The Cost of Historic Earthquakes Today – Economic Analysis since 1900 through the use of CATDAT

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Abstract

The newly-formed CATDAT damaging earthquakes database contains economic damage and historical impact data on over 6500 earthquakes worldwide since 1900. This paper details the economic trends in earthquakes since 1900, with many economic loss values not reported in existing databases. Historical GDP, exchange rate, wage information, population and insurance information have been collected globally to form these comparisons.
It was found that the 1988 Spitak earthquake in Armenia caused the greatest impact on a country's economy as a proportion of nominal GDP (well over 300%), whereas the highest absolute economic loss was seen from Japan's 1923 Great Kanto Earthquake with approx. $204 billion USD damage (2010 HNDECI adjusted).
A separate analysis for earthquake shaking versus secondary effects (tsunami, liquefaction, landslide, fire etc.) as a proportion of historical economic losses is also shown.
Detailed economic analysis done as part of this study shows that the adjustment utilised by historic databases using simple inflation via Consumer Price Index greatly underestimates the impact of historic earthquakes, giving less significance to historic events. Thus, a hybrid index is shown to better account for the historical cost of earthquakes in today's terms, using a combination of wages, construction costs, workers' production, GDP, CPI and other tools.
The results of the global analysis using this index show that there is not a significant increasing trend in global annualized economic losses due to earthquakes, indicating that the second half of the century has not experienced a major urban centre affecting earthquake like the 1923 Great Kanto earthquake. This increase is not as marked as in other studies (MunichRe 2000, 2002; Vranes et al. 2009; Swiss Re 2009), when different economic conversion indices are used.

Keywords: CATDAT, socio-economic analysis, economic loss, earthquake cost, historic earthquakes.

NOTE:-The concepts in this paper are to be submitted to a journal.

Introduction

To compare the economic losses of any two historic earthquakes in history, they need to be brought forward to present value. This is not simply an inflation adjustment but is representative of what would be paid in today's dollars for the event-year earthquake effects.

An extensive global database of exchange rate, CPI and GDP (nominal and real) information was created in order to be able to adjust and compare foreign earthquake loss estimates. Global databases of wage rate and other parameters such as PPP were also created as part of the study from sources such as Maddison (2001, 2003), Officer and Williamson (2010), World Bank (2010), IMF (2010) etc as these details are required to effectively convert loss estimates from around the world into present-day costs.

The newly built worldwide CATDAT damaging earthquakes and secondary effects (tsunami, fire, landslides, liquefaction and fault rupture) database was developed to validate, remove discrepancies and expand greatly upon existing global earthquake databases (EM-DAT, NGDC, UTSU, PAGER-CAT, MRNATHAN etc.); and to better understand the trends in vulnerability, exposure and possible future impacts of historic earthquakes. Over 14000 sources of information have been utilised over the last few years to present data from over 11600 damaging earthquakes historically, with over 6500 earthquakes since 1900 examined and validated before insertion into the database. Each validated earthquake includes seismological information, secondary effects (social, economic and type), building damage (levels, important infrastructure etc.), ranges of social losses to account for varying sources (deaths, injuries, homeless and affected) and ranges of economic losses (direct, indirect, aid contribution and insurance details). An upper bound and lower bound range of economic loss estimates for each earthquake through history is contained within the database, including a median estimate. There are a significantly increased number of exact economic loss estimates as compared to other databases found from various sources in foreign literature sources. For further information as to the database, refer to Daniell (2010).

A damaging earthquake is entered into the CATDAT database by the following criteria:-

- Any earthquake causing collapse of structural components.
- Any earthquake causing death, injury or homelessness.
- Any earthquake causing damage or flow-on effects exceeding $10,000 international dollars, Hybrid Natural Disaster Economic Conversion Index adjusted to 2010.
- Any earthquake causing disruption to a reasonable economic or social impact as deemed appropriate.
- A requirement of validation of the earthquake existence via 2 or more macroseismic recordings and/or seismological information recorded by stations and at least 1 of the 4 definitions above.

Through the CATDAT damaging earthquake database, it can be seen that the generalised annual earthquake economic loss is increasing due to an increase in exposure and population, with only a slight decrease in relative vulnerability of the building stock. However, this increase is not as marked as some other studies (MunichRe 2000, 2002; EM-DAT 2004; Vranes et al. 2009; Swiss Re 2009), when different economic conversion indices are used. This statement will be explored below in addition to other trends.

What is contained in an earthquake total economic loss estimate?

First, it is important to define what parameters are included in earthquake loss estimates. Previously, earthquake economic loss was limited to property loss and other stock losses as an estimate in addition to relief costs. Globally, however, there is no set standard for calculating the total economic loss due to an earthquake e.g. HAZUS employs a different method (Cochrane, 2004) when compared to Middleman (2007), BTE (2001) or UNDP (2009).

Table 1 – Types of losses accounted for in economic analysis of natural disasters

Loss Type	Descriptor
Direct Losses	• Property (Private with residential and non-residential, Public infrastructure).
Indirect Losses	• Business Disruption, Indirect loss from inter-industry effects, Loss of Public Services. • Household alternative accommodation • Agriculture • Transport networks • Relief and Response costs • Residential and Non-Residential cleanup wages and materials (with associated demand surge (Olsen 2008)) • Postponed impacts – cuts in household spending.
Intangible costs	• Fatalities, injuries, homelessness, health effects (debilitation) • Lost tourism – Environmental, cultural and historic assets.

In the opposite way, there are offsets due to all these net regional losses.

Net Regional Losses	• Rebuilding assistance, survivor benefits, unemployment compensation, aid payments, node and network disruptions, bottleneck losses outside earthquake affected area, systematic financial and institutional disruption losses.

<u>How do we evaluate the historical cost of an earthquake in present-day terms?</u>

In order to compare the relative economic loss of two or more earthquakes, these earthquake economic loss estimates need to be adjusted to a common year in order to gain the relative differences.

Currently, historical loss catalogues (MRNATHAN (MunichRe); NGDC; EM-DAT (CRED)) use USA-based inflation-adjustment to bring the economic loss forward to current day dollars, or leave the economic loss in historical-day costs. Leaving economic loss in historical-day costs is a problem for trend analysis as it grossly underestimates earthquakes a long way in the past. Thus, many graphics such as the one in Figure 1 below wrongly show a very low cost associated with historic pre-1980 earthquakes.

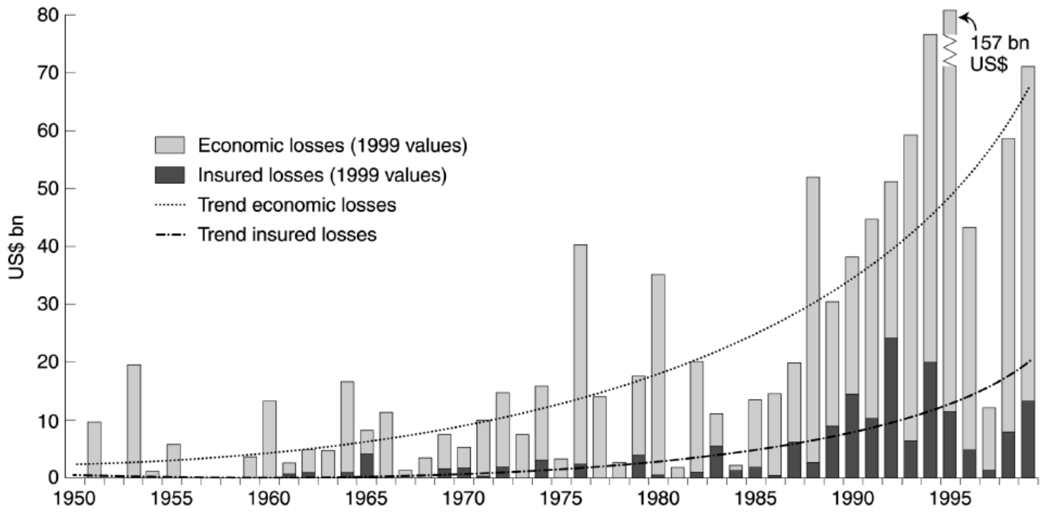

Figure 1 – MunichRe Data for Natural Disasters from 1950-1999 brought to 1999 dollars – this can be seen to not correlate with actual economic trending losses (MunichRe 2000)

In fact, there are many ways to bring historic earthquake damage loss estimates forward to current-day dollars. The following list shows inflation adjustment measures for economic costs commonly used worldwide.

1) ***CPI (Consumer Price Index) adjustment***

This is the most common method and employs a cost comparison of consumer goods and services. It forms the basis for a country's inflation rate. However, as an earthquake economic loss is generally not related to food and electrical goods costs it is not generally reasonable.

2) ***GDP Deflator***

This is a measure of average prices, including not just consumer goods and services but comparing the cost of housing, transportation, food etc.

3) ***The Consumer Bundle***

This is the average annual expenditure of a family or household, which is comparable to an increase in cost of goods and services but also the amount of goods and services that are used by the household through time.

4) ***The Unskilled Wage***

This is the wage of an unskilled worker. This can be assumed to be a function of the amount of work as well as the wage. It is assumed that unskilled work remains constant through time and so is a good measure of wage (it does not take into account the percentage of changing composition of workforce away from unskilled labour towards skilled labour).

5) ***The Worker's Production Index***

This is an index which is based on the wage of a production worker in manufacturing (i.e. in a specific job), thus also includes earnings as well as the increase in added benefits through time.

6) ***The Average Wage***

This includes the average of all wages in the country and is influenced by changes in the composition of the workforce towards more skilled labour and also higher wages on the top end. This is therefore not as good a measure through time, as it is difficult to know what values were included in the early 1900s and which were not.

7) ***Project Escalation Indices***

These are methods using a combination of indices in terms of construction materials, wages, inflation and other measures, in an attempt to account for the cost of an engineering project spanning a number of years.

8) ***The GDP per capita***

The Gross Domestic Product per capita is also a good measure of the general output of a single person and has a good correlation with average income; thus, it is probably a better proxy for income than average wage for the early 1900s.

9) ***Gross Domestic Product***

The Gross Domestic Product is the market value of all goods and services produced in a country in a year. If this is used for determining the earthquake loss as a percentage, then it can be seen how much loss is the percentage of all output in that year. Therefore, this usually will overestimate greatly the cost of a natural disaster in current terms due to the large increase in population and the associated infrastructure.

With the increasing development of high seismic risk countries such as China, India and Indonesia, it is important to correctly characterise this increase in trends when bringing economic loss from natural disasters (and specifically earthquakes) forward.

Which GDP type should be used for evaluating historic earthquake loss as a function of GDP?

There are two main types of Gross Domestic Product that characterise a country's official market value economic output. This can also be complicated by the use of purchasing power parity, international currencies, hyperinflation, currency changes and different base years. ***Nominal GDP*** shows the current-dollar amount of Gross Domestic Product. ***Real GDP*** adjusts the nominal amount for inflation or deflation i.e. adjusted for price changes.

Purchasing Power Parity (PPP) also can be used for each of these showing what the local currency unit is worth within a country. This is useful for comparisons of what certain items cost. Thus, for big countries, this is a more useful method for comparison of GDP (nominal) of particular countries. It can be seen to follow a certain link to the development status of a country when compared to the United States with a value of 1. Currently in 2010, $1.54 in Bermuda will buy the same as $1 in the US. On the other end of the scale is Zimbabwe, whose national currency has been suspended as of April 2009, due to hyperinflation. Guinea has the lowest PPP without hyperinflation with $0.12 of the same purchasing power as $1 in the US.

Thus, two forms of GDP are proposed for comparison of countries when looking at the total economic loss as a function of GDP – GDP (Nominal) and GDP (Nominal, PPP). This is because the total economic loss at the time of the disaster can be compared directly with the consequences at that time.

The following is a list from CATDAT of the greatest economic losses as a function of GDP (Nominal) and GDP (Nominal, PPP). The median cost shown in Table 2 presented in US dollars is the most accepted value of total economic loss at the time of the earthquake as found from CATDAT through the literature. This is classified as the median cost of the event. In the full CATDAT database, there is a range of accepted loss estimates for each earthquake that are not included in this paper. This was generally presented in US dollar values in the literature (converted from local currency using time-of-event exchange rate).

It is also important to take into account that the economic loss is generally borne over a few years following the disaster. In the case of the 06.12.1988 Spitak Earthquake, this was extremely important as the Soviet Union changed into individual states before much reconstruction and relief had been done (it was seen that 1 or 2 years after the earthquake, camps were still in place and not much had happened since the disaster). Thus, the Soviet collapse significantly impacted upon Armenia's resilience from such an earthquake, which is not taken into account from a 1988 value of the Soviet Union GDP. It can be seen in Table 2 that the percentage of GDP is generally higher than that of GDP (PPP). This is because most of these earthquakes have occurred in countries where the PPP is much less than in the United States (a proxy for developing countries) and so the nominal GDP is much less than the nominal GDP (Purchasing Power Parity adjusted). It can be seen from the percentages in the table below that when evaluating the Kobe 1995 earthquake, the PPP was greater in Japan than the United States for the year of 1995 – a function of the strength of Japan's economy at that time. There is no one global GDP database based on current prices and hence a great deal of effort was needed to create databases to develop Table 2 (Daniell, 2010c).

Table 2 – The highest ranked earthquake losses since 1900 in terms of percentage of nominal GDP (both unadjusted and purchasing power parity) – CATDAT v4.31, J. Daniell, 2010.

Rank	Earthquake	Date	Median cost at time of event in $US	% of Nominal GDP (PPP)	% of Nominal GDP
1	Spitak, Armenia	07.12.1988	16.20 bn	92.3*	358.9*
2	Port-au-Prince, Haiti	12.01.2010	7.754 bn	70.3	119.8
3	Guatemala	04.02.1976	3.900 bn	44.6	98.0
4	Managua, Nicaragua	23.12.1972	0.845 bn	19.7 to 38.3	67.1 to 96.2
5	Cartago, Costa Rica	04.05.1910	0.025 bn	63.5	≈90.0
6	Maldives Tsunami**	26.12.2004	0.603 bn	50.1	77.7
7	Concepcion, Chile	17.08.1906	0.260 bn	47.8	55 to 82.86
8	Wallis and Futuna	12.03.1993	0.014 bn	51.9	54.0
9	Great Kanto, Japan	01.09.1923	3.840 bn	29.8	52.8
10	Nicaragua	31.03.1931	0.030 bn	26.5	51.0
11	Jamaica	14.01.1907	0.013 bn	23.9	45.9
12	El Salvador	10.10.1986	1.500 bn	12.8	39.77
13	Chillan, Chile	25.01.1939	0.361 bn	21.5	31.75
14	Racha, Georgia*	29.04.1991	1.700 bn	3.5 to 17.0 (5.4)	17.2 to 85.0 (26.8)
15	Samoa**	29.09.2009	0.147 bn	17.8	26.34
16	El Salvador	08.06.1917	0.025 bn	15.8	≈26.0
17	Romania	04.03.1977	4.513 bn	8.54	17.23
18	Skopje, TFYR Macedonia***	26.07.1963	1.100 bn	9.00	16.50
19	Quito, Ecuador	06.03.1987	1.500 bn	7.21	16.48
20	Fukui, Japan	28.06.1948	1.000 bn	3.59	15.56
21	Chile	27.02.2010	30.00 bn	11.7	15.27
22	Agadir, Morocco	29.02.1960	0.300 bn	9.25	14.73
23	Nepal**	29.07.1980	0.210 bn	3.66	12.59
24	Valdivia, Chile	22.05.1960	0.550 bn	6.50	12.49
25	El Asnam, Algeria	10.10.1980	5.200 bn	9.19	12.28
26	Ecuador	05.08.1949	0.053 bn	4.68	15.36
27	El Salvador	13.01.2001	1.604 bn	5.58	11.61
28	Guam	08.08.1993	0.300 bn	9.38	10.29
29	Peru	31.05.1970	0.550 bn	2.95	9.25
30	Valparaiso, Chile	03.03.1985	1.500 bn	3.95	9.10
31	Manjil, Iran	20.06.1990	8.000 bn	3.73	8.85
32	Izmit, Turkey	17.08.1999	20.000 bn	4.92	8.03
33	Bourmedes, Algeria	21.05.2003	5.000 bn	2.53	7.35
34	Tangshan, China	27.07.1976	11.000 bn	5.02	7.25
35	Limon, Costa Rica	22.04.1991	0.510 bn	2.84	7.12
	El Salvador	*06.05.1951*	*0.023 bn*	*2.62*	*6.11*
	Hawkes Bay, NZ	*02.02.1931*	*0.025 bn*	*3.42*	*5.70*
	Kobe, Japan	*16.01.1995*	*123.000 bn*	*4.23*	*2.34*

*Accounts for a partial Soviet Union response – doubling the 1990 Nominal GDP and GDP (PPP) of Armenia. In terms of the Georgian earthquake, hyperinflation made it very difficult to properly determine the GDP of the time; thus, a range has been given incorporating different sources from 1991-95 using an average value through this period consistent with the reconstruction payout.

** 1. Only Samoan loss counted – other affected countries include American Samoa, Tonga and French Polynesia. 2. Similarly for Maldives in the Indian Ocean Tsunami of 2004. 3. Only Nepalese loss counted. India also affected.

***If counted as only a proportion of TFYR Macedonia, the value would have been about 165% of the GDP of the Macedonian part of the former Yugoslav republic.

Other Assumptions

- 1902 Uzbekistan (7.715 million USD), 1902 Shemakha, 1907 Karatag (8 million USD), 1948 Turkmen SSR are deemed to be part of the Russian empire. Similarly many other earthquakes including 1905 Albania & 1906 Taiwan, fall into previous empires (Ottoman, Japan, Yugoslav etc.)
- 1902 Guatemala (up to 25 million USD, up to 35% GDP(PPP)), is difficult to discern which losses are earthquake and which losses are volcano-related (Santa Maria).
- 1918 Puerto Rico (up to 29 million USD) was deemed to be part of the USA. If not, the output for the year was 36.8 million USD – translating into approximately 80% of output.
- 1917 El Salvador (25 million USD, 15.7% GDP(PPP)), 1928 Bulgaria (16 million USD, 3.85% of nominal GDP), 1931 Nicaragua (30 million USD, 26.5% GDP(PPP)), 1934 Bihar (25 million USD, 6.6% GDP(PPP)), 1935 Pakistan (25 million USD, deemed India), 1945 Pakistan (25 million USD, deemed India), 1982 Yemen (90-320 million USD, up to 10% GDP(PPP)) have not been included in the table above due to uncertainties in the nominal GDP data collected.

An example – The Great Kanto Earthquake of 1923, Japan

Table 3 shows the different total damage costs from some of the major world earthquake databases as well as other Japanese sources. In 1923, 1 USD was equivalent to 2.162 yen (¥). Thus, the conversion is shown in 1923-dollars.

Table 3 – The cost of the Great Kanto Earthquake from various sources (CATDAT v4.07, 2010)

Reference	Cost	Year of Cost	Cost in 1923 USD	Adjustment Method
EM-DAT	$600m	1923	$600m	None
NGDC	$600m (chosen from EM-DAT)	1923	$600m	None
MunichRe MRNATHAN	$2800m ($30129m)	1923 (2003)	$2800m	CPI – US dollars
BSSA - Davidson	$4586m	1923	$4586m	None
Baron Inouye, Finance Minister	7000m-10000m ¥	1923	$3238m-$4625m	None
Chugai Commerce News	1494m ¥ (Insured cost)	1923	$691m (Insured)	None
Contemporary Newspapers	2200m ¥ (Insured cost)	1923	$1018m (Insured)	None

It can be seen that there is much discrepancy in the economic damage estimates from the Great Kanto Earthquake. It can also be seen that the value that EM-DAT and NGDC choose is very low, as it is below the insured loss estimates from official records. Even if the insured loss was the same as the total loss, this figure would still be too low, as the lowest insurance value came from Chugai Commerce News at a converted $691 million USD (1923).
Thus, the MunichRe estimate of $2800m seems the lowest possible plausible estimate. The values of Davidson and the Finance Minister of Japan are preferred, however, due to the source being dated from close to the earthquake (late 1923 to 1925). Nonetheless, it is unknown where the MunichRe estimate of $2800 million estimate comes from in literature. Therefore, CATDAT takes a range of $3238 million to $4625 million with a median value of approximately $3840 million when putting a weighting of the terms.

Thus for the analysis, the CATDAT value in 1923-dollars of $3840 million will be used (or 8.3 billion yen). The MunichRe NATCAT estimate of 2003 was trended forward using United States conditions of Consumer Price Index in attempting to bring the 1923 earthquake into the economic terms of 2003. However, the US trends are of course different to Japanese CPI estimates since 1923. Because the economy of every nation is different through history, the cost of an historic earthquake in today's dollars should be trended on an individual country's index, not just on the US CPI series. This would mean we introduce a term into earthquake loss economics – '2010 US Nation-adjusted Dollars'. The entire CATDAT database uses US nation-adjusted dollars.

Let us explore the difference between a US trended and Japanese trended value (Table 4). The Japanese value needs to be adjusted for the fact that the current 2010 Yen value is approximately 85.46¥ to 1USD compared with 2.162¥ to 1USD in 1923; therefore the CPI trend needs to be exchange rate adjusted.

Table 4 – The difference of CPI adjustment using US trended or Japanese trended data for the 1923 Great Kanto Earthquake

Reference	Original CPI 1923 Index	2010 Index	Cost in July 2010 USD	Adjustment Method
USD	0.0769	1	$49934m	USD CPI
Japanese Yen	0.0731	1	$52531m	Japanese CPI

Up to 1930, the USD and Japanese Consumer Price Index trends are reasonably similar (Figure 2); however, for adjustment of earthquake losses from 1930 onwards, the difference would be a lot between using US and Japanese series adjusted for US dollar exchange rates.

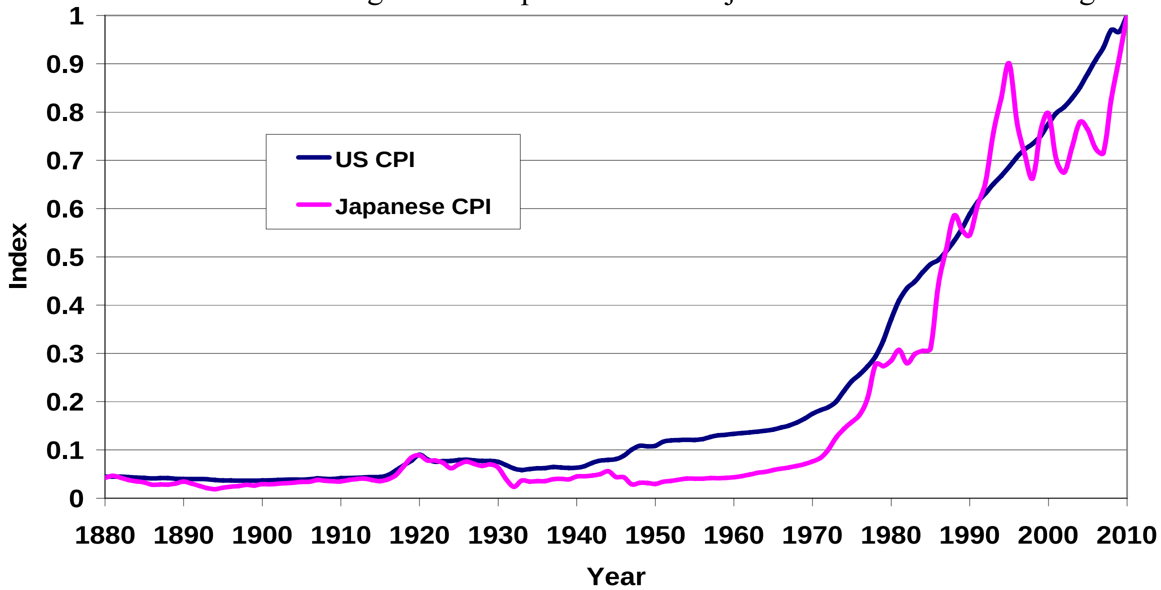

Figure 2 – Japanese CPI (US dollars adjusted) vs. United States CPI from 1880-2010

For the Niigata Earthquake in 1964, CATDAT shows a median economic loss estimate of $800 million USD.

Table 5 – The difference of CPI adjustment using US trended or Japanese trended data for the 1964 Niigata Earthquake

Reference	Original CPI 1964 Index	2010 Index	Cost in July 2010 USD	Adjustment Method
USD	0.1398	1	$5722m	USD CPI
Japanese Yen	0.0546	1	$14652m	Japanese CPI

Thus, this shows the importance of adjusting for differing country CPI series, if inflation is to be used. This shows one of the errors in existing databases. However, through the creation of the CATDAT databases, it has been seen that using CPI adjustment does not account correctly for earthquake loss (Table 6).

Table 6 – The effect of trending data to 2010 dollars using various economic adjustment concepts

Adjustment Type	**Niigata 1964 Earthquake Total Economic Cost**	**Great Kanto 1923 Earthquake Total Economic Cost**
Consumer Price Index	$14652m	$52531m
GDP Deflator	$12529m	
Unskilled Wage	$37320m	$203489m (0.0188)
GDP per capita	$44243m	$247686m
GDP	$51601m	$2783518m

It must be noted that there is a difficulty where hyperinflation occurs, when using indices. The 1948 Fukui earthquake is a good example of this. This earthquake occurred in post-war Japan where hyperinflation was occurring. The estimate of 305 billion yen corresponded to an approximately $1 billion price tag. As a percentage of GDP at the time, it was approximately 15% of the nominal GDP. If we use Japanese CPI to trend this forward, a value of $32 billion results; yet using the average wage index, a value of $246 billion today results. However, if an unskilled wage index is taken into account, a value of $144 billion results. Looking at the destruction in the Fukui earthquake, it is comparable to the damage of the Kobe earthquake in terms of deaths and injuries but there was less damage to buildings and infrastructure. As a proportion of the GDP of Japan, it was much greater than Kobe (2-3%). Thus, the converted value of the Fukui earthquake in 2010 dollars should probably take into account an unskilled wage index.

The Hybrid Economic Natural Disaster Loss Conversion Index (HNDECI)

CPI is not a function of earthquake reconstruction cost and may only have a link to some materials used in construction. 485 items are used in the IMF (International Monetary Fund) version of the CPI adjustment. However, in periods of hyperinflation, CPI should be used relative to a stable currency. A common component of the construction cost index which is incomplete for all countries globally since 1900 is **unskilled wage**. This is the cost of labour for construction and adds up to approximately 50% of most construction cost indices (OECD, Sources and Methods, Construction Price Indices, 2009). The price of building materials can generally be classified in the same realm as the unskilled wage but is a little increase on inflated values (CPI). This theory has been tested for datasets where the construction cost index exists through time. However, an earthquake disaster is not only made up of construction cost indices. Another method to validate the theory is by looking at project escalation indices. Therefore, more research has been undertaken into escalation indices due the large amount money invested globally into project construction costs.

Trending the cost escalation in the previous 10 years in USA from 1999-2008, the CPI increased by 22%, whereas cost escalation was at a rate of about 38%-50%. The cost escalation is approximately 2 times the increase of CPI. Again in the US, the steel price from 2003-2007 increased by 50%, yet the CPI increase was about 5%. This is synonymous with the increase in wages over this time. It should be noted that demand surge is extremely complex and further research will be undertaken to account for this in the natural progression of bringing earthquake loss to present-day value.

In the Hybrid Natural Disaster Economic Index (HNDECI) developed as part of this study, components of the earthquake loss (direct and indirect) are assigned a inflation adjustment measure to bring it to present day value in much the same way as a project escalation index.

In this way, the total earthquake loss will be defined to present day value, eliminating the error of CPI adjustment.

Through the descriptions of major earthquake damage costs in CATDAT and through reconstruction costs it can be seen that 33% of the cost of an earthquake comes under reconstruction unskilled wages. This changes from country to country. Depending on the country used, the EQLIPSE generalised building typologies should be used to work out the reconstruction material. For each building material in each country, the trend of prices should be looked at through time. Through most countries, building materials have been seen to be increasing ahead of CPI due to increasing demand and a bigger import cost where non-natural materials are used.

Lifeline costs, such as telecommunications, water systems and other utilities, have been trended towards a Worker's Production Index type value. Some other damage, such as flow-on effects or economic downtime, can be characterised as a combination of the unskilled wage and also the CPI. Life cost is also seen to relate to average wage as this is a main component of the life cost of a human being – the ability to earn money and make money for the community. BTE (2001) studied the theory for Australia, and this assumption held. Thus, the BTE (2001) method of life costing has been added to the economic loss where the total loss estimate was deemed not to include the flow-on life effects of earthquakes. The economic costs for fatalities, major injuries and minor injuries have been trended through history using proportionate unskilled wage, because the proportion of the losses for fatalities, major injuries and minor injuries comes from lost wages and lost time. Accordingly, this is shown as a trended value globally using global life insurance data and more commonly a country-based unskilled wage index through time.

An overview list of the components and assumptions for the HNDECI is found below in Table 7. This will be discussed in further depth in a subsequent paper only on this index in the global economic climate.

Table 7 – The assumptions for adjustment within the Hybrid Natural Disaster Economic Index

Natural Disaster Parameter	Adjustment to future terms	Reason
Property Loss (commercial, industrial and public buildings)	Country-based unskilled wage index	Historical trends have been matched to property loss with good correlation
Reconstruction Cost of Residential Buildings	Country-based EQLIPSE Building Inventory analysis and historical material databases	Building costs analysis via historical components of houses gives closest value.
Crops, pastures, livestock	Using historical databases – if not, CPI.	CPI is most likely closest to the cost of crops and livestock.
Life Insurance and Intangible costs (Deaths, Injuries, Disability)	Proxy on premiums. Country-based average wage or Worker's Production Index or 1.5 times unskilled wage.	BTE (2001) trended most of this cost to above an unskilled wage trend – with increasing GDP playing a role.
Indirect Losses via business interruption	Consumer Price Index	Economic values should be CPI adjusted (or interest rate)
Clean-up	A combination of material costs (CPI) and demand surge wage. However, this is constant through time.	A 50-50 combination of CPI and unskilled wage.
Utilities and Transport Damage	Unskilled wage index.	Tied closer to construction materials and labour.

Thus, the most difficult part is the reconstruction material cost assumption due to the difficulties in finding datasets for all parameters. Historical datasets will be looked at to build a global adjustment; however, for the moment a value directly between the CPI and the unskilled wage is chosen where data is lacking. A good assumption on a sliding scale is that the economic loss of an earthquake should be brought forward using a value slightly greater than the unskilled wage. Shown are the indices when referring to Australia (Figure 3). Indices have been created for each country.

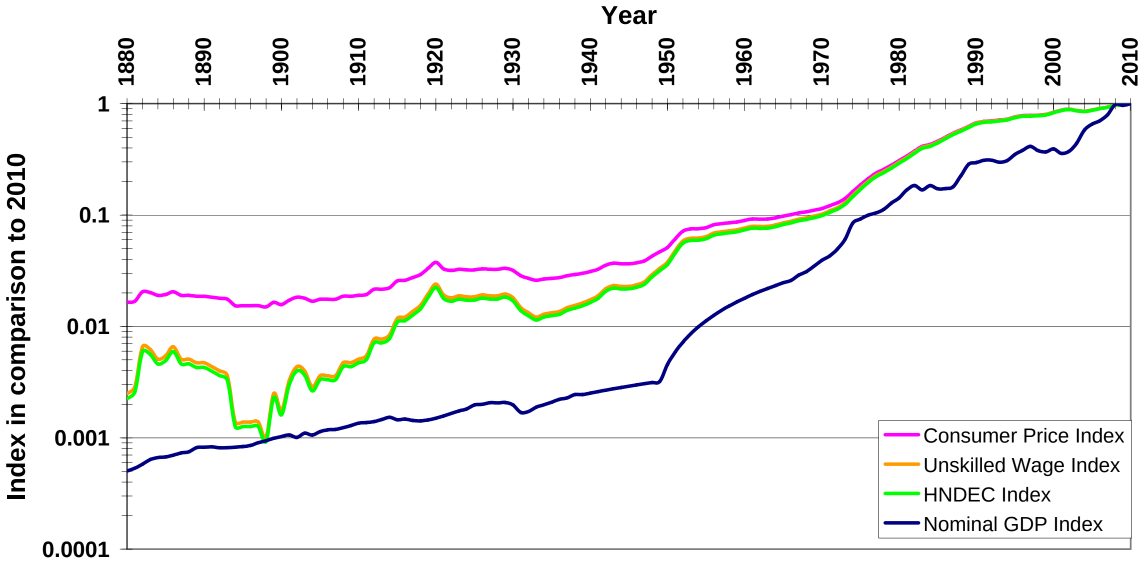

Figure 3 – Australian measuring worth indices including the HNDEC Index.

Using the HNDECI for all worldwide earthquakes to adjust them to 2010 dollars, Figure 4 shows the results of cumulative economic loss for each year.

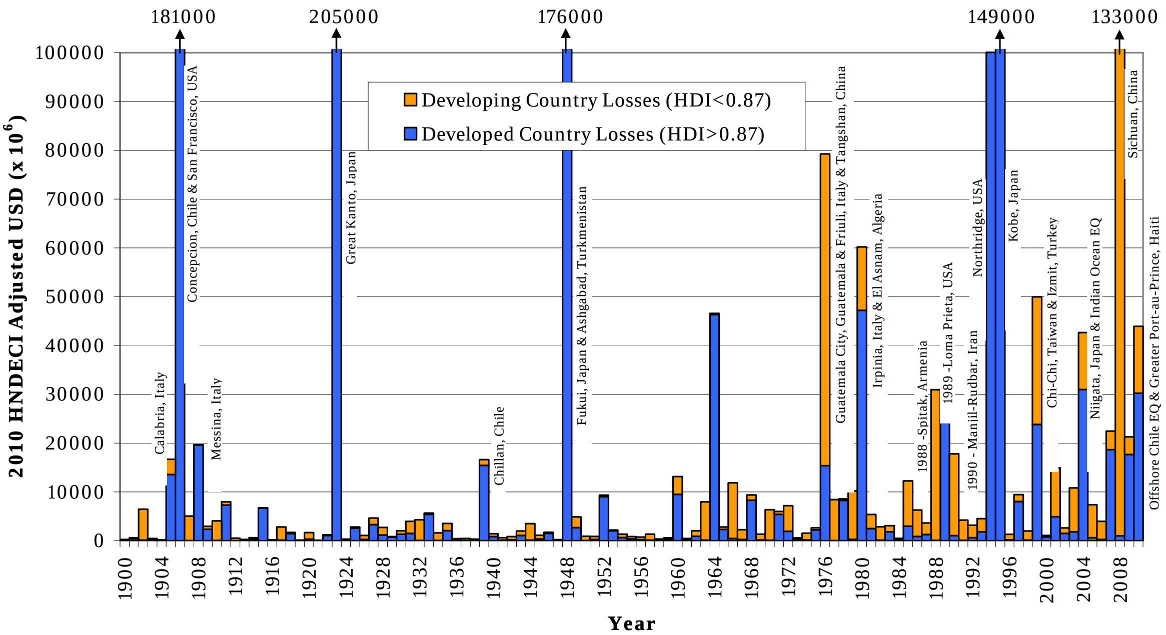

Figure 4 – CATDAT v4.12 Damaging Earthquakes – Economic Losses (Hybrid Natural Disaster Economic Conversion Index adjusted) for 6400 earthquakes from the year 1900-2010 worldwide

The baseline of economic losses from earthquakes is increasing; however, this looks very different from the sharp rise in economic losses from natural disasters as shown by MunichRe (1999, 2009) or EM-DAT (2004). The use of CPI adjustment based on one economy is therefore outdated in a natural disasters forward costing context. For the moment, looking at

trends from 1950-2010 or from 1900-2010 as seen in Figure 5, there is no real increase in economic loss. However, the trend does show a greater proportion of economic losses in latter years, indicating that smaller disasters are causing a greater proportion of damage. This is shown below via the regression analysis. However, using a linear trend for the entire series from 1900-2010 still gives the best correlation coefficient of 0.95, compared to a power law of 0.86. Nevertheless, the main city growth on a global scale in the developing world has occurred since the 1950s. Therefore, splitting the regression into 1900-1955 and 1955-2010, a slight increase in economic loss trend is seen (25% increase) as demonstrated below in Figure 5. This lack of increase despite population could be for the following reasons:-
1) That earthquake fire management is becoming better, reducing economic losses. The Great Kanto earthquake and San Francisco earthquake were dominated by fire losses.
2) That increasing exposure and population are being offset by a decrease in vulnerability.
3) That we have not had an earthquake of such significant magnitude in our current population settings. It could be expected in the future that the increasing exposure should lead to a much larger disaster at some point on account of a longer return period earthquake due to the sheer amount of infrastructure and population and the fact is that the vulnerability of the housing stock is not reducing the resistance to earthquakes significantly.

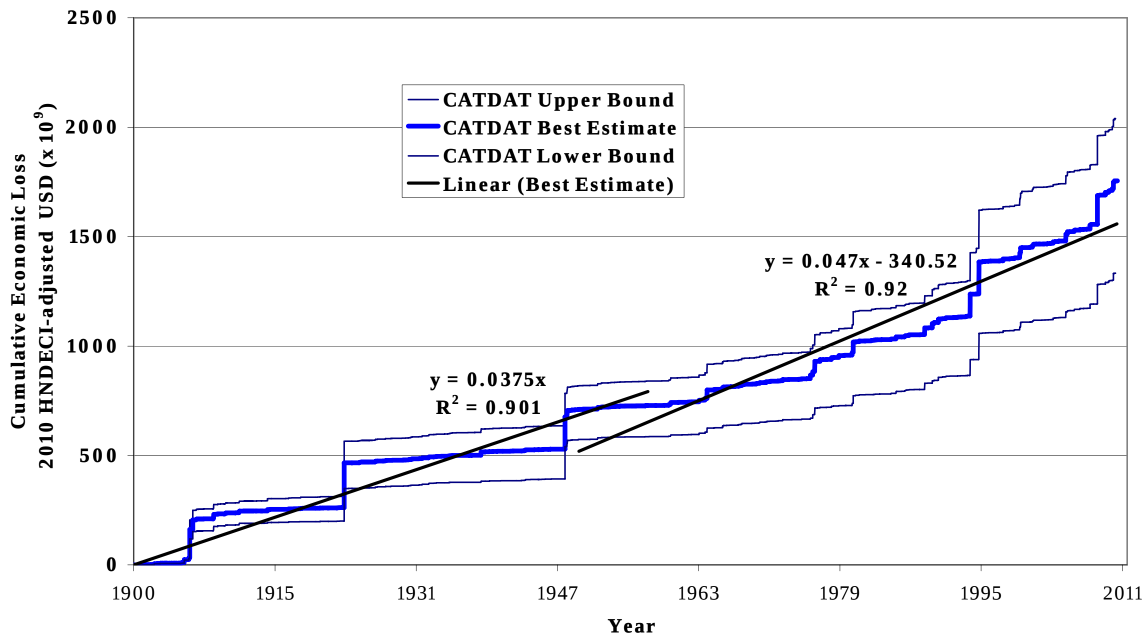

Figure 5 – Accumulated range of Global Economic Losses from earthquakes (Hybrid Natural Disaster Economic Conversion Index adjusted) for 6400 earthquakes from the year 1900-2010 (CATDAT EQ v4.12, J. Daniell, 2010)

It should be understood the next Great Kanto, San Francisco, Chillan or Aschgabad earthquake should cause a much larger economic loss than the 2010 adjusted values seen in CATDAT. This is due to the increase in population and hence infrastructure in these locations. Another useful tool of such a database is that as the relative housing stock vulnerability changes, population changes in the location and infrastructure changes can be multiplied to create an approximate forward estimate for such a disaster in today's terms without modelling. This will be discussed in a subsequent paper for the global dataset of earthquakes, but details are available for normalised Australian earthquakes in Daniell and Love (2010). The data shows that appropriate conversion via vulnerability reduction, population change information and accurate conversion of historic earthquake loss to today's terms, could produce a reasonable first-order estimate of a much more complex analysis. Adding to this, an approach such as seen in any of the software packages reviewed in the

OPAL process will show the quality of such a trended approach (Daniell 2009). A final view shows the trend of fatalities and economic losses versus World GDP and Population. As part of the process of Daniell (2010b) to create the World Human Development Index through time for every country in the world from 1900-2010, a global historic database of GDP (PPP) per capita was created as seen below in Figure 6.

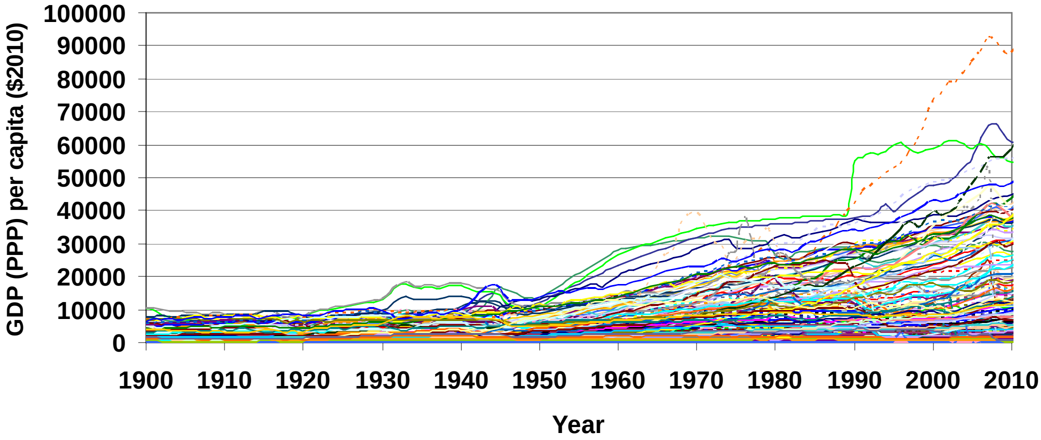

Figure 6 – GDP (Purchasing Power Parity) per capita in 2010 constant dollars –for all 244 nations, from 1900-2010, Daniell 2010c.

Figure 7 shows that while population has only increased 5 times since 1900, World GDP in constant 2010 dollars has multiplied over 25 times. However, the average fatalities and economic losses have remained reasonably constant through the period 1900-2010. Thus, the GDP increase and population increase have not shown a major impact on earthquake loss trends as yet.

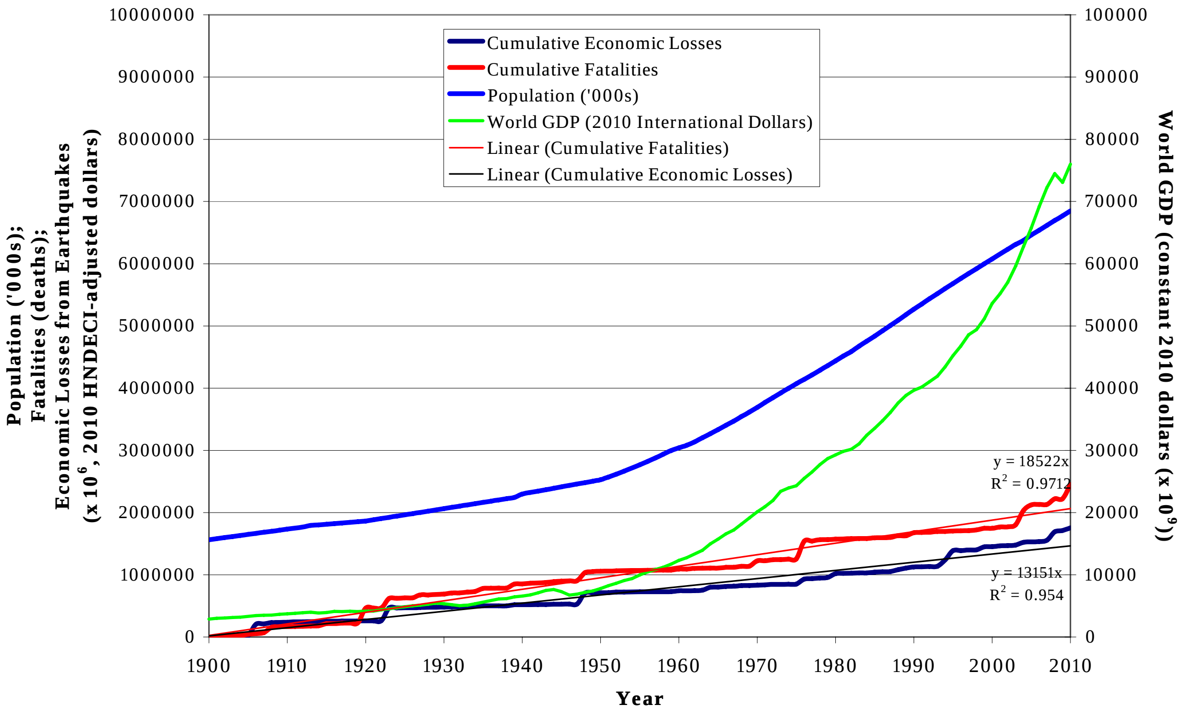

Figure 7 – The relative impact of Global Population and Gross World Product on Cumulative Earthquake Economic Losses and Fatalities (all values in 2010 dollars) – CATDAT EQ v4.12, 2010.

Conclusion

It is suggested that such a Hybrid Natural Disaster Economic Conversion Index should be used for bringing forward an earthquake economic loss to present-day terms, keeping the same event loss parameters. This has been integrated into the CATDAT database, giving upper, median and lower bound cost estimates of historic earthquakes in present-day terms, in addition to building damage and social parameters.
Including refinements of many historic earthquake economic losses from many sources and improvements in quality control, the CATDAT Damaging Earthquakes database shows an accurate representation of historical losses. It can be seen that **there has not** been a significant increase in economic losses through time as reported by a number of sources.

This paper also shows the error made in many databases trending international disasters based on United States CPI. The CPI is not the same in every country and can give extremely different results. Thus, trending must be done based on a country-by-country basis. More research will be undertaken into refining the disaster conversion index with improved socio-economic databases to attain better conversion quality. The differences in developing and developed countries' economies will also be explored further and additional work undertaken to fill in and improve GDP, wage and CPI series globally through time.

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