

Stock-Market Crashes and Depressions*

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Long-term data for 30 countries up to 2006 reveal 232 stock-market crashes (multi-year real returns of -25% or less) and 100 depressions (multi-year macroeconomic declines of 10% or more), with 71 of the cases matched by timing. The United States has two of the matched events—the Great Depression 1929-33 and the post-WWI years 1917-21, likely driven by the Great Influenza Epidemic. 41% of the matched cases are associated with war, and the two world wars are prominent. Conditional on a stock-market crash (return of -25% or less) in a non-war environment, the probability of a minor depression (macroeconomic decline of at least 10%) is 22% and of a major depression (at least 25%) is 3%. For contexts of currency or banking crises that occur during times of global distress, these probabilities rise to 46% and 8%, respectively. These depression odds applied to the stock-market crashes of 2008 in the United States and many other countries. In reverse and again in a non-war environment, the probability of a stock-market crash (return of -25% or worse) is 67%, conditional on a depression of 10% or more, and 83% for 25% or more. Thus, the largest depressions are particularly likely to be accompanied by stock-market crashes. We allow for flexible timing between stock-market crashes and depressions for the 71 matched cases to compute the covariance between stock returns and an asset-pricing factor, which depends on the proportionate decline of consumption during a depression. If we assume a coefficient of relative risk aversion around 3.5, this covariance is large enough to account in a familiar looking asset-pricing formula for the observed average (levered) equity premium of 7% per year. This finding complements previous analyses that were based on the probability and size distribution of macroeconomic disasters but did not consider explicitly the covariance between macroeconomic declines and stock returns.

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“Wall Street indexes predicted nine out of the last five recessions!” Samuelson (1966).

The Samuelson quote is remarkable because it is simultaneously extremely clever and extremely misleading. We find, for 30 countries with long-term data, that stock-market crashes (cumulated multi-year real returns of -25% or less) go along with minor depressions (multi-year declines of consumption or GDP by 10% or more) 31% of the time and major depressions (declines by 25% or more) 10% of the time. In reverse, minor depressions feature stock-market crashes 71% of the time, whereas major depressions feature these crashes 92% of the time. Thus, as the Samuelson quote suggests, stock-market crashes are far more frequent than depressions. Nevertheless, a stock-market crash provides good reason for concern about the macro economy—because the conditional 31% chance of a minor depression and 10% chance of a major depression are far above the typical probabilities. In reverse, the absence of a stock-market crash is reassuring in the sense that a depression is highly unlikely.

The overall probability of moving from a “normal state” into a minor depression turns out to be 3.8% per year (3 per century). But knowing that there is no stock-market crash lowers the odds to 1.0% per year (1 per century). For a major depression, the overall probability is 0.9% per year (1 per century), but conditioning on no stock-market crash reduces this chance to 0.07% per year (less than 1 per millennium). Hence, although Samuelson is right in some sense, stock returns still provide important guidance about the prospects for depression. This kind of information is particularly valuable in the financially turbulent environment of 2008-09.

In the first part of this paper, covering sections I and II, we study the extent to which stock-market crashes have predictive power for depressions by analyzing their frequency distributions from a long-term and cross-country perspective. Part of this analysis entails

splitting the sample into different “bins” or categories, defined by the magnitudes of the stock-market crashes or by the type of environment that characterized those events; for example, wars, currency or banking crises, and periods of global economic distress. An important aspect of this analysis is the flexibility in the matching of events according to their timing. Excluding exceptional cases that involve measurement problems, including price controls, stock-market crashes tend to occur slightly prior to macroeconomic contractions. Therefore, the “predictive” power that we isolate for stock-market crashes with respect to depressions typically constitutes predictability in the usual chronological sense.

In Section III, we study some of the asset-pricing implications from our matching of stock-market crashes with depressions. This work complements the analysis of the equity premium in Barro and Ursua (2008) by considering the co-movement between macroeconomic declines and stock-market returns in the form of a “flexible covariance analysis.” The matched cases of stock-market crashes and depressions provide most of the explanatory power for generating a reasonable equity premium with a familiar asset-pricing formula. The required coefficient of relative risk aversion is in the range of three to four. Section IV concludes and sketches plans for future research.

I. Stock-Market Crashes and Depressions in the Long-Term International Data

This study uses an updated version of the macroeconomic and stock-return data described in Barro and Ursua (2008). For the macroeconomic aggregates, we have annual time series from before 1914 for real per capita consumer expenditure, C , for 24 countries and real per capita GDP for 36 countries. Our earlier study and the online information available at

http://www.economics.harvard.edu/faculty/barro/data_sets_barro provide a detailed description of the methods and sources used to construct the data on C and GDP.¹

For stock returns, the data come mainly from Global Financial Data (described in Taylor [2005]).² When available, we used nominal total return indexes, deflated by consumer price indexes, to compute annual, arithmetic real rates of return. In other cases, we used nominal stock-price composite indexes, deflated by consumer price indexes, and then added estimates (or sometimes actual values) of dividend yields to estimate the arithmetic real rates of return. The present study focuses on 30 countries (20 OECD) with annual stock-return data since at least the early 1930s. Our annual real rates of return apply from the end of the previous year to the end of the current year.³

As in Barro and Ursua (2008), we gauge “depressions” by peak-to-trough declines in real per capita consumer expenditure, C, or GDP. These declines can apply to multiple years, such as 1912 to 1918 for Germany during World War I, 1929 to 1933 for the U.S. Great Depression, 1935 to 1937 during the Spanish Civil War, 1938 to 1943 for France in World War II, 1972 to 1976 covering the Pinochet coup in Chile, 1981 to 1988 in Mexico during the Latin American

¹ Barro and Ursua (2008) compare our GDP data with those in Maddison (2003). One problem with the Maddison data is his propensity to interpolate in poorly documented ways over periods with missing data.

² We use the data from Dimson, Marsh and Staunton (DMS), available through Morningstar, for Canada 1900-13, Denmark 1900-14, Italy 1900-05, Netherlands 1900-19, Sweden 1900-01, Switzerland 1900-10, and South Africa 1900-10. Care should be taken in using the DMS data for later periods, usually wars, with missing entries in Global Financial Data. These DMS data appear to be generated (for periods such as France 1940 and Portugal 1974-77 when stock-return data seem to be unavailable) by interpolation. We have not used any of this information. We use stock-price data for Argentina 1900-35 from Nakamura and Zarazaga (2003), for Japan 1893-1914 from Fujino and Akiyama (1977), and for Mexico 1902-29 (missing 1915-18) from Haber, Razo, and Maurer (2003). For Brazil 1900-1942 we used data generously provided by Aldo Musacchio, and for 1945-1953 we used data from Goldsmith (1986).

³ For many cases with missing data, usually during wars and sometimes because of closed markets, we were able to compute cumulative multi-year real returns across the gaps. These cases are Belgium 1914-18 and 1944-46, France 1940-41, India 1926-27, Mexico 1915-18, Netherlands 1944-46, Spain 1936-40, Portugal 1974-77, and Switzerland 1914-16. However, we could not use this approach for Brazil 1943-1944, or countries with larger gaps in the stock-return data: Argentina 1958-66, Austria 1939-44, Greece 1941-52, and Indonesia 1940-77.

debt crisis, and 1989 to 1993 during the financial crisis in Finland.⁴ In the main analysis, we follow our previous study in focusing on contractions in C or GDP of size 0.10 or more. However, we also consider higher thresholds for labeling an economic decline as a depression.

In terms of asset pricing, the analysis maps more closely to consumption than to GDP. However, our C measures refer, because of data availability, to personal consumer expenditure, rather than consumption. Moreover, in many cases, the measurement error in C is likely to be greater than that in GDP. The analysis in Barro and Ursua (2008, section V) found that major contractions in C and GDP were similar overall in terms of timing. The average proportionate size of contraction was also similar during non-war periods. However, because of the large expansion in military purchases during wars, the average proportionate contraction in C during wartime was, on average, five percentage points greater than that in GDP. For example, the United Kingdom had depressions gauged by C during the two world wars but not by GDP. Moreover, some non-war aftermaths, such as the United States from 1944 to 1947, featured substantial declines in GDP but not in C—because of the massive demobilization that featured sharp declines in military purchases. This kind of post-war event does not constitute a depression in an economic sense.

Putting these results together, we decided to measure macroeconomic contractions during non-war years as the average of those found in C and GDP. (If only one of the variables was available—in practice, GDP but not C—we gauged the contraction by the available variable.) In war aftermaths, we used only the information on C (and left the data as missing when only GDP was available). In war periods, we typically used only the data on C. However, we used an

⁴ In Barro and Ursua (2008) and in our main analysis here, we sometimes have intermediate years with small increases in C or GDP. However, the results do not change a lot if we constrain multi-year contractions to have declines in C or GDP for every year included in the multi-year interval.

average of C and GDP when the contraction indicated by GDP was larger or when only the GDP data were available and the indicated contraction size was at least 0.10. For the 30 countries in the present study (3037 annual observations), this procedure yields 100 cases of macroeconomic contraction of size 0.10 or more.

We now apply an analogous peak-to-trough procedure to gauge stock-market crashes. In our main analysis, we focus on cumulative, multi-year real returns that were -0.25 or less. For the 30 countries, this procedure yields 232 cases of stock-market crashes.

Table 1 illustrates our methodology for U.S. data since 1869. We found 7 stock-market crashes (not including 2008, since our main sample goes to 2006), using the definition of cumulative real returns of -0.25 or less.⁵ The worst is -0.55 for 1929-31 (Great Depression), followed by -0.49 for 1973-74, -0.47 for 1916-20, and -0.42 for 2000-02. The value -0.37 for 2008 (using data only through 2008) would be worth fifth place if it were included in the sample. The others are -0.32 for 1907, -0.37 for 1937, and -0.29 for 1939-41.

We matched stock-market crashes with depressions (macroeconomic contractions of size 0.10 or more) by finding periods that were coincident or adjacent. Table 1 illustrates our general procedure by providing the details for the United States from 1869 to 2006. The first two columns refer to the stock-market crashes, of which there were seven up to 2006 (and one more for 2008). The “macro contraction” in columns 7 and 8 is calculated by the method described earlier from the C and GDP declines shown in columns 3-6. The United States from 1869 to 2006 experienced only two periods with macro contractions of size 0.10 or more—the Great Depression of 1929-33, with a contraction of 0.25, and 1917-21, with a decline by 0.16. As

⁵ The October 1987 U.S. stock-market crash does not show up as a decline for the full year. However, 1987 does appear as a sharp fall in the annual data for many other countries, including Argentina, Brazil, Denmark, France, Germany, India, Italy, Mexico, Norway, and Switzerland.

discussed in Barro and Ursua (2008, section III), the 1917-21 contraction likely reflects the Great Influenza Epidemic, rather than World War I, per se. The other five periods with stock-market crashes were not associated with depressions, although 1906-08 comes close; 1937-38, 1973-75, and 2000-01 are all recession periods; and 1941-42 shows a decline in C but not in GDP. Of course, we do not yet know what will happen in the years following 2008. Note also that, unlike many other countries, the United States from 1869 to 2006 had no depressions that were not associated with stock-market crashes.

We applied the same methodology to all 30 countries (20 OECD) with long-term data on stock returns and the macroeconomic variables (at least GDP).⁶ The matching of periods of stock-market crashes with those of macroeconomic declines were sometimes less clear cut than for the United States, but these considerations appear to be minor overall. Table 2, panel A lists the 71 cases of stock-market crashes (returns of -0.25 or less) that paired up with depressions (macro contractions of 0.10 or more)—as already noted, two of these are for the United States. In this sample, the average stock return was -0.53, with an average duration of 3.8 years, and the average macroeconomic contraction size was 0.23, with an average duration of 4.1 years.

Panel B lists the 29 cases of depressions that were not associated with stock-market crashes—of which there were none for the United States. In this sample, the average stock return was -0.09, with an average duration of 1.7 years, and the average macroeconomic contraction size was 0.17, with an average duration of 3.8 years. There are another 161 cases (5 for the United States) of stock-market crashes not associated with depressions, but these are not

⁶ The countries with long-term data on GDP but not C are Greece, Indonesia, New Zealand, and South Africa. In addition, Austria has a major gap in the C series around World War II. In many other cases, the GDP data start well before the C data.

shown in the table. The average stock return in this group was -0.43, with an average duration of 2.9 years, and the average contraction size was 0.01, with an average duration of 1.5 years.

Among the 71 cases of paired stock-market crashes and depressions shown in Table 2, panel A, 16 are associated with World War II (including the neutral countries Spain, Sweden, and Switzerland), 13 with the Great Depression of the early 1930s, and 10 with World War I (including Sweden and Switzerland). There are 8 pairings associated with the Latin American debt crisis of the 1980s, 10 other post-World War II cases in Latin America, and 6 events with troughs in 1920-21, likely reflecting the Great Influenza Epidemic. The other cases involve Japan during the Russo-Japanese War (1904-05), the Mexican Revolution and Civil War (1910-20), the culmination of the German hyperinflation (1922-23), the Spanish Civil War (1936-39), India during the post-WWII conflict with Pakistan (1947-48), the peaceful (“Carnation”) revolution in Portugal (1974-75), the early 1990s financial crisis in Finland, and the 1997-98 Asian Financial Crisis in Indonesia.

In Table 2, a bold entry for the macroeconomic period indicates a time of war (defined to include only active combatants).⁷ Overall, 41% of the cases in Panel A (29 of 71) are associated with war.

Table 2, panel A misses a number of paired stock-market crashes and depressions other than that for Indonesia during the Asian financial crisis of the late 1990s because the countries involved lack the long-term stock-return data needed to qualify for our sample. For example,

⁷We used *Correlates of War*, inter- and intra-state conflicts (Sarkees [2000]), and other sources to designate times of “major” war. In Table 2, the conflicts designated as war for active combatants are Franco-Prussian War 1870-71, Russo-Japanese War 1904-05, World War I 1914-18, Mexican Revolution and Civil War 1909-18, Mexican War of the Cristeros 1926-29, Spanish Civil War 1936-39, World War II 1939-45, India-Pakistan War 1947-48, Pinochet coup in Chile 1973, Portugal Carnation Revolution 1974-75, Argentina during the Falklands War 1982, and Peru’s guerrilla conflicts 1987-92.

South Korea has a stock return of -0.63 for 1995-97 and a macro contraction of 0.11 for 1997-98, Malaysia has a stock return of -0.54 for 1997-98 and a macro contraction of 0.11 for 1997-98, and Thailand has a stock return of -0.81 for 1995-98 and a macro contraction of 0.14 for 1996-98. Our sample also excludes recent cases in Russia and other former Communist countries that lack long-term data.

In Table 2, panel B, for the 29 cases of depression unaccompanied by stock-market crashes, 7 are related to World War II (including the neutral country Portugal), 6 with the Great Depression, 4 with World War I (including the neutral country Chile), and 1 probably with the Great Influenza Epidemic. Other cases were the depression in Australia in the early 1890s, Argentina 1899-1900, Canada in 1906-08 (likely related to the U.S. financial panic of 1907), Brazil 1907-09, Mexico in the early 1920s, Denmark in 1946-48, France around 1871 (Franco-Prussian War), France in the 1880s, Portugal at the time of the Spanish Civil War in 1934-36, Spain in the 1890s, and South Africa in the mid 1980s (possibly related to international sanctions against Apartheid). Overall, 28% of these cases (8 of 29) are associated with war. In contrast, for the 161 cases of stock-market crashes not associated with depressions, only 11 (7%) are associated with war.

II. Frequencies of Stock-Market Crashes and Depressions

Table 3 shows the overall frequency of stock-market crashes, defined as cumulative multi-year returns of -0.25 or less—or, as alternative thresholds, -0.40 or less and -0.50 or less. The table also shows the frequency of macroeconomic contractions, defined as cumulative multi-year declines by at least 0.10, 0.15, 0.20, 0.25, or 0.30. Part A of the table combines non-war

and war observations, Part B distinguishes non-war from war events, and part C considers non-war samples related to currency, banking, and global crises.

Begin with Part A of Table 3 and consider the pairing $(-0.25, 0.10)$, which was used before. By this definition, the overall sample (30 countries, 3037 annual observations) has 232 stock-market crashes and 100 macro contractions. The average durations were 3.2 years for the stock-market crashes and 4.0 years for the macro contractions. When expressed as a probability per year of moving from “normalcy” into each state, the values are 0.101 for the stock-market crashes and 0.038 for the macro contractions. Thus, as Samuelson suggested, stock-market crashes are far more frequent than depressions—reflecting the much greater volatility of stock returns than of consumption or GDP growth rates.

Among the 232 stock-market crashes and 100 macro contractions, Table 3, part A shows that 71 were matched events—occurring over overlapping or adjacent years. Thus, 31% and 71%, respectively, of the stock-market crashes and macro contractions are paired with the other decline. To put it another way, if one knows that a stock-market crash (return of -0.25 or less) occurred, it is 31% probable that a depression (of size 0.10 or more) also occurred. In terms of applications, this finding has predictive content because the typical pattern is for stock-market crashes to precede, to some extent, depressions. Conversely, if one knows that a depression (of size 0.10 or more) occurred, it is 71% probable that a stock-market crash (of size -0.25 or worse) also occurred.

Not surprisingly, the probability of depression, conditional on observing a stock-market crash, declines as one raises the standard for declaring a depression. Table 3, part A indicates that, conditional on a stock-market crash (-0.25 or worse), the probability of depression is 0.31

for size 0.10 or more, 0.19 for size 0.15 or more, 0.13 for size 0.20 or more, 0.10 for size 0.25 or more, and 0.07 for size 0.30 or more.

In the reverse direction, the probability of a stock-market crash, conditional on seeing a depression, becomes larger the higher the standard for labeling a macro contraction as a depression. Table 3, part A shows that the conditional probability of a stock-market crash (-0.25 or less) goes from 0.71 when depressions are of size 0.10 or more to 0.73 at 0.15, 0.78 at 0.20, 0.92 at 0.25, and 0.94 at 0.30. Thus, the largest depressions are almost surely accompanied by stock-market crashes. (Table 2, panel B shows that the two largest depressions not accompanied by stock-market crashes were in Australia—in the early 1890s and during World War II.) Another way to view the result is that, if one knows that there is no stock-market crash, it is extremely unlikely that a major depression exists.

The results can be expressed as probabilities per year of entering into various states. Without knowing whether there is a stock-market crash, the unconditional probability per year of moving from “normalcy” into a major depression (0.25 or more) is 0.0089 per year, a little less than 1 per century. Knowing that there is no stock-market crash lowers these odds by a factor of 10 to 0.0007 per year, less than 1 per millennium. The change is less dramatic if one considers depressions of size 0.10 or more. In this case, the unconditional probability per year of entering into a depression is 0.038 per year (3-4 per century), whereas conditioning on no stock-market crash lowers the chance to 0.010 per year (1 per century). In other words, the conditioning reduces the depression odds by a factor of roughly four.

Table 3, part A also considers the breakpoint of -0.40 or less for declaring a stock-market crash. The number of these larger crashes is 124, corresponding to a probability of 0.049 per

year of entering into this state. Among the 100 macro contractions of size 0.10 or more, 50 are paired with a stock-market crash of -0.40 or worse. Conditional on observing a stock-market crash of this larger magnitude, the probability of seeing a depression (0.10 or more) is higher than before, 0.40 versus 0.31. Similarly, the chance of encountering a depression of any given size (0.15 or more, and so on) is greater when the stock-market crash is -0.40 or worse, rather than -0.25 or worse. For example, for a stock-market crash of -0.40 or worse, the chance of seeing a major depression (size 0.25 or more) is 0.15, compared to 0.10 from before. The overall tendency, as would be expected, is that the depression odds go up as the observed size of the stock-market crash increases.

Table 3, part A also has results for samples limited to the 20 OECD countries. The patterns are similar to those for the group of 30 countries. Thus, in the sample that combines non-war and war events, the predictive element of a stock-market crash is about the same in developed countries as in a set of middle-income countries from Latin America and Asia (although stock returns and growth rates of macroeconomic aggregates are more volatile in the middle-income countries).

Table 3, part B shows the results that separate non-war from war events. In the non-war sample, considered in columns 3-5, the biggest change from before is the decrease in depression probability, conditional on seeing a stock-market crash. For all 30 countries, for a stock-market crash of -0.25 or worse, the conditional probability of a minor depression (0.10 or more) is now 0.22, compared to 0.31 in the combined sample, and of a major depression (0.25 or more) is only 0.03, rather than 0.10. For a stock-market crash of -0.40 or worse, the probability of a minor depression is now 0.30, compared to 0.40, and the probability of a major depression is 0.04, compared to 0.15. For the OECD, the changes are in the same direction but more pronounced

than for the overall sample. The sample of OECD non-war events has only three major depressions—Australia in the 1890s (which did not have a stock-market crash) and the Great Depression in Canada and the United States (which had stock-market crashes).

We can apply the findings from the non-war sample to the 2008-09 environment, in which many countries experienced stock-market crashes (returns of -0.25 or worse) but not major wars. For example, for the United States through the end of 2008, the stock-market return was -0.37, close to the value -0.40 included in Table 3, part B. This size of stock-market crash implied (for the full sample of countries in a non-war environment) a probability of minor depression (0.10 or more) of 22% and a probability of major depression (0.25 or more) of 3%.

The war sample is considered in columns 6-8 of Table 3, part B. The main change from the sample that includes all events is the much higher probability of depression, conditional on observing a stock-market crash. For all 30 countries, for a stock-market crash of -0.25 or worse, the conditional probability of a minor depression (0.10 or more) is now 0.73, compared to 0.22 in the non-war sample, and of a major depression (0.25 or more) is 0.45, rather than 0.03. These results are similar for the OECD group. Thus, in a wartime context, a stock-market crash is highly predictive of depression (perhaps because of the signal that a country is doing badly during the war).

In contrast, the probability of a stock-market crash, contingent on seeing a depression, is similar for the war and non-war samples. For example, for a minor depression (0.10 or more), the conditional probability of a stock-market crash (-0.25 or less) in the sample of 30 countries is 0.67 for the non-war sample and 0.78 for the war sample. For a major depression (0.25 or more), the conditional probability of a stock-market crash is 0.83 for the non-war sample and 0.95 for

the war sample. Thus, in peace and war, depressions—especially the larger ones—are highly likely to be accompanied by stock-market crashes.

Table 3, part C, shows results obtained by restricting the sample to stock-market crashes and depressions occurring during non-war times and in the context of currency or banking crises, global crises, or both categories jointly.⁸ For currency and banking crises, we used country-specific yearly indicators assembled by Carmen Reinhart and Kenneth Rogoff.⁹ We linked an event in our sample with these types of crises if at least one of their yearly crisis indicators appeared between the peak and the trough that define the corresponding stock-market crash or depression. For example, the United States has a currency crisis during 1929-31 and a banking crisis during 1929-33. We therefore considered the matched event of the Great Depression for the United States (formed by the combined stock-market crash spanning 1929-31 and depression spanning 1929-33) as belonging to the category of events occurring in the context of a currency or banking crisis. Other events taking place during the Great Depression that showed only one of these indicators were also classified in this category; for example, Canada (which had a currency crisis) and France (which had a banking crisis).

The category of global crisis reflects the degree to which an event occurred for a country in isolation or in tandem with other countries. To measure “globalness,” we assigned for every year a score equal to the proportion of countries that were in a disaster state (gauged by a stock-market crash or a depression). In turn, for each event in our sample, we averaged the scores of

⁸We found that similar information was conveyed by a currency crisis or a banking crisis; therefore, we do not distinguish these two types of events in our present discussion.

⁹A preliminary version of this data set was kindly made available to us by the authors. Currency crises are defined as annual depreciations of the exchange rate (versus a relevant anchor currency, typically the U.S. dollar) by 15% or more. Banking crises are broadly defined as events characterized by substantial bank runs and governmental closures or takeovers of financial institutions. See Reinhart and Rogoff (2009). For Switzerland, we used an updated version of the data from Bordo et al. (2001), whose original version is available at <http://michael.bordo.googlepages.com/home3>

the years covering its duration. A stock-market crash or a depression, or the combination of both, was classified as part of a global crisis if that average was above 50%; in other words, if the event took place mostly during a time when more than half of the countries in our sample were also undergoing a crisis. For example, events occurring during the early years of WWI (when more than 65% of countries in our sample were undergoing a disaster) were classified in the global-crisis category. In contrast, Mexico's matched event of the mid 1990s or Finland's earlier in that decade were not in the global-crisis category because fewer than 30% of the countries in our sample were in a disaster state at those times.

The results in columns 3-5 in Table 3, part C show that during a currency or banking crisis the odds of a depression conditional on the occurrence of a stock-market crash are higher than in the overall non-war sample considered in Part B. The conditional probability of a minor depression is now 0.31, while that of a major depression is now 0.04. The odds of minor and major depressions are also higher if the non-war sample is restricted to events occurring during global crises (see columns 6-7), coincidentally also at 0.31 and 0.04, respectively, for a -0.25 or worse stock-market crash.

The categories can be combined to compute the conditional probability of a depression given that a stock-market crash occurred during non-war times in the context of a currency or banking crisis and in the midst of a global crisis (as shown in columns 9-11 of Table 3). In this case, the conditional probability of a 0.10 depression is 0.46 and of a 0.25 depression is 0.08. These odds are almost twice as large as those estimated by restricting the sample only to non-war cases. For larger stock-market crashes, the odds of a minor depression in these combined circumstances are above 0.50.

Once again, we can apply these results to the 2008-09 economic context, which we classify as non-war. Many countries experienced a currency or banking crisis in these years. The crises have also been global in terms of the number of countries in distress. As we have seen, the conditional probability of a 0.10 depression given a stock-market crash (-0.25 or less) is 22% for the standard non-war sample. Restricting the non-war sample to events occurring in the context of a currency or banking crisis raises these odds to 31%. Further conditioning these crises to times of global turmoil takes the odds to 46%. Thus, there was legitimate reason for most countries to worry about depression potential early in 2009 (although most observers subsequently became more optimistic).

III. Rare Disasters and the Equity Premium

The analysis in Barro and Ursua (2008) followed the approach of Mehra and Prescott (1985), Rietz (1988), and Barro (2006) in asking whether a model calibrated to include rare disasters gets into the right ballpark for explaining observed equity premia. Based on long-term data on real returns on stocks and government bills, the challenge is to explain an average levered equity premium of around 7% per year. Correspondingly, with a debt-equity ratio of about one-half, the challenge is to explain an unlevered equity premium of around 5%.

a. Asset-Pricing Formulas

Barro (2009) and Barro and Ursua (2008) showed that equivalent results for the equity premium arose within two tractable models: a Lucas (1978)-tree model with i.i.d. shocks to

productivity growth and an AK model with i.i.d. shocks to the depreciation rate (corresponding to destruction of “trees”). In both models, the economy was closed, and government consumption was not considered explicitly. In the former model, the number of trees was fixed, GDP and consumption coincided, and the expected growth rate was exogenous. The latter model allowed for endogenous investment (and saving) and growth but had a fixed price of equity shares (corresponding to Tobin’s q equaling one).

For present purposes, it is sufficient to provide a brief sketch of the Lucas-tree setting. The log of GDP and consumption, C_t , follow the stochastic process:

$$(1) \quad \log(C_{t+1}) = \log(C_t) + g + u_{t+1} + v_{t+1} .$$

The random term u_{t+1} is i.i.d. normal with mean 0 and variance σ^2 . This term reflects “normal” economic fluctuations. The parameter $g \geq 0$ is a constant that reflects exogenous productivity growth. The random term v_{t+1} picks up rare disasters, which occur with a constant probability $p \geq 0$ per unit of time. In a disaster, output contracts instantaneously by the fraction b , where $0 < b < 1$. Thus, the distribution of v_{t+1} is given by

$$\text{probability } 1 - p : v_{t+1} = 0 ,$$

$$\text{probability } p : v_{t+1} = \log(1 - b) .$$

The disaster size, b , follows some probability distribution, gauged by the empirical distribution of these sizes. (Barro and Jin [2009] find that this size distribution is well described, above some cutoff value, by a power-law distribution.)

The representative household has preferences given by an Epstein-Zin-Weil utility function, as developed by Epstein and Zin (1989) and Weil (1990). This specification separates

the coefficient of relative risk aversion, denoted γ , from the reciprocal of the intertemporal-elasticity-of-substitution (IES) for consumption, denoted θ . Hence, the framework allows for values of γ that are large enough (in the range of 3-4) to accord with observed equity premia. In addition (unlike with the usual power-utility formulation when $\gamma > 1$), $\text{IES} > 1$ is possible. This condition is important because it is required to generate some plausible properties of equity prices—in particular, if $\text{IES} > 1$, a once-and-for-all increase in uncertainty (a rise in p or σ or an outward shift in the distribution of b) reduces the price-dividend ratio for unlevered equity, whereas a once-and-for-all rise in the expected growth rate (reflecting an increase in g) raises this ratio. The condition $\text{IES} < 1$, although often assumed, generates the reverse, implausible properties for the price-dividend ratio. For further analysis, including discussion of empirical evidence on the IES, see Bansal and Yaron (2004) and Barro (2009).

Because the growth-rate shocks are i.i.d. (equation [1]), the model with Epstein-Zin-Weil utility satisfies an asset-pricing condition of familiar form (see Barro [2009] for a derivation):

$$(2) \quad C_t^{-\gamma} = \left(\frac{1}{1 + \rho^*} \right) \cdot E_t(R_t \cdot C_{t+1}^{-\gamma}),$$

where R_t is the gross, one-period return on any asset. Two key points are, first, the negative exponent on C_t and C_{t+1} is γ , the coefficient of relative risk aversion, not θ , the reciprocal of the IES, and, second, the effective rate of time preference, denoted ρ^* , differs from the usual rate, denoted ρ , when γ and θ diverge.¹⁰

¹⁰ The formula is, if $\gamma \neq 1$, $\rho^* = \rho - (\gamma - \theta) \cdot \left\{ g - (1/2)\sigma^2(\gamma - 1) - \left(\frac{p}{\gamma - 1} \right) \cdot [E(1 - b)^{1-\gamma} - 1] \right\}$, where E is the expectations operator.

Equation (2) can be used to derive the equity premium in the model. As the length of the (arbitrary) period approaches zero, the formula becomes

$$(3) \quad r^e - r^f = \gamma\sigma^2 + p \cdot E\left\{b \cdot [(1-b)^{-\gamma} - 1]\right\},$$

where r^e is the (constant) expected rate of return on unlevered equity, and r^f is the (constant) risk-free rate. The first term on the right-hand side, $\gamma\sigma^2$, corresponds to the equity premium in Mehra and Prescott (1985) and is trivial for reasonable values of γ and σ . Barro (2006) and Barro and Ursua (2008) show that, if γ is 3-4, the second term can explain an unlevered equity premium of around 5% when p and the distribution of b are calibrated from the sample of observed macroeconomic disasters, analogous to those shown in Table 2.

In the model, unlevered equity prices have the same volatility as GDP and consumption. Levered equity prices have more volatility but not enough more to explain the observed variance of stock prices. Explaining this “excess volatility” requires some underlying parameter involving uncertainty or expected growth to move around. For example, Gabaix (2008) relies on movements in p , whereas Bansal and Yaron (2004) rely on shifts in long-run growth rates, g . If these shifts are temporary and orthogonal to contemporaneous consumption, the model’s implications for the average equity premium do not change a lot from the formula in equation (3). Thus, this extended framework may explain the average equity premium along with the high volatility of stock prices.

Another issue is that the empirical applications of the model in Mehra and Prescott (1985), Rietz (1988), Barro (2006), and Barro and Ursua (2008) do not consider the observed time series of stock returns, except to gauge the average equity premium. In equation (3), in the last term on the right-hand side, the first “ b ” represents the proportionate negative effect of a

disaster on real stock prices (occurring at an instant of time when the period length approaches zero). The term $(1 - b)^{-\gamma}$ can be viewed heuristically (not literally in an Epstein-Zin-Weil setup) as the marginal utility of consumption in a disaster state expressed as a ratio to the marginal utility in a normal state. The “ b ” that appears here represents the proportional loss of consumption during a disaster. The previous applications assume that the two b ’s are the same—because, in the model, a disaster causes unlevered stock prices to decrease in the same proportion as consumption and GDP.

A different, complementary approach uses the observed time series of stock returns during crises (and, perhaps, also at other times) to calibrate an analog to the last term on the right-hand side of equation (3). More formally, the equation can be replaced by a familiar looking formula that involves the covariance between stock returns and an asset-pricing factor, which depends on $(1 - b)^{-\gamma}$, where b is the proportionate fall of consumption during a disaster.

Consider the asset-pricing condition in equation (2) when applied over a period of length T years. Let R_T be the gross return on any asset from the time t to $t + T$. Equation (2) implies

$$(4) \quad (1 + \rho^*)^T = COV \left[R_T, \left(\frac{C_{t+T}}{C_t} \right)^{-\gamma} \right] + ER_T \cdot E \left(\frac{C_{t+T}}{C_t} \right)^{-\gamma},$$

where COV is the covariance operator.¹¹ When applied to the gross risk-free return, R_T^f , the result is

¹¹ Equation (2) applies in the Epstein-Zin-Weil setting only when the shocks to consumption growth are i.i.d. In this case, the covariance and the expectations shown in equation (4) and subsequent expressions will be time invariant; that is, they do not have to be conditioned on t .

$$(5) \quad (1 + \rho^*)^T = R_T^f \cdot E\left(\frac{C_{t+T}}{C_t}\right)^{-\gamma}.$$

Substituting for $E\left(\frac{C_{t+T}}{C_t}\right)^{-\gamma}$ from equation (5) into equation (4) yields

$$(6) \quad \frac{ER_T}{R_T^f} = 1 - \frac{1}{(1 + \rho^*)^T} \cdot COV\left[R_T, \left(\frac{C_{t+T}}{C_t}\right)^{-\gamma}\right].$$

We can verify that equation (6) implies equation (3) as the period length, T , approaches zero, when R_T is the gross return on Lucas-tree equity (a perpetual consumption claim) and C_t is generated from equation (1). The derivation of equation (3) from equation (6) relies on the condition (implied by equation [1]) that the proportionate change in unlevered equity prices always equals the proportionate change in consumption. Instead of imposing this condition, we can implement equation (6) directly by computing the covariance between gross stock returns and the asset-pricing factor, $\left(\frac{C_{t+T}}{C_t}\right)^{-\gamma}$. Since this approach uses observed returns on levered equity, the left-hand side of equation (6) will refer to the levered equity premium, empirically averaging around 7% per year (see Barro and Ursua [2008, section II]). That is, the model has to generate a higher equity premium than before, where the target was the 5% value corresponding to the estimated average unlevered equity premium.

b. Covariance Calculations

Our first approach implements equation (6) with all of the available long-term data for 25 countries on gross real stock returns, R_T , and consumption ratios, C_{t+T}/C_t . (We omitted five countries—Argentina, Austria, Brazil, Greece, and Indonesia—that have large or unconnected gaps in the stock-return series.) These calculations use various period lengths, T (in years), and coefficients of relative risk aversion, γ .¹² This analysis measures consumption changes from the data on real per capita consumer expenditure; that is, we use no GDP data. In the main analysis, we interact the consumption ratio, C_{t+T}/C_t , computed from annual data for years t and $t + T$, with returns, R_T , calculated from the end of year $t - 1$ to the end of year $t + T - 1$.¹³ To implement equation (6), we use $\rho^* = 0.029$ per year (from Barro and Ursua [2008, Table 10]). However, for small values of T (such as $T = 1$ year), the results depend little on ρ^* .

The bottom line is that these calculations yield equity premia that are too low by a factor of around 10, compared with the target of 0.07 per year for the levered equity premium. For example, with $\rho^* = 0.029$, $T = 1$ and $\gamma = 3.5$, there are 2401 observations, the covariance is -0.006, and the equity premium is 0.006 per year. For $T = 2$ and $\gamma = 3.5$, there are 2381 (overlapping) observations, the covariance is -0.011, and the equity premium is 0.005 per year. If we shift the timing to measure returns from the end of year t to the end of year $t + T$ or from the end of year $t - 2$ to the end of year $t + T - 2$, the computed equity premia are even smaller.

We know from Barro and Ursua (2008, Tables 10 and 11) that the calibrated results for the equity premium depend mostly on the cases of extreme macroeconomic contraction. These

¹² For cases of missing stock-return data, as described in n.3, we computed multi-year real returns across the gaps.

¹³ We could get a better match in the timing between consumption changes and stock returns if we used the monthly data on stock returns that are available for some countries and time periods. This extension is worth pursuing, but we doubt that the results will change a lot.

events, with contractions of size 0.10 or more, are the ones shown in Table 2 for 30 countries. Examination of Panel A, which has the 71 cases of paired stock-market crashes and depressions, suggests two key properties. First, crashes and depressions usually arise as multi-year events—but this feature was already captured in the covariance analysis by allowing for period lengths, T , that exceeded one year. Second, the timing between the stock-market crashes and the depressions is irregular. That is, unlike our covariance calculations, the matches do not always refer to the same timing, such as relating consumption changes between year t and year $t + T$ to gross stock returns from the end of year $t - 1$ to the end of year $t + T - 1$.

A prototypical case is the United States during the Great Depression—the stock return is -0.55 for 1929-31 (gross return of 0.45), and the macroeconomic contraction is 0.25 for 1929-33. This pattern—with the strongly negative stock return applying slightly prior to or coincident with the macro contraction—also applies to other cases in Table 2, panel A. Examples include Denmark, Sweden, Switzerland, and the United Kingdom in World War II; Argentina, Austria, Chile, France, Germany, Indonesia, Mexico, and Spain during the Great Depression; Canada over the period of World War I and the Great Influenza Epidemic; Norway, Sweden, and the United States during this epidemic; Germany at the end of the hyperinflation in 1922-23; India during its 1947-48 conflict with Pakistan; Chile in the 1970s; Chile, Mexico, and Peru in the 1980s; Finland in the early 1990s; and Indonesia during the Asian Financial Crisis of the late 1990s.

Some cases that deviate from this prototypical pattern can be explained by measurement issues. For example, the need to bridge the gaps in the stock-return data for Mexico 1915-18, Belgium in World Wars I and II, Portugal 1974-77, and Spain 1936-40 likely explains the

patterns in which the negative stock returns appear to lag the macroeconomic declines. The same consideration applies to missing stock-return data for Austria during World War II.

Other cases are likely to be affected strongly by wartime controls on prices and other variables. An extreme example is Germany during World War II, where the controls—holding down reported consumer prices starting in 1936 and propping up reported stock prices starting in 1943—lapsed only in 1948. The measured real stock return for 1948, -0.89, is misleadingly low, particularly because the controls prevented the posted nominal stock prices from falling earlier. Correspondingly, during the war and through 1947, the underestimation of true inflation and the propping up of reported stock prices led to a substantial overstatement of real returns. These considerations likely explain why the real stock return of -0.91 shown for 1944-48 in Table 2, panel A appears to lag the macroeconomic decline of 0.41 for 1939-45. Moreover, an important point is that longer-term real returns that bridge the controls are likely to be satisfactory. For example, the measured, cumulative real stock return in Germany for 1939-48 of -0.85 is probably accurate.

Analogous effects from price controls likely arise for France and other countries during World War II and, perhaps also, World War I.¹⁴ For France (also affected by missing data for 1940-41), the cumulative real return for 1939-47 is -0.41. This gauge, which bridges the missing data and the likely price controls, is probably reliable. In contrast, there is an apparent mismatch in timing between the reported real stock return of -0.69 shown for 1943-45 in Table 2, panel A

¹⁴ For the United States, in a case not included in Table 2, the measured real stock return of -0.25 for 1946-47 is likely to be far below the “true” value because of the unwinding of price controls from 1945 to 1948. Barro (1978, Table 2) estimates that the “true” price level was 53% above the reported value in 1945, 21% above in 1946, and 8% above in 1947. Conversely, during the war, the controls led to an understatement of inflation and, hence, to an overestimate of real stock returns.

and the macroeconomic contraction of 0.58 for 1938-43. Again, measurement problems likely explain the mismatch.

These considerations suggest that an alternative way to evaluate the formula for the equity premium in equation (6) is to focus on the 71 cases of paired stock-market crashes and depressions (Table 2, panel A) and to calculate the covariance in a flexible way that allows for different timing for each case. Essentially, we compute the cross product between the demeaned values of the stock returns shown in column 3 and the macro contractions shown in column 5.¹⁵ Then, in applying the result to equation (6), we measure the period length, T , as the average duration (4.9 years) for the 71 paired cases. Subsequently, we go further by bringing into the calculation the additional 190 cases that had either a stock-market crash or a depression but not both (of which 161 had a stock-market crash and 29—those shown in Table 2, panel B—had a depression).

In the first application of the method, we begin by computing the covariance for the 71 paired cases shown in Table 2, panel A. To carry out this calculation, we use the values shown in columns 3 and 5 to express each gross stock return (one plus the rate of return) and

transformed consumption ratio, $\left(\frac{C_{t+T}}{C_t}\right)^{-\gamma}$, as a deviation from the respective overall sample

mean.¹⁶ (We use values of γ equal to 3, 3.5, and 4.) Then we add up the cross terms and divide by the number of cases, 71, to compute the sample covariance. To get the contribution to the overall covariance, we multiply by the weight applicable to the matched sample. This weight,

¹⁵ In these calculations, we did not adjust for price controls, such as in Germany and France, by measuring real stock returns over longer periods than those shown in Table 2, panel A. Such adjustments, in conjunction with a systematic analysis of price controls, might improve the results.

¹⁶ For example, for the United States 1929-31, the gross real stock return of 0.45 is taken as a deviation from 1.28, which is the overall sample mean for the 25 countries without large gaps in the stock-return data of gross real stock returns over 3-year periods.

denoted p_T , is the ratio of the number of years in the 71-case sample (349, corresponding to an average duration of $T = 4.9$ years) to the total sample years (3037). The result is $p_T = 0.115$, shown on the first line of Table 4. To calculate the term on the right-hand side of equation (6), we multiply 0.115 by the 71-case covariance and then divide by $(1 + \rho^*)^T$, using $\rho^* = 0.029$ per year, as before, and $T = 4.9$ years. Using $T = 4.9$ again on the left-hand side of equation (6), we then compute the equity premium, expressed per year.

The results for the full sample under the three assumed values of γ are shown on the first line of Table 4, Part A. The computed levered equity premium is 0.043 per year when $\gamma = 3$, 0.061 when $\gamma = 3.5$, and 0.085 when $\gamma = 4$. Thus, the model accords with the observed average levered equity premium of 0.07 if γ is between 3.5 and 4. Note that this match relies only on the behavior during the 71 matched stock-market crashes and depressions. Implicitly, the contribution to the covariance from the other 2688 years in the sample is taken to be roughly zero.

The model still gets into the right ballpark for the equity premium with a coefficient of relative risk aversion, γ , of 4 or less if the sample is restricted in various ways. Table 4 considers samples limited to cases of standard stock-market crashes (-0.25 or worse) and large depressions (0.25 or more), cases of large stock-market crashes (-0.40 or worse) and large depressions (0.25 or more), cases of war, and cases involving a currency or banking crisis. These results are shown in lines 2-5 of Table 4, Part A. As an example, in the war sample, p_T is reduced to 0.052, yet the computed equity premia for values of γ between 3.5 and 4 are in the range between 0.051 and 0.073.

The last line of Table 4, Part A, repeats the calculations for a sample limited to the 20 OECD countries (which have a total of 2152 observations). The computed equity premia are somewhat larger than those from the full sample—0.049 when $\gamma=3$, 0.071 when $\gamma=3.5$, and 0.101 when $\gamma=4$. Although the weight, $p_T = 0.096$, is smaller for the OECD than for the overall sample, the OECD also exhibits a higher frequency of very large macroeconomic contractions. This last consideration turns out to dominate and leads, thereby, to a higher equity premium for the OECD than for the full sample. For the OECD, a value for γ of 3.5 is adequate to roughly match the observed average levered equity premium of 0.07.

Part B of Table 4 shows the results with the larger sample of events that includes stock-market crashes without depressions and depressions without stock-market crashes. Thus, there are now 261 events for 30 countries and 164 events for 20 OECD countries. The fraction, p_T , of the overall sample years contained in these sub-samples is much larger than before—0.31 for the 30 countries and 0.27 for the OECD. However, since the covariance between stock returns and macro contractions is not so high in the newly added group (because these events were selected not to have pairings of stock-market crashes with depressions), the incremental contribution to the computed equity premium is positive but modest in size. For the full group of countries, the equity premium is now 0.050 at $\gamma=3$, 0.070 at $\gamma=3.5$, and 0.098 at $\gamma=4$. For the OECD, the results are 0.057 at $\gamma=3$, 0.081 at $\gamma=3.5$, and 0.116 at $\gamma=4$. Thus, $\gamma=3.5$ is now more clearly adequate to match the target value of 0.07.

Another 69% of the sample years for the 30 countries (73% for the OECD) are contained neither in a stock-market crash nor a depression. We have not studied in detail the contribution of this part of the sample to the computed equity premium. However, we can get an idea of the

effect by calculating the covariance between the one-year stock returns and the asset-pricing factors, $(C_{t+1}/C_t)^{-\gamma}$. That is, we use our initial approach for computing the covariance but look here only at the years not contained within a stock-market crash or a depression. The result when $\gamma=3.5$ is that the covariance is -0.005 for this sample when applied to 25 countries and -0.003 for 18 OECD countries (where we omit the 5 countries with large or unconnected gaps in the stock-return data). Weighting by the fraction of the overall years in the sample (0.69 for the overall group and 0.73 for the OECD) implies that the incremental contribution to the equity premium is 0.003 for the overall group and 0.002 for the OECD. Thus, by these calculations, the inclusion of the rest of the sample years in the analysis has a positive, but minor, impact on the equity premia reported in Table 4.

The bottom line is that a “flexible covariance analysis” applied to the asset-pricing formula in equation (6) generates a reasonable levered equity premium if the coefficient of relative risk aversion, γ , is around 3.5. The main element in this computation is the flexible interpretation of the timing between stock-market crashes and depressions during the small number of paired, multi-year events (71 in our sample).

This conclusion accords with the one reached by Barro and Ursua (2008, Tables 10 and 11), who followed Mehra and Prescott (1985) by considering only the sizes of macroeconomic contractions and not the covariance with stock returns. This previous analysis looked at multi-year depressions but did not require measurement of the timing between depressions and stock-market crashes. In other words, the assumption that prices of unlevered equity claims move in the same proportion as consumption (aside from temporary orthogonal noise) substituted for the complexities associated with matching the timing of stock returns and consumption changes.

A key point is that the covariance calculation that “works” for the equity premium relies almost entirely on the roughly 12% of the time-series observations that apply to matched stock-market crashes and depressions (Table 2, panel A). The inclusion of the additional 19% of the observations that feature unmatched stock-market crashes and depressions has a minor effect (Table 4, Part B), and the consideration of the remaining 69% of the data from “normal times” has a trivial effect. We think that further refinement of the results should focus even more on the 12% of the data that matters for the equity premium. In particular, we need to consider more rigorously how to carry out a covariance analysis that allows for flexible timing between stock returns and consumption changes. An important part of this analysis is to deal more satisfactorily with periods of missing annual data and with the price controls that characterize many of the wartime crises.

IV. Conclusions and Future Research

The long-term history for 30 countries indicates that stock-market crashes (cumulative real returns of -0.25 or worse) have substantial predictive power for depressions (cumulative macroeconomic declines by 10% or more). In a non-war environment, the realization of a stock-market return of -0.25 or worse implies that the probability of a minor depression (macroeconomic decline by 10% or more) is 22%, and the probability of a major depression (decline by 25% or more) is 3%. When the stock return is -0.40 or worse, the corresponding depression probabilities are 30% and 4%. The probabilities are 46% and 8%, respectively, when a stock-market crash of -0.25 or worse in a non-war period is accompanied by a currency or banking crisis and occurs during a time of global economic turmoil. Given the stock-market

crashes for the United States and other countries in 2008 (characterized as non-war, featuring a currency or banking crisis, and occurring during a global event), these last probabilities applied at the beginning of 2009.

The long-term data also show that the majority (67%) of minor, non-war depressions are accompanied by stock-market crashes, whereas most major, non-war depressions (83%) are accompanied by these crashes. Therefore, in the absence of a stock-market crash, the occurrence of a depression is highly unlikely.

The full history of 3037 annual observations reveals 71 matched cases of stock-market crashes and depressions, of which 41% are associated with war. The years contained in the 71 cases constitute 12% of the overall sample (because the average duration of a crisis was 4.9 years). The co-movement between stock returns and macroeconomic changes for the 71 cases may be sufficient to explain the observed equity premium of 7%, assuming that the coefficient of relative risk aversion is between 3.5 and 4. The required coefficient falls to 3.5 or less if we bring in the additional 19% of the sample that features a stock-market crash or depression but not both. A crucial aspect of this analysis is that the computed covariances allow for a flexible timing pattern between stock returns and macroeconomic changes. In future research, we plan to assess this flexible covariance approach in more detail. Part of this research involves the roles of missing data and wartime price controls, which can distort the covariances calculated from a rigid timing structure.

References

- Bansal, R. and A. Yaron (2004). "Risks for the Long Run: A Potential Resolution of Asset-Pricing Puzzles," *Journal of Finance*, 59, August, 1481-1509.
- Barro, R.J. (1978). "Unanticipated Money, Output, and the Price Level in the United States," *Journal of Political Economy*, 86, August, 549-580.
- Barro, R.J. (2006). "Rare Disasters and Asset Markets in the Twentieth Century," *Quarterly Journal of Economics*, 121, August, 823-866.
- Barro, R.J. (2009). "Rare Disasters, Asset Prices, and Welfare Costs," *American Economic Review*, 99, March, 243-264.
- Barro, R.J. and T. Jin (2009). "On the Size Distribution of Macroeconomic Disasters," National Bureau of Economic Research, working paper 15247, September.
- Barro, R.J. and J.F. Ursua (2008). "Macroeconomic Crises since 1870," *Brookings Papers on Economic Activity*, Spring, 255-350.
- Bordo, M. and B. Eichengreen, D. Klingebiel and M.S. Martinez-Peria (2001). "Is the Crisis Problem Growing More Severe?," *Economic Policy*, 16, April, 51-82.
- Dimson, E., P. Marsh, and M. Staunton (2008). "The Worldwide Equity Premium: A Smaller Puzzle," in R. Mehra, ed., *Handbook of the Equity Risk Premium*, Amsterdam, Elsevier.
- Epstein, L.G. and S.E. Zin (1989). "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework," *Econometrica*, 57, July, 937-969.

- Fujino, S. and R. Akiyama (1977). *Security Prices and Rates of Interest in Japan: 1874-1975*, Tokyo, Hitotsubashi University.
- Gabaix, X. (2008). “Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-Finance,” National Bureau of Economic Research Working Paper 13724, January.
- Goldsmith, R.W. (1986). *Brasil 1850-1984: Desenvolvimento Financeiro sob um Século de Inflação*, São Paulo, Harper and Row do Brasil.
- Haber, S., A. Razo, and N. Maurer (2003). *The Politics of Property Rights: Political Instability, Credible Commitments, and Economic Growth in Mexico, 1876-1929*, New York, Cambridge University Press.
- Lucas, R.E. (1978). “Asset Prices in an Exchange Economy,” *Econometrica*, 46, November, 1429-1445.
- Maddison, A. (2003). *The World Economy: Historical Statistics*, Paris, OECD (on the Internet at www.ggdc.net/maddison).
- Mehra, R. and E.C. Prescott (1985). “The Equity Premium: A Puzzle,” *Journal of Monetary Economics*, 15, March, 145-161.
- Nakamura, L. and C. Zarazaga (2003). “Banking and Finance in Argentina in the Period 1900-35,” in Della Paolera, G. and A.M. Taylor, eds., *A New Economic History of Argentina*, Cambridge, Cambridge University Press.
- Reinhart, C. and K. Rogoff (2009). *This Time is Different: Eight Centuries of Financial Folly*, New Jersey, Princeton University Press.

Rietz, T.A. (1988). "The Equity Risk Premium: A Solution," *Journal of Monetary Economics*, 22, July, 117-131.

Samuelson, P.A. (1966). "Science and Stocks," *Newsweek*, September 19.

Sarkees, M. R. (2000). "The Correlates of War Data on War: An Update to 1997," *Conflict Management and Peace Science*, 18/1, 123-144, accessed on the Internet at <http://www.correlatesofwar.org/Datasets.htm>, version 3.0.

Taylor, B. (2005). "GFD Guide to Total Returns on Stocks, Bonds and Bills," available on the Internet from Global Financial Data at www.globalfindata.com.

Weil, P. (1990). "Nonexpected Utility in Macroeconomics," *Quarterly Journal of Economics*, 105, February, 29-42.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stock period	Stock return (-)	C period	C contraction	GDP period	GDP contraction	Macro period	Macro contraction
1907-07	0.32	1906-08	0.04	1906-08	0.10	1906-08	0.07
1916-20	0.47	1917-21	0.16	1918-21	0.12	1917-21	0.16
1929-31	0.55	1929-33	0.21	1929-33	0.29	1929-33	0.25
1937-37	0.37	1937-38	0.02	1937-38	0.04	1937-38	0.03
1939-41	0.29	1941-42	0.03	1939-40	-0.08	1941-42	0.03
1973-74	0.49	1973-74	0.02	1973-75	0.03	1973-75	0.02
2000-02	0.42	2000-01	-0.01	2000-01	0.00	2000-01	-0.01
2008-08	0.37	?	?	?	?	?	?

Notes: Underlying stock returns are real rates of return (arithmetic) from end of previous year to end of current year. Stock return in column 2 is cumulated real return (all negative) over period shown in column 1. For example, 1929-31 refers to the cumulated return from the end of 1928 to the end of 1931. The cases selected are those with returns ≤ -0.25 . C in columns 3 and 4 is real per capita consumer expenditure. Contraction in column 4 is cumulated fractional decline over period shown in column 3. For example, 1929-33 refers to the ratio of consumer expenditure in 1933 (annual average) to that in 1929 (annual average). GDP is real per capita GDP. Contraction in column 6 is cumulated fractional decline over period shown in column 5. Macro contraction in column 8 is the average for C and GDP for non-war cases and C value for wars and war aftermaths. The macro period in column 7 is the overlap for C and GDP when the macro contraction is the average for C and GDP. When only C is used, the macro period corresponds to that for C. For the United States, there are no other macroeconomic contractions of size 0.10 or more. (The period 1913-14 has a GDP contraction of 0.10 but a C contraction of only 0.05—the stock return for 1913-14 is -0.16.)

Table 2 Depressions with and without Stock-Market Crashes (30 countries with long-term data on stock returns and macro aggregates)				
Panel A: Stock-Market Crashes and Depressions (71)				
(1)	(2)	(3)	(4)	(5)
Country	Stock-Market Period	Stock Return (negative)	Macro Period	Macro Contraction
OECD countries				
Australia	1929-30	0.25	1926-32	0.23
Austria	1929-33	0.48	1929-34	0.23
	1947-50*	0.84	1941-45	0.59
Belgium	1914-18*	0.76	1913-18	0.46
	1929-31	0.48	1930-34	0.10
	1937-39	0.26	1937-42	0.53
	1942-48*	0.74	1942-46	0.13
Canada	1916-20	0.27	1918-21	0.20
	1929-32	0.54	1928-33	0.29
Denmark	1917-17	0.27	1914-18	0.12
	1919-22	0.60	1919-21	0.24
	1937-40	0.27	1939-41	0.26
Finland	1989-91	0.47	1989-93	0.13
France	1913-20	0.62	1912-18	0.25
	1929-31	0.46	1929-35	0.12
	1943-45	0.69	1938-43	0.58
Germany	1914-20	0.91	1912-18	0.42
	1922-22	0.63	1922-23	0.13
	1929-31	0.52	1928-32	0.20
	1944-48	0.91	1939-45	0.41
Greece	1939-40*	0.37	1939-42	0.66
Italy	1944-45	0.89	1939-45	0.35
Japan	1897-98	0.54	1899-06	0.12
	1943-47	0.97	1937-45	0.64
Netherlands	1918-22	0.47	1912-18	0.44
	1944-46*	0.42	1939-44	0.54
Norway	1917-18	0.36	1916-18	0.17
	1919-21	0.55	1919-21	0.16
Portugal	1974-78*	0.97	1974-76	0.10
Spain	1929-31	0.53	1929-33	0.10
	1935-40*	0.43	1935-37	0.46
	1935-40*	0.43	1940-45	0.14
Sweden	1917-18	0.60	1913-18	0.13
	1919-20	0.30	1920-21	0.13
	1939-40	0.26	1939-45	0.14

Switzerland	1914-20*	0.68	1912-18	0.15
	1939-40	0.28	1939-45	0.15
United Kingdom	1912-20	0.60	1915-18	0.17
	1937-40	0.41	1938-43	0.17
United States	1916-20	0.47	1917-21	0.16
	1929-31	0.55	1929-33	0.25
Non-OECD countries				
Argentina	1910-17	0.53	1912-17	0.24
	1929-32	0.48	1928-32	0.19
	1949-52	0.82	1948-53	0.12
	1980-82	0.56	1980-82	0.11
	1986-87	0.33	1987-90	0.15
	2000-01	0.37	1998-02	0.24
Brazil	1990-90	0.67	1987-92	0.14
Chile	1929-31	0.40	1929-32	0.37
	1972-72	0.27	1972-76	0.40
	1981-84	0.56	1981-85	0.25
Colombia	1931-31	0.28	1929-32	0.11
India	1940-42	0.30	1937-42	0.13
	1940-42	0.30	1943-46	0.13
	1946-49	0.49	1947-50	0.18
Indonesia	1928-31	0.54	1930-33	0.11
	1997-98	0.69	1997-99	0.12
Mexico	1909-18*	0.79	1909-16	0.25
	1924-31	0.55	1926-32	0.31
	1980-82	0.81	1981-88	0.14
	1994-96	0.38	1994-95	0.10
Peru	1967-76	0.66	1975-79	0.14
	1981-82	0.86	1981-83	0.11
	1987-88	0.76	1987-92	0.31
Venezuela	1946-47	0.28	1948-52	0.14
	1958-61	0.34	1957-64	0.19
	1977-81	0.65	1977-86	0.28
	1988-89	0.70	1988-89	0.10
	1992-95	0.55	1992-99	0.11
	1997-2001	0.60	2001-03	0.16
South Africa	1920-20	0.38	1919-20	0.24

Panel B: Depressions without Stock-Market Crashes (29)				
(1)	(2)	(3)	(4)	(5)
Country	Stock-Market Period	Stock Return (negative)	Macro Period	Macro Contraction
OECD countries				
Australia	1889-89	0.02	1889-95	0.27
	1915-15	0.16	1913-18	0.24
	1940-41	0.09	1938-44	0.30
Canada	1907-07	0.09	1906-08	0.10
	1913-14	0.18	1912-15	0.13
Denmark	1947-48	0.07	1946-48	0.14
Finland	1928-29	0.12	1928-32	0.13
	1939-39	0.05	1938-42	0.24
France	1871-71	0.12	1864-71	0.16
	1882-85	0.13	1882-86	0.11
New Zealand	1930-31	0.13	1929-32	0.18
	1940-40	0.01	1939-44	0.22
Norway	1939-40	0.05	1939-44	0.15
Portugal	1936-36	-0.03	1934-36	0.13
	1937-40	0.22	1939-42	0.10
Spain	1896-96	0.07	1892-96	0.15
Non-OECD countries				
Argentina	1900-00	0.03	1899-1900	0.17
Brazil	1908-08	0.07	1907-09	0.11
	1929-31	0.20	1928-31	0.15
Chile	1913-15	0.08	1911-15	0.21
	1920-20	0.05	1918-22	0.15
Colombia	1940-41	0.03	1939-43	0.14
Mexico	1920-20	0.12	1921-24	0.12
Peru	1930-32	0.18	1929-32	0.20
South Africa	1914-15	0.08	1912-17	0.23
	1931-32	0.15	1928-32	0.12
	1981-81	0.12	1981-87	0.10
Venezuela	1932-32*	0.04	1930-33	0.24
	1942-42	0.03	1939-42	0.11

*These periods include interpolated or missing stock returns.

Notes to Table 2

See notes to Table 1 on measures of stock returns and macroeconomic contractions. Panel A shows the 71 paired cases with stock-market crashes (cumulative returns of -0.25 or less) and depressions (macroeconomic contractions of 0.10 or more). Panel B shows the 29 cases of macro contractions not accompanied by stock-market crashes. Not shown are 161 cases with stock-market crashes unaccompanied by depressions. Bold for macro period indicates wartime interval (limited to active combatants).

For most non-war cases, macro contractions are the average of the contractions shown by consumer expenditure, C, and GDP. When C data are missing, macro contractions were based on GDP except for war aftermaths (which were left as missing data) and during wars when the indicated GDP fall was less than 0.10 (also left as missing data). For wartime contractions, when C and GDP data were available, the macro contraction was based on C when this decline was greater than that in GDP. When the GDP decline was larger, the macro contraction was computed as the average of the C and GDP contractions. Annual data on stock returns were missing (typically because of closed markets) for Belgium 1914-18 and 1944-46, Mexico 1915-18, Netherlands 1944-46, Spain 1936-40, Portugal 1974-77, and Switzerland 1914-16. The stock returns that include these periods were based on cumulative, multi-year returns over periods that bridged the gaps in the annual data. Stock-return data are also missing for Argentina 1936-38 and 1958-65, Brazil 1943-44, Austria 1939-44, Greece 1941-52, and Indonesia 1940-77.

Table 3 Frequencies of Stock-Market Crashes and Depressions				
Part A: Non-War and War Observations Combined				
		Numbers of events		
Stock return \leq	Macro Contraction \geq	Stock-Market Crashes	Depressions	Both
All countries (30)				
-0.25	0.10	232	100	71 (.31, .71)
	0.15		59	43 (.19, .73)
	0.20		40	31 (.13, .78)
	0.25		25	23 (.10, .92)
	0.30		17	16 (.07, .94)
-0.40	0.10	124	100	50 (.40, .50)
	0.15		59	30 (.24, .51)
	0.20		40	22 (.18, .55)
	0.25		25	18 (.15, .72)
	0.30		17	12 (.10, .71)
-0.50	0.10	79	100	38 (.48, .38)
	0.15		59	22 (.28, .37)
	0.20		40	18 (.23, .45)
	0.25		25	15 (.19, .60)
	0.30		17	9 (.11, .53)
OECD countries (20)				
-0.25	0.10	148	57	41 (.28, .72)
	0.15		37	28 (.19, .76)
	0.20		26	21 (.14, .81)
	0.25		18	16 (.11, .89)
	0.30		13	12 (.08, .92)
-0.40	0.10	79	57	31 (.39, .54)
	0.15		37	21 (.27, .57)
	0.20		26	16 (.20, .62)
	0.25		18	13 (.16, .72)
	0.30		13	10 (.13, .77)
-0.50	0.10	47	57	21 (.45, .37)
	0.15		37	15 (.32, .41)
	0.20		26	12 (.26, .46)
	0.25		18	10 (.21, .56)
	0.30		13	7 (.15, .54)

Part B: Non-War and War Observations Compared							
		Numbers of Events					
		Non-war only			War only		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stock ≤	Macro ≥	Stock	Depression	Both	Stock	Depression	Both
All countries (30)							
-0.25	0.10	192	63	42 (.22, .67)	40	37	29 (.73, .78)
	0.15		30	21 (.11, .70)		29	22 (.55, .76)
	0.20		17	13 (.07, .76)		23	18 (.45, .78)
	0.25		6	5 (.03, .83)		19	18 (.45, .95)
	0.30		1	1 (.01, 1.00)		16	15 (.38, .94)
-0.40	0.10	98	63	29 (.30, .46)	26	37	21 (.81, .57)
	0.15		30	13 (.13, .43)		29	17 (.65, .59)
	0.20		17	8 (.08, .47)		23	14 (.54, .61)
	0.25		6	4 (.04, .67)		19	14 (.54, .74)
	0.30		1	0 (.00, --)		16	12 (.46, .75)
-0.50	0.10	60	63	22 (.37, .35)	19	37	16 (.84, .43)
	0.15		30	10 (.17, .33)		29	12 (.63, .41)
	0.20		17	7 (.12, .41)		23	11 (.58, .48)
	0.25		6	4 (.07, .67)		19	11 (.58, .58)
	0.30		1	0 (.00, --)		16	9 (.47, .56)
OECD countries (20)							
-0.25	0.10	118	29	20 (.17, .69)	30	28	21 (.70, .75)
	0.15		14	11 (.09, .79)		23	17 (.57, .74)
	0.20		8	7 (.06, .88)		18	14 (.47, .78)
	0.25		3	2 (.02, .67)		15	14 (.47, .93)
	0.30		0	0 (.00, --)		13	12 (.40, .92)
-0.40	0.10	60	29	15 (.25, .52)	19	28	16 (.84, .57)
	0.15		14	8 (.13, .57)		23	13 (.68, .57)
	0.20		8	5 (.08, .63)		18	11 (.58, .61)
	0.25		3	2 (.03, .67)		15	11 (.58, .73)
	0.30		0	0 (.00, --)		13	10 (.53, .77)
-0.50	0.10	32	29	9 (.28, .31)	15	28	12 (.80, .43)
	0.15		14	6 (.19, .43)		23	9 (.60, .39)
	0.20		8	4 (.13, .50)		18	8 (.53, .44)
	0.25		3	2 (.06, .67)		15	8 (.53, .53)
	0.30		0	0 (.00, --)		13	7 (.47, .54)

Part C: Types of Crises Compared (Non-War Sample)													
		Numbers of events											
		Currency or Banking Crisis			Global Event			Currency or Banking Crisis & Global					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)			
Stock ≤	Macro ≥	S.	D.	Both	S.	D.	Both	S.	D.	Both			
All countries (30)													
-0.25	0.10	115	48	36 (.31, .75)		75	33	23 (.31, .70)		37	21	17 (.46, .81)	
	0.15		24	19 (.17, .79)			19	14 (.19, .74)			15	12 (.32, .80)	
	0.20		14	11 (.10, .79)			11	9 (.12, .82)			8	7 (.19, .88)	
	0.25		6	5 (.04, .83)			3	3 (.04, 1.0)			3	3 (.08, 1.0)	
	0.30		1	1 (.01, 1.0)			1	1 (.01, 1.0)			1	1 (.03, 1.0)	
-0.40	0.10	69	48	28 (.41, .58)		43	33	13 (.30, .39)		24	21	12 (.50, .57)	
	0.15		24	13 (.19, .54)			19	8 (.19, .42)			15	8 (.33, .53)	
	0.20		14	8 (.12, .57)			11	4 (.09, .36)			8	4 (.17, .50)	
	0.25		6	4 (.06, .67)			3	2 (.05, .67)			3	2 (.08, .67)	
	0.30		1	0 (.00, --)			1	0 (.00, --)			1	0 (.00, --)	
-0.50	0.10	46	48	21 (.46, .44)		22	33	9 (.41, .27)		14	21	8 (.57, .38)	
	0.15		24	10 (.22, .42)			19	6 (.27, .32)			15	6 (.43, .40)	
	0.20		14	7 (.15, .50)			11	4 (.18, .36)			8	4 (.29, .50)	
	0.25		6	4 (.09, .67)			3	2 (.09, .67)			3	2 (.14, .67)	
	0.30		1	0 (.00, --)			1	0 (.00, --)			1	0 (.00, --)	

Note: Part A combines non-war and war events. Part B considers non-war and war events separately (where “war” indicates that the period of macroeconomic contraction overlaps with active combat status in a major inter-state or intra-state conflict). Part C considers non-war events with currency or banking crises, global crises, and both categories at the same time. The numbers of events refer to stock-market returns \leq the amount shown or macro contractions \geq the amount shown or both. In the last column of part A, columns 5 and 8 of part B, and columns 5, 8 and 11 of part C, the fractions in parentheses are, first, the frequency of contractions \geq the amount shown, given that the stock return is \leq the amount shown, and, second, the frequency of stock returns \leq the amount shown, given that the contraction is \geq the amount shown. The letters S and D in the headings of part C represent Stock-Market Crashes and Depressions, respectively.

Table 4 Stock-Market Crashes and Depressions, Implications for Equity Premium						
Part A: Stock-Market Crashes (returns ≤ -0.25) and Depressions (contractions ≥ 0.10) for 30 countries						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample criterion:	N	T	p_T	Equity Premium		
				$\gamma = 3.0$	$\gamma = 3.5$	$\gamma = 4.0$
Full sample	71	4.9	0.115	0.043	0.061	0.085
Crash ≤ -0.25 and Depression ≥ 0.25	23	5.6	0.042	0.035	0.051	0.074
Crash ≤ -0.40 and Depression ≥ 0.25	18	6.1	0.036	0.029	0.042	0.061
War	29	5.5	0.052	0.034	0.051	0.073
Currency or Banking Crisis	61	5.1	0.103	0.042	0.059	0.083
OECD only (20 countries)	41	5.0	0.096	0.049	0.071	0.101
Part B: Stock-Market Crashes (returns ≤ -0.25) or Depressions (contractions ≥ 0.10) for 30 countries						
Sample criterion:	N	T	p_T	Equity Premium		
				$\gamma = 3.0$	$\gamma = 3.5$	$\gamma = 4.0$
Full sample	261	3.6	0.311	0.050	0.070	0.098
Crash ≤ -0.25 or Depression ≥ 0.25	234	3.6	0.279	0.049	0.069	0.096
Crash ≤ -0.40 or Depression ≥ 0.25	131	4.4	0.189	0.045	0.063	0.088
War	48	5.0	0.079	0.036	0.053	0.076
Currency or Banking Crisis	162	4.0	0.216	0.047	0.066	0.092
OECD only (20 countries)	164	3.5	0.270	0.057	0.081	0.116

Note: Part A encompasses events for which stock returns are -0.25 or less *and* macro contractions are 0.10 or more (except for the rows where different thresholds are indicated). Part B considers cases for which returns are -0.25 or less *or* macro contractions are 0.10 or more (except for the rows where different thresholds are indicated). (Part A is a subset of Part B.) N in column 2 is the number of occurrences of the state described by the sample criterion in column 1. T in column 3 is the average duration in years of these states. p_T in column 4 is the fraction of the total observations (3037 for all countries, 2152 for OECD) represented by the selected sample. The calibrated (levered) equity premium in columns 5-7 is calculated as discussed in the text. The results are for the coefficient of relative risk aversion, γ , set to 3, 3.5, or 4.