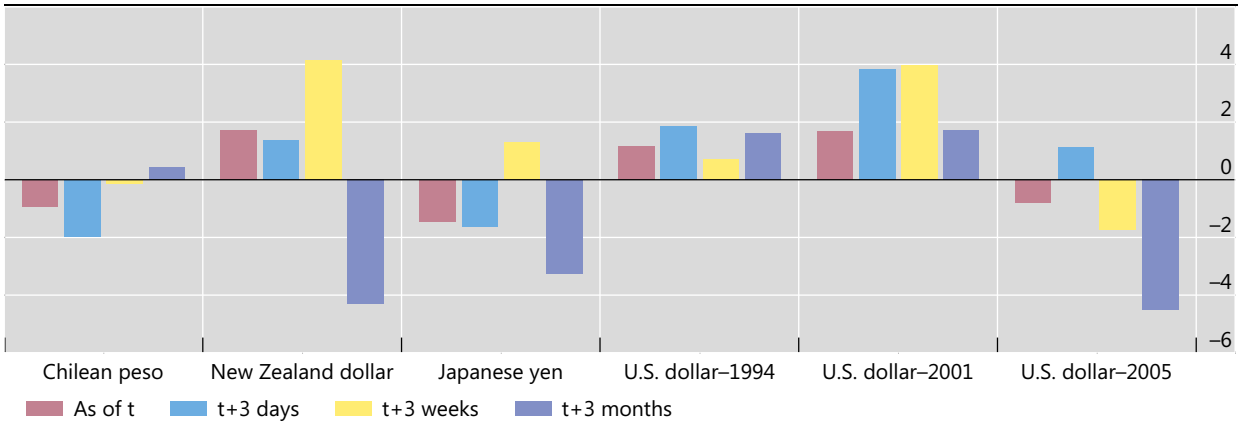
This possibly perverse revaluation channel motivates us to ask how the exchange rate actually responds to disasters? Graph A3.2 shows how the exchange rate

responded to the disasters of our interest, namely, the Maule earthquake in Chile in 2010, the Great East Japan Earthquake in 2011, the Canterbury Earthquakes in New Zealand in 2011, the Northridge Earthquake in 1994, and the September 11 attack in 2001 and Hurricane Katrina in 2005 in the US. It shows the depreciation of the currencies of the disaster-hit countries in four windows including the date of the occurrence of the disaster: the day itself (*t*; blue); three days after the occurrence (*t* + 3 days; orange), three weeks afterwards (*t* + 3 weeks; grey), and three months afterwards (*t* + 3 months; yellow).[24] The depreciation is shown vis-à-vis the dollar for all but the United States, for which the dollar against the Swiss franc is used.

Exchange rate depreciation vs the USD after major disasters (CHF for USD)

In per cent

Graph A3.2



Sources: IMF, *International Financial Statistics*; Authors' estimations.

No particular regularity is discernible in the way the exchange rate responds to a disaster. Furthermore, the magnitude of change in the exchange rate is not significant. After the Chilean and Japanese earthquakes, the Chilean peso and the Japanese yen *appreciated* on the day the disaster hit and three days after.[25] However, in the immediate aftermath of the New Zealand earthquake, its dollar depreciated.

Special considerations apply to the Japanese yen. Its 2011 earthquake was perceived as a global shock disrupting the global supply chain and increasing the level of uncertainty in not just the Asian region but also the world. In such a case, investors may deleverage their carry trades involving the yen.

Graph A3.3 repeats the exercise on a nominal effective exchange rate (NEER) basis, which allows a symmetric treatment of the US dollar and other currencies. On the NEER basis, the currencies of the disaster economies appear to have appreciated three months after the occurrence of the disasters, except for the case of the Northridge earthquake of 1994. However, the size of currency appreciation was rather small.

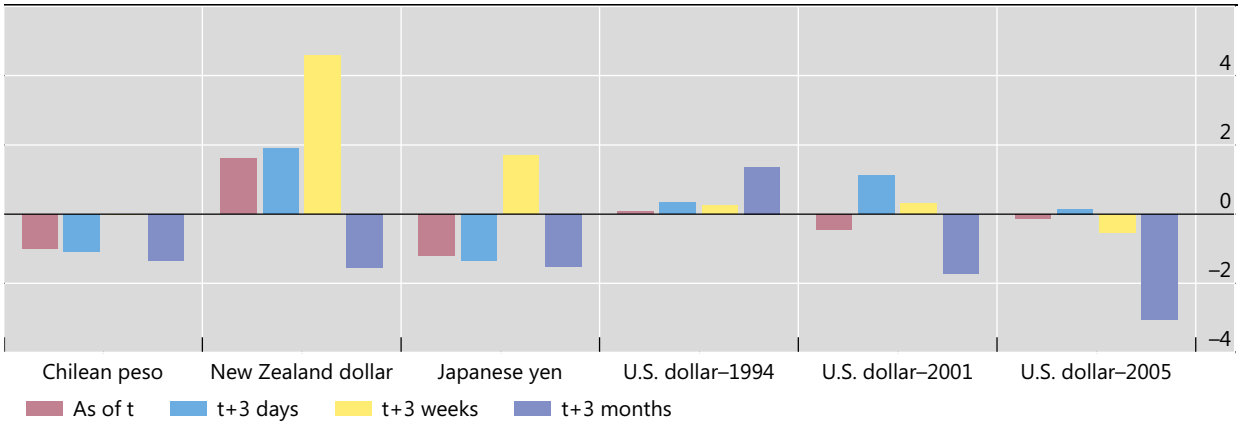
[24] In the field of emergency management and recovery, researchers usually focus on the state of the crisis-stricken area as of the latter three windows.

[25] The Japanese yen depreciated three weeks after the crisis because the monetary authorities actively intervened in the foreign exchange markets to change the tide of the exchange rate movements.

Nominal effective depreciation after major disasters

In per cent

Graph A3.3



Sources: IMF, *International Financial Statistics*; Authors' estimations.

Appendix 4: Other impacts of disasters on the current account

In addition to the reinsurance claims described in Appendix 2, other flows related to disasters may appear in the balance of payments. The discussion can be divided into current account and capital account.

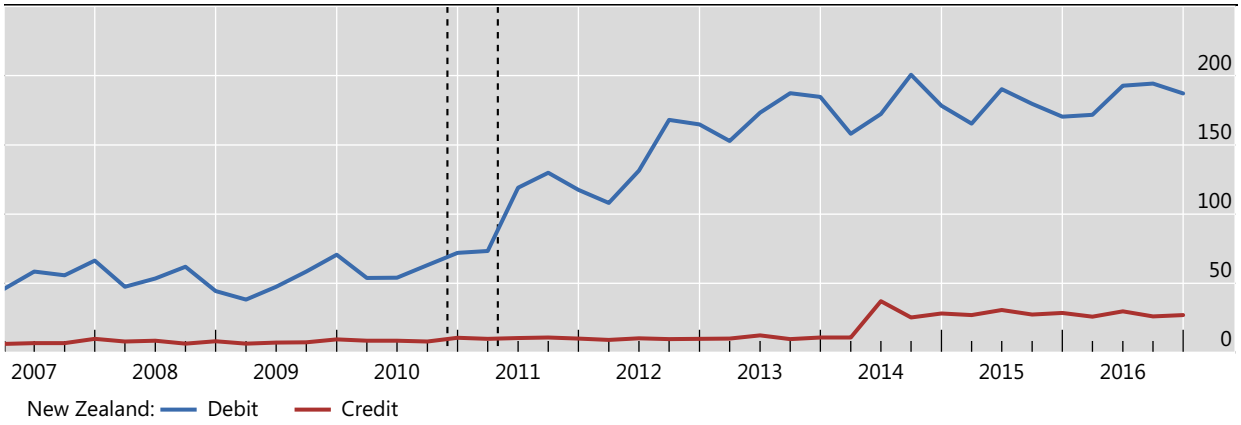
In the current account, one might expect the trade account to deteriorate because reconstruction efforts would usually lead to a rise in absorption (ie the sum of private consumption, private investment, and government expenditure) for a given level of income. However, the findings of Noy (2009) and von Peter et al (2012) that GDP can fall as a result of a disaster leaves this effect ambiguous.

Also in the current account are services and these can deteriorate in the wake of a disaster. In particular, reinsurers may raise insurance premiums in the aftermath of a catastrophic disaster that inflicts big losses on insurance companies. Payments for insurance premiums to overseas reinsurers are recorded in the services trade of the current account (ie debit in insurance and pension services). Graph A4.1 shows a rising trend in the service trade debit for insurance (and pension) services of New Zealand in the aftermath of the Canterbury earthquake. The service trade of the current account could also deteriorate due to a decline in tourism.

Also in the current account are unrequited transfers. If the disaster-hit economy receives international aid (in the form of either cash and in kind), it will appear as credit in unilateral transfers. If a disaster-hit economy receives debt forgiveness as a means of international support, however, this will appear as credit in capital transfer in the capital account alongside any reinsurance receipts (for a big disaster).

Insurance services in New Zealand's service trade

In millions of USD — Graph A4.1



The two dotted lines correspond to the earthquakes in September 2010 and February 2011.

Source: Statistics New Zealand.

If many overseas migrants leave the disaster-stricken economy, the transfer of leaving migrants (capital transfer outflows) can increase, or the transfer of goods and financial assets of entering migrants (capital transfer inflows) can decline, both negatively affecting the capital account.

Appendix 5: International risk-sharing and Japan's earthquake insurance

The analysis in the text has shown that, despite its high propensity to experience earthquakes, Japan does not share the risk of earthquake internationally. The lack of international risk-sharing through earthquake reinsurance stands out in an international comparison. To shed further light on the issue of international risk-sharing of Japan's earthquake insurance, an understanding of some institutional aspects of the country's earthquake insurance system becomes necessary.

In Japan, earthquake insurance is offered by two entities: private, shareholder-owned nonlife insurance companies that are heavily backstopped by a government agency and cooperative mutual insurers, aka, *kyosai*. Prominent among the latter is the National Mutual Insurance Federation of Agricultural Cooperatives (JA Kyosai), by far the biggest kyosai, and Japanese Consumers' Co-operative Union.[26] While both offer similar insurance coverage, they set insurance premiums differently. The premiums for private earthquake insurance vary depending on the (eight) zones where the property is located as well as the type of construction, ie whether wooden or non-wooden. The premiums for kyosai earthquake insurance are flat rates – it only depends on the type of construction.[27]

Private earthquake insurance has been taken up by twice the households that have taken up kyosai earthquake insurance. An option on top of fire insurance,[28] about 62% of fire insurance holders took earthquake insurance in 2016,[29] leading to a penetration rate among the households of 30.5%. According to World Bank (2014), the penetration rate of kyosai is 14%. Taking these figures together the total penetration rate of private earthquake insurance and kyosai mutual insurance among the households is less than half.

Japan's private earthquake insurance market can be considered the marketing face of a public-private consortium. Non-life insurance companies sell earthquake insurance but they are legally prevented from differentiating their products. Moreover, the nonlife insurance companies must "cede" 100% of the earthquake insurance premia and liabilities to the Japan Earthquake Reinsurance (JER) Co. (A5-1). That means that the JER is the de facto sole earthquake insurer for the private earthquake insurance market. Out of the insurance premiums paid by private nonlife insurance companies, about 27% remain at the JER as reserves, about 70% are be used to purchase reinsurance from the Japanese government's Earthquake Reinsurance Special Account and 3% are ceded back on a pooled basis to the private insurers. Reserves collected at the Earthquake Reinsurance Special Account are

[26] While nonlife insurance companies are under the jurisdiction of the Ministry of Finance, kyosai are under the jurisdiction of the ministry in charge of supervising the cooperative a kyosai is created for. For example, the kyosai for the Japan Agricultural Cooperatives (JA Kyosai) is under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries, and the National Federation of Workers and Consumers Insurance Cooperatives' kyosai is under the Ministry of Health, Labour and Welfare. Thus, usually kyosai are supervised by other ministries than the Ministry of Finance.

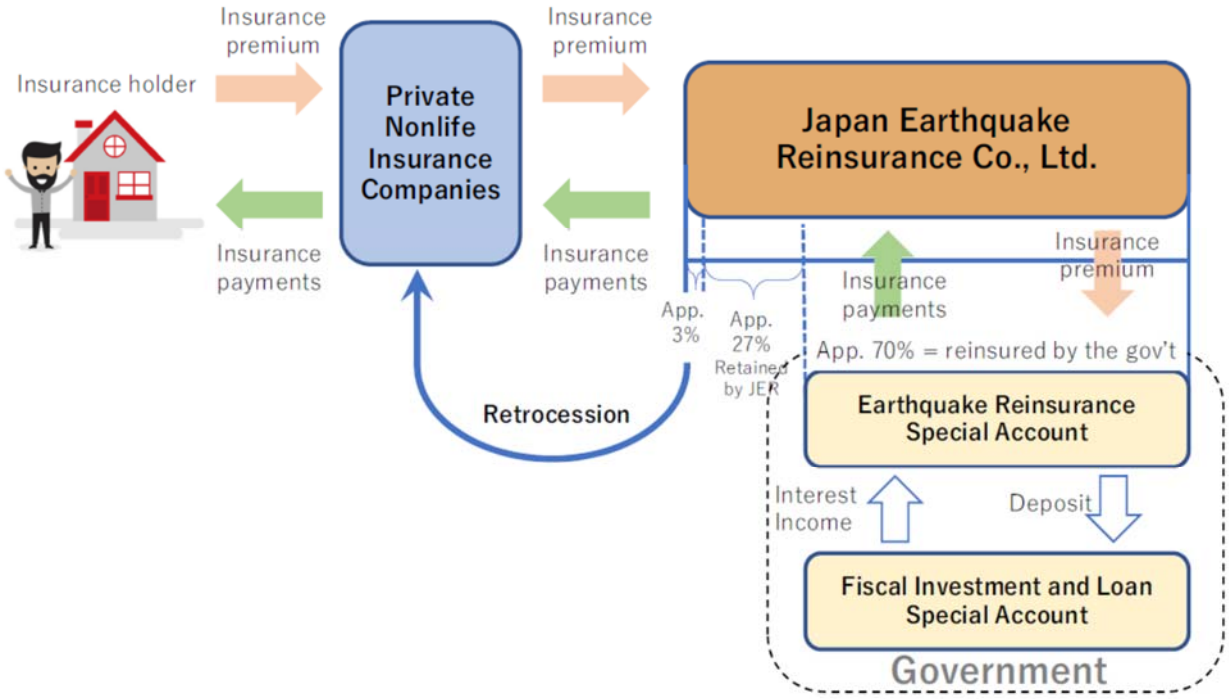
[27] For more details refer to World Bank (2014) and GIROJ (2014).

[28] Earthquake insurance alone cannot be purchased. It must be added to fire insurance. Fire insurance is an option to home or apartment owners, but applying for a mortgage usually requires fire insurance.

[29] As of March 2011, only 48.1% of fire insurance policy holders held earthquake insurance.

deposited in the Fiscal Investment and Loan Special Account, and interest income yielded from JGBs held by this account accumulate in the Earthquake Reinsurance Special Account (Graph A5-1). The sharing of the losses by the three entities, private nonlife insurers, the JER, and the government, differs depending on the total amount of insurance claims for a given earthquake.

Japan's earthquake insurance system — Graph A5-1



Notes: This figure is created based on the Japan Ministry of Finance (www.mof.go.jp) and JER (2016, 2017). The shares of reserves to be paid by the JER are as of the first quarter of 2017.

The current limit (ie as of 2017) of total amount of insurance claims is set at 11.3 trillion yen ($102.7 billion). Of this amount, the maximum liability of the government of Japan is as high as 98.5%, with that of JER and private insurers being 1.3% and 0.2%, respectively (JER (2017)).

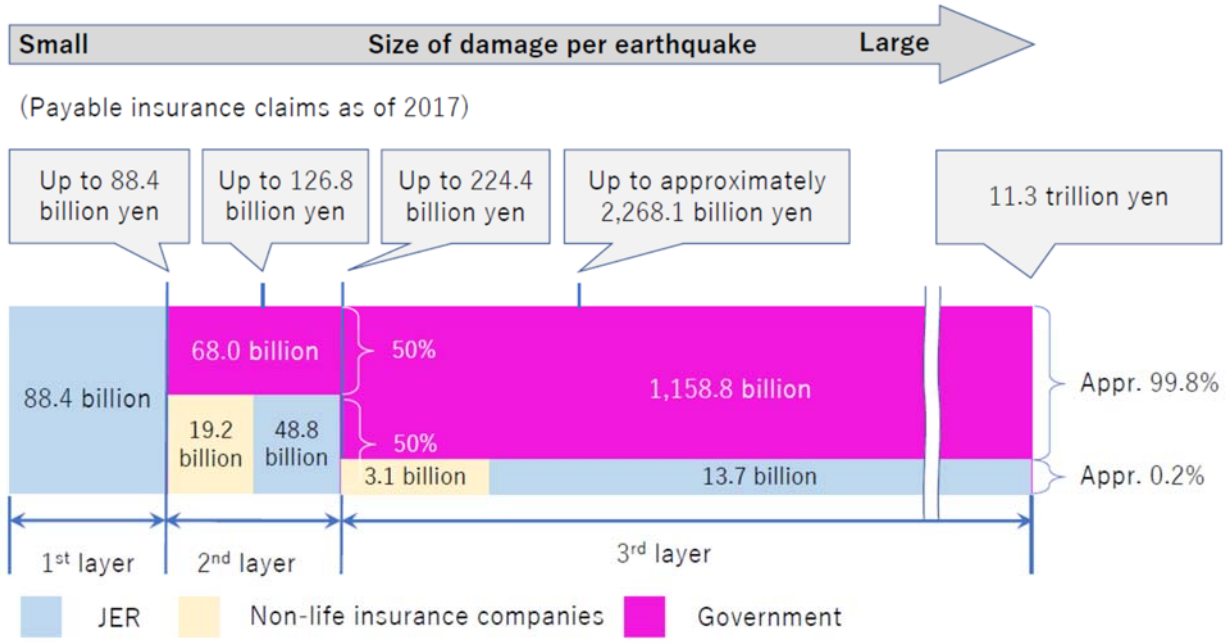
The layering puts the private firms in the middle. For claims per earthquake up to 88.4 billion yen, only the JER makes payments ("first layer"; Graph A5-2). For the portion of losses from 88.4 billion yen up to 224.4 billion yen, the loss is shared among the three ("second layer"). For the portion exceeding 224.4 billion yen up to the limit of 11,300 billion yen, the government pays most of it (approximately 99.8%) with the remaining mostly paid for by the JER.[30]

[30] Hence, when the limit liability of 11,300 billion yen is reached, the shares of liabilities among the government, JER, and private insurers become 98.5%, 1.3%, and 0.2%, respectively, as already mentioned in the text. Before the March 11, 2011 earthquake, the government's liability was only 78% with the rest shared equally between JER and private insurance companies (out of the limit liability of 5,500 billion yen – See Appendix 3). Soon after the Tohoku earthquake (as of May 2011), the government's liability was raised to 87% with the shares of JER and private insures reduced to 10% and 3%, respectively. Since then, the shares have been revised several times with the government's share increased and the private insurers' share reduced in each revision.

Thus, for much of Japan's earthquake insurance system, clearly, the central government plays an overwhelming role. It is no exaggeration to say that the country's earthquake insurance system is in effect run by the public sector.

Coming back to the extent of international risk-sharing, the leading role played by the government in the earthquake insurance industry may explain the low degree of international risk-sharing. The Ministry of Finance essentially runs (and sends its "old boy" to be the head of) the JER and administers both the Earthquake Reinsurance Special Account and the Fiscal Investment and Loan Special Account (sometimes referred to as the "second budget" without any need for democratic approval). By building up domestic reserves, it increases the market for Japanese government bonds relative to a counterfactual in which re-insurance is purchased abroad, and reserves are invested in other bonds.

Liabilities sharing in Japan's reinsurance scheme — Graph A5-2



Source: JER (2017).

Now that we have seen that most of earthquake reinsurance risk is taken by the government sector instead of being subject to markets or international risk-sharing, we know that earthquake risk which "private" nonlife insurers ostensibly cover is being "internalised" by the Japanese government. In other words, as far as private earthquake insurance is concerned, the government is the insurer of first and last resort.

However, as previously mentioned, in addition to private nonlife insurers whose penetration rate is 30%, kyosai also provide earthquake insurance, adding another 14%. Unlike private earthquake insurance, kyosai earthquake insurance is mostly reinsured internationally in the markets, which means the earthquake insurance scheme kyosai provide is akin to the one shown in A2-1.

At the time of the 2011 earthquake-tsunami crisis, out of the total estimated economic losses of 16,900 billion yen, 16%, or 2,750 billion yen, was insured, 78% (2,137 billion yen) of which was residential and 22% (613 billion yen) was commercial.

In the 2,137 billion yen insured residential loss, private nonlife insurers took 56.2%, or 1,200 billion yen, while kyosai did the remaining 43.8%, or 937 billion yen. The 1,200 billion yen claims went through the process shown in Graph A5-2. The shares retained by the JER, private nonlife insurers, and the government are 12.8%, 42.0%, and 45.2%, respectively (Graph A5-3). See Appendix 3 for how the shares of liabilities among the government, JER, and private nonlife insurers are calculated. Additionally, according to the World Bank, JA kyosai, the biggest kyosai, incurred estimated losses of 830 billion yen, 90%, or 747 billion yen, of which were residential.[31] Then, 58% of the residential losses insured by JA kyosai are reinsured internationally (Graph A5-3).

What do these statistics mean? These statistics show how international reinsurance is conducted almost solely by kyosai.

If we assume all the other kyosai also internationally reinsure 58% of their losses as JA kyosai does, the aggregate reinsurance for the residential losses purchased by all kyosai can be estimated as 543.7 billion yen (= 937 billion yen x 58%), or $6.8 billion.[32]

Using the data shown in Table 2, we know that the aggregate reinsurance for the residential losses purchased by all kyosai is about 3% of total estimated direct economic losses (= $6.8 billion / $225 billion). In Table 2, we reported the estimated ratio of international reinsurance in the estimated economic losses was 3.8%.[33] This means that 79% of international reinsurance was done by kyosai.

Is kyosai the only entity that shares earthquake risk internationally?

According to the JER (http://www.nihonjishin.co.jp/insurance/) and the Japan Ministry of Finance (www.mof.go.jp), about 3% of insurance premiums ceded to the JER is *retroceded* to non-life insurance firms as well as a Japanese private reinsurance company called Toa Reinsurance (Graph A5-1). According to Toa Re (http://www.toare.co.jp/index.htm),[34] the firm does not purchase reinsurance from abroad, but does *swap* natural disaster risks with overseas insurance and reinsurance companies. However, considering that only 3% of insurance premiums ceded to the JER is retroceded to non-life insurance firms and Toa Re, even if Toa Re were to swap all the risk, it would not be too large.

JER on its website (http://www.nihonjishin.co.jp/top.html) makes it clear that it does not reinsure or retrocede internationally. All these pieces of information suggest that kyosai is almost the sole insurer that shares risk internationally. Except for that, JER and the Japanese government are the terminal insurers.

From a different angle, if all the entities, the Japanese government, JER, and private non-life insurance firms, had reinsured internationally to the same extent as JA kyosai did, 58% of the 2011 disaster's direct economic loss would have been

[31] Using the data for JA kyosai, the amount of reinsured residential losses can be calculated as 433.3 billion yen (= 830 billion yen x 90% x 58%). Considering that 937 billion yen of the residential losses were insured by kyosai in total, JA kyosai accounts for 79.7% of the total.

[32] The dollar yen exchange rate used here is $1 = 80 yen, which is the average exchange rate for the year of 2011.

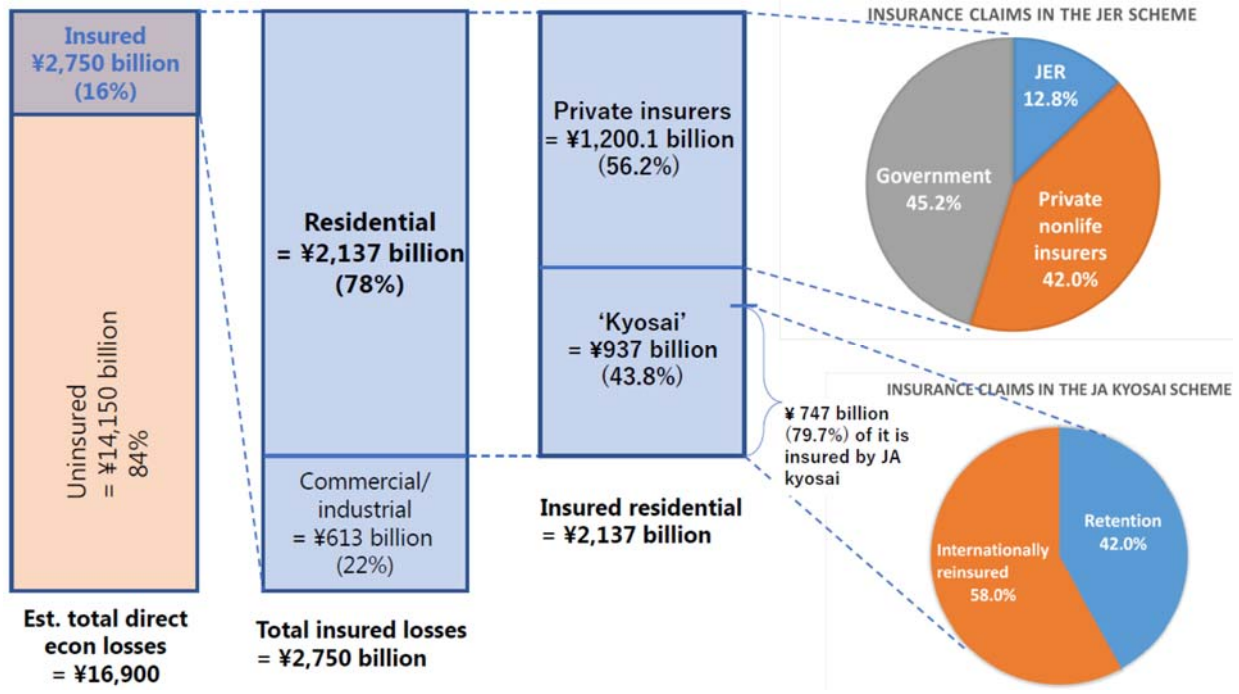
[33] The World Bank (2014) estimates it as 3.7% of total estimated economic losses (row (A5) in Table 2).

[34] It is Japan's only private reinsurance firm. According to A.M. Best, it is ranked as the 20th largest reinsurance firm (in terms of unaffiliated gross premium written in 2016).

reinsured, which would be comparable to the New Zealand's 2011 earthquake and the September 11th attack.

Thus, active involvement of the Japanese government, both directly and indirectly through JER, has contributed to keeping international risk-sharing minimal. Conversely, it suggests that if the government sector reduced its role as provider of earthquake insurance, it may help Japan to benefit more from international risk-sharing.

Detailed look at insurance claims for the Great East Japan Earthquake of 2011 Graph A5-3



Appendix 6: Risk-sharing among the Japanese government, JER, and private insurers in 2011

The liabilities of insurance claims arising from the March 11, 2011 Tohoku earthquake were determined according to the scheme implemented in April 2009. In this liability-sharing scheme (Graph A4-1), the limit of total amount of insurance claims was set at 5.5 trillion yen (almost exactly half of the current limit). Under this scheme, for the total insurance claims per earthquake up to 115 billion yen, the payments are to be made solely by the JER ("first layer"). The portion exceeding 115 billion yen up to 1,925.0 billion yen is equally shared by the government and the other two entities (ie JER and private nonlife insurers) ("second layer"). Notice that, compared to the current scheme (as of 2017) shown in Graph A6-1, the liabilities shared by JER and private insurers prior to the Great East Japan Earthquake used to be much higher. For the portion exceeding 1,925.0 billion yen up to the limit liability of 5,500 billion yen, the government pays 95% of it with the remaining 5% paid for by the JER and private insurers.[35]

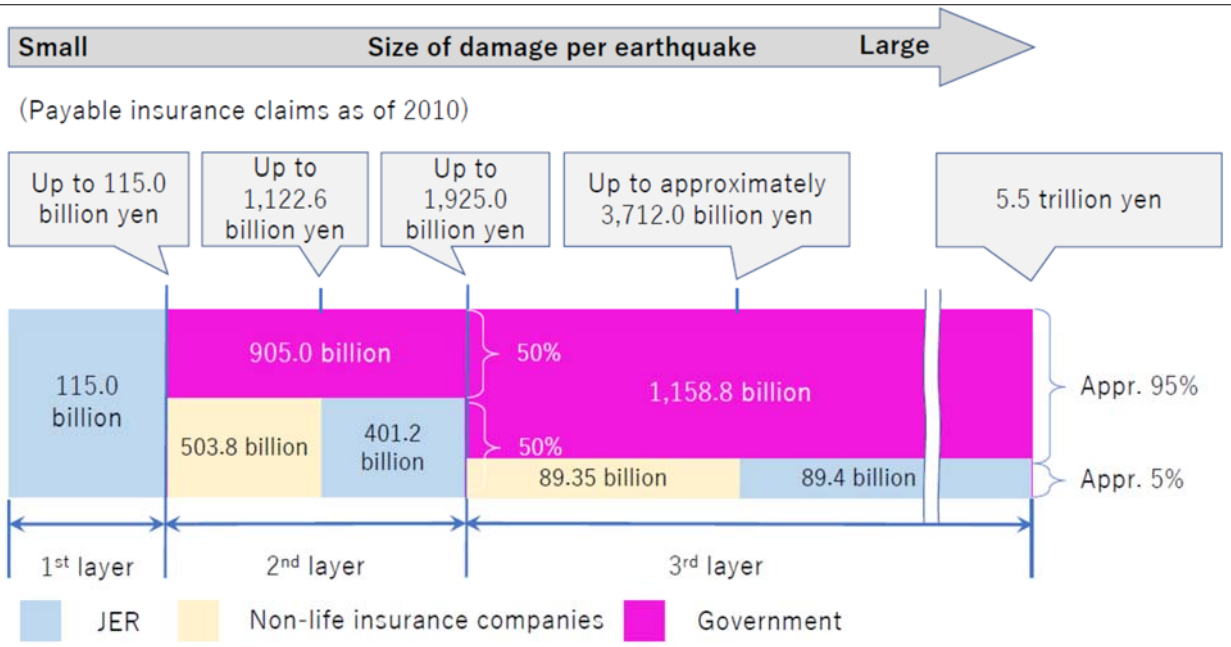
As mentioned in the text, at the time of the Great East Japan Earthquake, the residential loss insured by private nonlife insurers was 1,200 billion yen (56.2% of the total insured residential loss of 2,137 billion yen with the remaining insured by kyosai, Graph A5-3), which reached the second layer of the pre-2011 liability-sharing scheme (Graph A6-2).

Based on the liability-sharing scheme, the amount above the first layer was equally divided between the government and the combination of JER and private nonlife insurers. This left the government's liability at 542.5 billion yen (= (1,200 – 115)/2). The other half of 542.5 billion yen was divided between JER and private insurers, but because the total liability exceded 1,122.6 billion yen, the ceiling for JER's liability, it was liable for just 503.8 billion yen (= (1,122.6 – 115)/2). Private insurers took the rest, that is 38.7 billion yen (= 1,200 – (115 + 542.5 + 503.8)).

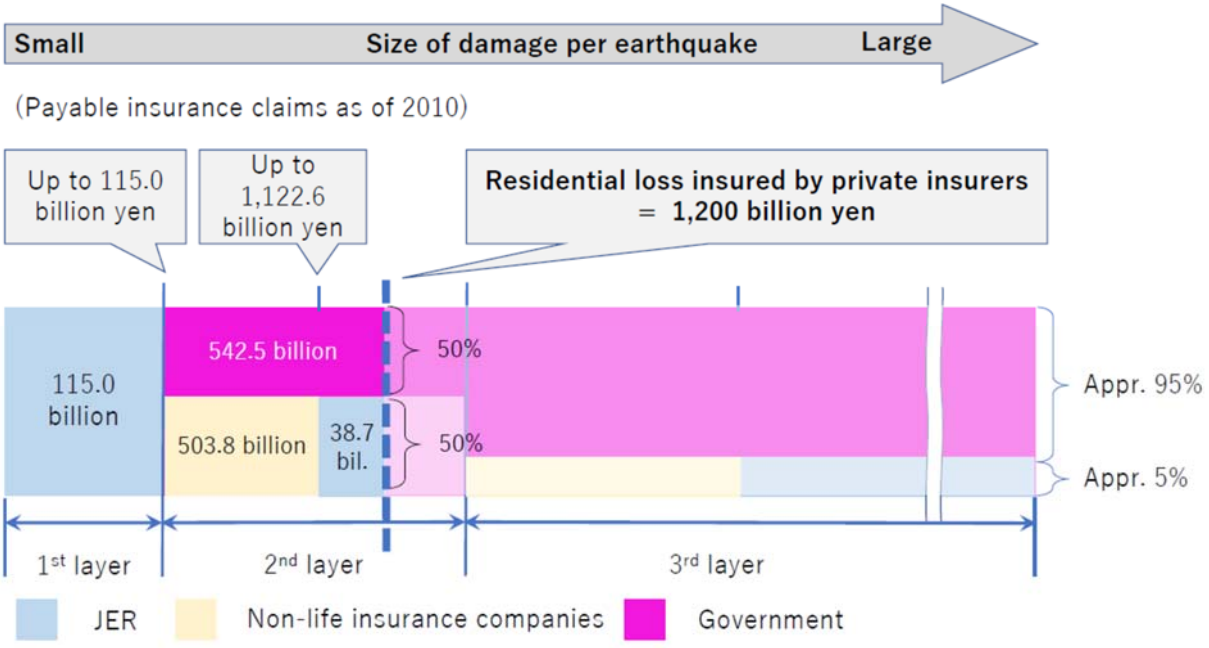
With these calculations, the total loss taken by the government is 542.5 billion yen, or 45.2%. The loss taken by JER is 153.7 (= 115 + 38.7) billion yen, or 12.8%. then the loss taken by private nonlife insures is 503.8 billion, or 42.0%. These shares are shown in the pie chart in the right top corner of A5-3.

[35] Hence, if the limit liability of 5,500 billion yen is reached, the shares of liabilities among the government, JER, and private insurers would become 78%, 11%, and 11%, respectively, as already mentioned.

Liability-sharing scheme as of pre-2011 earthquake Graph A6-1



Shared liabilities-sharing at the time of the 2011 Tohoku earthquake Graph A6-2



Source: JER (2010), authors' calculation.

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