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Macroeconomic Crises since 1870

ABSTRACT We build on Angus Maddison's data by assembling international time series from before 1914 on real per capita personal consumer expenditure, C, and by improving the GDP data. We have full annual data on C for twenty-four countries and GDP for thirty-six. For samples starting at 1870, we apply a peak-to-trough method to isolate economic crises, defined as cumulative declines in C or GDP of at least 10 percent. We find 95 crises for C and 152 for GDP, implying disaster probabilities of 3½ percent a year, with mean size of 21–22 percent and average duration of 3½ years. Simulation of a Lucas-tree model with i.i.d. shocks and Epstein-Zin-Weil preferences accords with the observed average equity premium of around 7 percent on levered equity, using a coefficient of relative risk aversion of 3.5. This result is robust to several perturbations, except for limiting the sample to nonwar crises.

An earlier study by Barro used Thomas Rietz's insight on rare economic disasters to explain the equity premium puzzle introduced by Rajnish Mehra and Edward Prescott.[1] Key parameters were the probability p of disaster and the distribution of disaster sizes b. Because large macroeconomic disasters are rare, pinning down p and the b distribution from historical data requires long time series for many countries, along with the assumption of rough parameter stability over time and across countries. Barro's 2006 study relied on long-term international GDP data for thirty-five countries from Angus Maddison's 2003 dataset.[2] Using the definition of an economic disaster as a peak-to-trough fall in GDP per capita of at least 15 percent, Barro found sixty disasters, corresponding to $p = 1.7$ percent a year. The average disaster size was 29 percent, and the empirical size distribution was used to calibrate a model of asset pricing.

1. Barro (2006); Rietz (1988); Mehra and Prescott (1985).
2. Maddison (2003).

The underlying asset pricing theory relates to consumption, rather than GDP. This distinction is especially important for wars. For example, in the United Kingdom during the two world wars, GDP increased while consumer expenditure fell sharply, the difference representing mostly added military spending. Maddison's 2003 dataset provides national accounts information only for GDP. Our initial idea was to add consumption, which we approximate by real personal consumer expenditure, C, because of difficulties in most cases in separating durable goods consumption from that of nondurable goods and services. (We discuss later the breakdown of C into durables versus nondurables for a subset of countries with available data for crisis periods.) We have not assembled data on government consumption, some of which may substitute for C and thereby affect asset pricing. However, this substitution is probably unimportant for military expenditure, which is the type of government spending that moves sharply during some disaster events.

Maddison's 2003 dataset, with updates available on the Internet at www.ggdc.net/maddison, represents a monumental and widely used resource for international studies using long-term GDP data. Although much of the information is sound, close examination revealed many problems. For our purposes the most important shortcoming is that Maddison tends to fill in missing data with doubtful assumptions, and this practice applies especially to major crises.

As examples of problems, Maddison assumed that Belgium's GDP during World Wars I and II moved in tandem with France's; that Mexico's GDP between 1910 and 1919, the period including its revolution and civil war, followed a smooth trend, with no crisis; that GDP for Colombia moved over more than a decade with the average of Brazil and Chile; and that GDP in Germany for the crucial years 1944–46 followed a linear trend. There were also mismatches between originally cited works and published series for GDP in Japan and Austria at the end of World War II, in Greece during World War II and its civil war, and in South Korea during World War II and the Korean War.

Given these and analogous problems, our project expanded to estimating long-term GDP for many countries. The Maddison information was often usable, but superior estimates or longer time series could often be constructed. In addition, results from recent major long-term national accounts projects for several countries are now available and have not been incorporated into Maddison's Internet updates. These studies cover Argentina, Brazil, Colombia, Greece, Sweden, and Taiwan. Table A1 in appendix A summarizes the key differences, by country and time period, between Maddison's and our GDP data. Details and a list of data sources are available on the Internet (www.economics.harvard.edu/faculty/barro/data_sets_barro).

The first section of the paper describes the long-term data that we have assembled on real per capita personal consumer expenditure, C, and real per capita GDP. Our main analysis uses annual data from before 1914 for twenty-four countries on C and thirty-six countries on GDP. The second section discusses the long-term data that we use on rates of return for stocks, bills, and bonds. This information comes mostly from Global Financial Data. The third section describes our measurement of C and GDP crises, based primarily on peak-to-trough fractional declines during the crises. The fourth section discusses the limited information available on the breakdown of C into durables versus nondurables and services.

The fifth section compares disaster sizes and timing based on C with those based on GDP. The sixth section uses the crises data to measure disaster probabilities and frequency distributions of disaster sizes. The seventh section summarizes a representative-agent Lucas-tree model that relates disaster experience to expected rates of return and the equity premium. The eighth section simulates the Lucas-tree model using the empirically estimated disaster probability and the frequency distribution of disaster sizes. The simulated model with a reasonable coefficient of relative risk aversion accords reasonably well with observed equity premia. The ninth section modifies the simulation to use observed real stock-price changes to gauge crisis returns on stocks. We also discuss the low average real bill returns observed during crises. The final section concludes with plans for additional research.

Long-Term Data on Personal Consumer Expenditure and GDP

We are dealing with national accounts data for forty-two countries. This sample is the universe of countries that seem to be promising for constructing reasonably accurate annual data since before World War I. The current study focuses on the countries for which we have thus far assembled annual data from before 1914 to 2006 on C (twenty-four countries) and GDP (thirty-six countries).

Table 1 shows a list of included countries and starting years. The top panel applies to twenty-one "OECD countries" (not including Turkey or recently acceding members); seventeen of these are in our C sample, and all twenty-one are in our GDP sample. The bottom panel covers eighteen "non-OECD" countries, of which seven are in our C sample, and fifteen are in our GDP sample. The three countries that we are studying that are

Table 1. Starting Dates and Missing Values for Consumer Expenditure and GDP[a]

	Starting dates		Missing values	
Country	*C*	*GDP*	*C*	*GDP*
OECD countries[b]				
Australia	1901	1820		
Austria	1913[c]	1870	1919–23, 1945–46	
Belgium	1913	1846		
Canada	1871	1870		
Denmark	1844	1818		
Finland	1860	1860		
France	1824	1820		
Germany	1851	1851		
Greece	1938[c]	1833[e]		1944
Iceland	1945[c]	1870		
Italy	1861	1861		
Japan	1874	1870		
Netherlands	1814	1807		
New Zealand	1939[c]	1870	1940–43, 1945–46	
Norway	1830	1830		
Portugal	1910	1865		
Spain	1850	1850		
Sweden	1800	1800		
Switzerland	1851	1851		
United Kingdom	1830	1830		
United States	1869	1869		
Non-OECD countries				
Argentina	1875	1875		
Brazil	1901	1850		
Chile	1900	1860		
Colombia	1925[c]	1905		
India	1919[c]	1872		
Indonesia	1960[c]	1880		
Malaysia	1900[c]	1900[d]	1940–46	1943–46
Mexico	1900	1895		
Peru	1896	1896		
Philippines	1950[c]	1902[f]		1941–45
Singapore	1900[c]	1900[d]	1940–47	1940–49
South Africa	1946[c]	1911		
South Korea	1911	1911		
Sri Lanka	1960[c]	1870		
Taiwan	1901	1901		
Turkey	1923[c]	1923[d]		
Uruguay	1960[c]	1870		
Venezuela	1923[c]	1883		

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. C represents real per capita personal consumer expenditure; GDP represents real per capita GDP. Missing values apply to each period between country starting date and 2006. Criterion for inclusion in samples is presence of continuous annual data back before World War I.

b. Excludes recently acceding members and Turkey.

c. Excluded from analysis for C sample because of insufficient coverage.

d. Excluded from analysis for GDP sample because of insufficient coverage.

e. Included in the GDP sample with data for log(GDP) in 1944 interpolated between values for 1943 and 1945. This interpolation does not affect the estimated decline in GDP during World War II.

f. Included in part of the analysis of GDP data despite the gap in information for 1941–45. This gap does not hinder estimating the cumulative contraction in GDP associated with World War II.

omitted from table 1 because of insufficient progress with the data are Egypt, Ireland, and Russia. We start our analysis of growth rates in 1870, although earlier data are available in some cases.

Our present analysis uses growth rates of C and GDP and does not involve comparisons of levels across countries. Therefore we can use indexes of both variables, for example, setting their values at 100 for each country in 2000. However, the level comparisons matter for the construction of measures of C and GDP for groups of countries, such as the total of the OECD. To facilitate this analysis (and to allow for other uses of the data that depend on comparability of levels across countries), we set the level of per capita GDP for each country in 2000 to the purchasing power parity (PPP)–adjusted value in 2000 international dollars given in the World Bank's *World Development Indicators* (WDI). For per capita consumer expenditure, we set the level for each country in 2000 to the value given by the WDI for PPP-adjusted per capita GDP multiplied by the share of nominal personal consumer expenditure in the country's nominal GDP.

Sample selection issues particularly affect disaster studies because data tend to be absent during the worst crises, especially wars. As examples, Malaysia and Singapore have data on C and GDP since 1900 but are missing information during World War II. Inclusion of the incomplete Malaysian and Singaporean time series since 1900 in our analysis would bias downward the estimated disaster probabilities, since the missing periods almost surely contain crises. We take the approach of excluding cases with these kinds of selected gaps in the data. In addition to Malaysia and Singapore, we omit Turkey (whose C and GDP data start in 1923, after the Ottoman Empire's crisis during World War I), India for C (where the data start in 1919), and Austria for C (where the data start in 1913 but information is missing toward the ends of World Wars I and II). More broadly, our main response to this selection issue has been to try to expand the set of countries with at least roughly estimated full time series.

The construction of estimates of C relied on various procedures. In many cases we used existing long-term national accounts studies. Sometimes (for example, Canada before 1926) we estimated C as a residual, starting from GDP and subtracting estimates of the other components of GDP. Sometimes (for example, Switzerland before 1948 and Germany around World War I) we constructed C from quantities of specific consumption items, using estimates of expenditure shares to calculate changes in C. The details of our procedures are in our Internet report.

One issue is the treatment of border changes. An illustration is the reunification of Germany in late 1990. We have data on per capita C and

GDP for West Germany up to 1990 (ignoring, for now, the previous border changes) and also after 1990. We have data for unified Germany from 1991 on. Since per capita C and GDP in East Germany (not well measured before 1991) were much lower than in the West, the raw data on per capita quantities would show sharp drops in 1991 if we combined the West German values up to 1990 with the unified-Germany values thereafter. That is, this approach would treat the unification as a disaster event from the perspective of West Germans leading up to 1990. This perspective may or may not be accurate for this particular border change,[3] but we do not want to apply this approach to border changes in general. This procedure would imply that the initially richer part inevitably regards the coming combination as a disaster, and vice versa for the poorer part.

Even without border changes, the use of per capita C or GDP as a macro variable neglects the distribution of expenditure and income within a country. This macroeconomic approach, valid under some conditions,[4] assumes that we can apply a representative-agent framework to the macro variables, despite the underlying heterogeneity in productivity, wealth, and so on. In this case, the joining of West Germany with another state (East Germany) that happens to have distributions of expenditure and income with lower mean values need not invalidate the representative-agent representation. The appropriate macro-level procedure is then to smoothly paste together in 1990–91 the initial per capita series for West Germany with that for unified Germany thereafter. That is, the West German per capita growth rates apply up to 1991, and the unified Germany growth rates apply thereafter—with no discrete shift in levels of variables at the time of the reunification. We apply this methodology to all of our cases of border change because we think that this approach can yield satisfactory measures of per capita growth rates across these changes. However, this procedure can be misleading with regard to levels of variables. These issues do not affect our present analysis but would matter in the construction of measures of per capita C and GDP for broad groups of countries, such as the total of the OECD.

Table 2 reports means and standard deviations, by country, of annual growth rates of per capita C and GDP. We consider here only cases with annual data from 1914 or earlier. The sample periods end in 2006 and go

3. As an analogy, some South Koreans view a reunification with North Korea as a pending disaster.

4. For example, Caselli and Ventura (2000) show that the neoclassical growth model can provide a satisfactory representative-agent view of macroeconomic variables despite heterogeneity in underlying productivity and wealth.

Table 2. Means and Standard Deviations of Annual Growth Rates of Consumer Expenditure and GDP[a]

	C		*GDP*	
Country	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
OECD countries				
Australia	0.0154	0.0506	0.0159	0.0423
Austria	—	—	0.0217	0.0709
Belgium	0.0189	0.0904	0.0203	0.0838
Canada	0.0192	0.0474	0.0212	0.0511
Denmark	0.0163	0.0538	0.0190	0.0370
Finland	0.0239	0.0568	0.0237	0.0449
France	0.0162	0.0674	0.0191	0.0642
Germany	0.0189	0.0570	0.0212	0.0811
Greece[b]	—	—	0.0210	0.1013
Iceland	—	—	0.0254	0.0506
Italy	0.0173	0.0370	0.0213	0.0471
Japan	0.0248	0.0689	0.0277	0.0611
Netherlands	0.0190	0.0854	0.0188	0.0757
New Zealand	—	—	0.0143	0.0517
Norway	0.0194	0.0380	0.0231	0.0361
Portugal	0.0272	0.0448	0.0207	0.0431
Spain	0.0204	0.0727	0.0200	0.0453
Sweden	0.0208	0.0458	0.0230	0.0362
Switzerland	0.0150	0.0623	0.0150	0.0399
United Kingdom	0.0147	0.0283	0.0157	0.0293
United States	0.0185	0.0360	0.0217	0.0498
Non-OECD countries				
Argentina	0.0189	0.0823	0.0164	0.0674
Brazil	0.0277	0.0780	0.0192	0.0507
Chile	0.0191	0.0905	0.0204	0.0596
Colombia	—	—	0.0236	0.0229
India	—	—	0.0140	0.0487
Indonesia	—	—	0.0160	0.0556
Mexico	0.0176	0.0655	0.0187	0.0421
Peru	0.0174	0.0463	0.0207	0.0482
South Africa	—	—	0.0130	0.0485
South Korea	0.0293	0.0689	0.0352	0.0743
Sri Lanka	—	—	0.0144	0.0455
Taiwan	0.0344	0.0872	0.0386	0.0807
Uruguay	—	—	0.0143	0.0787
Venezuela	—	—	0.0251	0.0893

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. C represents real per capita personal consumer expenditure; GDP represents real per capita GDP. Countries included are those with full data from before World War I, as indicated in table 1. Periods are from 1870 (or the later starting date with available data) through 2006. The Philippines is not included in this table because data are missing for more than one year.

b. Value of log(GDP) in 1944 is interpolated between the values for 1943 and 1945.

Table 3. Mean Annual Growth Rates of Consumer Expenditure and GDP across Countries, Various Periods[a]

	C			*GDP*		
Country sample and period	*No. of countries*	*Mean of growth rates*	*Mean of standard deviations*	*No. of countries*	*Mean of growth rates*	*Mean of standard deviations*
OECD countries						
1870–1913	15	0.0141	0.0415	21	0.0141	0.0373
1914–47	15	0.0111	0.0871	21	0.0145	0.0885
1948–2006	15	0.0264	0.0257	21	0.0287	0.0284
1870–2006	15	0.0187	0.0538	21	0.0205	0.0544
Non-OECD countries						
1870–1913	6	0.0135	0.0837	11	0.0159	0.0668
1914–47	6	0.0147	0.0886	11	0.0132	0.0704
1948–2006	6	0.0264	0.0544	11	0.0257	0.0436
1870–2006	6	0.0225	0.0750	11	0.0198	0.0606
All countries						
1870–1913	21	0.0140	0.0536	32	0.0147	0.0475
1914–47	21	0.0121	0.0875	32	0.0140	0.0823
1948–2006	21	0.0264	0.0339	32	0.0276	0.0336
1870–2006	21	0.0196	0.0599	32	0.0202	0.0565

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. C represents real per capita personal consumer expenditure; GDP represents real per capita GDP. Samples are limited to countries from table 1 with complete data on growth rates from 1904 or earlier, so that each country has at least ten observations for 1870–1913. Averages are not weighted.

back as far as possible until 1870; that is, the first observation is for the growth rate from 1869 to 1870.

Table 3 considers three subperiods: 1870–1913 (pre–World War I), 1914–47 (which includes the two world wars and the Great Depression of the early 1930s), and 1948–2006 (post–World War II). The table shows averages across the included countries of growth rates and standard deviations of growth rates.[5] For the full period, 1870–2006, the average of the growth rates of C for twenty-one countries is 0.020 (that is, 2.0 percent a year), with an average standard deviation (s.d.) of 0.060. The average for fifteen OECD countries is 0.019 (s.d. = 0.054), and that for six non-OECD countries is 0.022 (s.d. = 0.075). For GDP, the average growth rate for thirty-two countries is 0.020 (average s.d. = 0.056). The average for twenty-one OECD countries is 0.020 (s.d. = 0.054), and that for eleven non-OECD countries is 0.020 (s.d. = 0.061).

5. In order to have at least ten years of coverage for the 1870–1913 subperiod, table 3 considers only countries with data going back at least to 1904.

Table 3 shows that the last subperiod, 1948–2006, has higher growth rates and lower standard deviations than the first subperiod, 1870–1913. For example, for GDP growth in the OECD countries, the reduction in the standard deviation—from 0.037 in 1870–1913 to 0.028 in 1948–2006—is the kind of change found by Christina Romer for the United States and plausibly attributed mainly to improved measurement of macroeconomic aggregates.[6] However, the most striking difference across the subperiods involves the turbulence of the middle interval. For C growth in the OECD group, the average standard deviation for 1914–47 is 0.087, compared with 0.042 for 1870–1913 and 0.026 for 1948–2006. Similarly, for GDP growth in the OECD group, the average standard deviation for the middle interval is 0.088, compared with 0.037 and 0.028 in the other two periods.

An important feature of the 1870–2006 samples is that they include realizations of disasters, notably those in the 1914–47 subperiod, which featured the two world wars and the Great Depression. These realizations create fat tails indicated by excess kurtosis and usually lead, thereby, to rejection in long samples of the hypothesis of normality for growth rates of C or GDP.[7] For C growth the only case out of twenty-one in which normality is accepted (by a Jarque-Bera test) at the 5 percent level is the United States ($p = 0.23$). For GDP growth normality is accepted among thirty-two cases only for Iceland ($p = 0.07$), Switzerland ($p = 0.15$), Brazil ($p = 0.05$), and Uruguay ($p = 0.51$).

Appendix B presents long-term graphs of real per capita C and GDP for the twenty-four countries that have annual data on both variables from before 1914. In each case the vertical axis has a natural-log scale that ranges from 5.5 to 11.0 ($245 to $59,900 in 2000 U.S. dollars). These graphs bring out the long-term trends and show the major economic contractions. Note that a movement by 0.1 along the vertical axis corresponds to a change in the level of per capita GDP or C of about 10 percent.

As examples, for Germany GDP and C fell during World War II, World War I, and the Great Depression of the 1930s. For France the dominant contraction was during World War II, with a lesser decline in World War I. For Spain the main adverse event was its civil war during the late 1930s. The United Kingdom shows declines in C during the two world wars; GDP did not fall during the wars, but it did during their aftermaths. In the United

6. Romer (1986).

7. The tendency for negative skewness—disasters rather than bonanzas—is less pronounced than we anticipated. Over the long samples, for C growth, eleven of twenty-one countries exhibit negative skewness, and for GDP growth, twenty-four of thirty-two exhibit negative skewness.

States the main declines in C took place during the Great Depression of the early 1930s and in the early 1920s; GDP also fell at these times, as well as in the aftermath of World War II. An unusual case is the very strong behavior of U.S. GDP during World War II, while C remained fairly stable. The United States is also an outlier in the sense of passing the "ruler test"—a ruler placed along the pre-1914 data happens to lie along the observations post-1950. As noted by Timothy Cogley and by Barro,[8] the United States is almost unique in displaying this apparent tendency for the GDP data to return to a fixed trend line. In other cases (even including Canada, which comes close) the fixed-trend hypothesis is rejected by the GDP data. The full dataset corresponding to the appendix figures and to the available time series for other countries is posted on the Internet.[9]

Rates of Return

Our study involves the interplay between macroeconomic variables, represented by consumer expenditure and GDP, and rates of return on various financial assets. It does not make a major contribution to the construction of long-term data on asset returns. Instead we rely mainly on existing information, primarily that provided by Global Financial Data.[10] Table 4 shows the dates over which we have been able to assemble time series on real rates of return. In all cases we compute arithmetic real rates of return, using consumer price indexes to deflate the nominal-return indexes. As far as possible, the return indexes and CPIs apply to the end of each year.

Table 4 considers three types of assets: stocks, short-term bills (government treasury bills with maturity of three months or less and analogous claims such as deposits), and long-term government bonds (usually of ten-year maturity). For stocks some of the information comes from total-return indexes, which combine price changes and dividends. In other cases we estimated returns from stock-price indexes, using rough estimates of dividend yields. We hope eventually to obtain data from Elroy Dimson, Paul Marsh, and Mike Staunton to extend our stock-return data backward for at least Canada, Denmark, Italy, the Netherlands, Norway, Sweden, and Switzerland.[11]

Table 5 shows means and standard deviations of rates of return for countries with nearly continuous annual time series going back at least to

8. Cogley (1990, table 2); Barro (forthcoming).
9. See www.economics.harvard.edu/faculty/barro/data_sets_barro.
10. See Taylor (2005).
11. Dimson, Marsh, and Staunton (2008).

Table 4. Starting Dates and Missing Values for Real Rates of Return[a]

Country	Stocks: Total returns	Stocks: Stock indexes	Bills	Bonds
OECD countries				
Australia	1883	1876	1862[b]	1862[b]
Austria	1970	1923 [1939–44]	1885[b] [1938–44]	1946
Belgium	1951	1898 [1914–18, 1940, 1944–46]	1849 [1945–46]	1836[b] [1945–46]
Canada	1934	1916	1903 [1914–34]	1880[b]
Denmark	1970	1915	1864	1822
Finland	1962	1923	1915[b]	1960
France	1896 [1940–41]	1857 [1940–41]	1841[b]	1841[b]
Germany	1870 [1917–23]	1841	1854	1924
Greece	1977	1929 [1941–52]	1915[b] [1944–45]	1993
Iceland	2003	1993	1988 [2004–06]	1993 [2004–06]
Italy	1925	1906	1868	1862
Japan	1921	1894	1883	1871
Netherlands	1951	1920 [1945–46]	1881[b]	1881[b]
New Zealand	1987	1927	1923	1926
Norway	1970	1915	1819	1877
Portugal	1989	1932 [1975–77]	1930[b]	1976
Spain	1941	1875 [1936–40]	1883	1941
Sweden	1919	1902	1857	1922
Switzerland	1967	1911 [1914–16]	1895	1916
United Kingdom[c]	1791	1791	1801	1791
United States	1801	1801	1836	1801
Non-OECD countries				
Argentina	1988	1939 [1958–66]	1978	—
Brazil	1988	1955	1995	—
Chile	1983	1895	1864	—
Colombia	1988	1928	1986	—
India	1988	1921 [1926–27]	1874	1874[b]
Indonesia	1988	1925 [1940–77]	1970	—
Malaysia	1973	1974	1960	1961

(continued)

Table 4. Starting Dates and Missing Values for Real Rates of Return[a] (*Continued*)

Country	*Stocks* Total returns	*Stocks* Stock indexes	*Bills*	*Bonds*
Mexico	1988	1930	1962	1995
Peru	1993	1927	1985	—
Philippines	1982	1953	1950	1997
Singapore	1970	1966	1960	1988
South Africa	1961	1911	1936	1896
South Korea	1963	1963	1951	1957
Sri Lanka	1993	1953 [1975–84]	1951	—
Taiwan	1988	1968	1962	1990
Turkey	1987	1987	1973	1996
Uruguay[d]	—	—	—	—
Venezuela	1988	1930[e]	1948	1984

Sources: Authors' calculations using data mostly from Global Financial Data; stock-price indexes for Japan 1893–1914 are from Fujino and Akiyama (1977); bills data for Colombia, Indonesia, and Peru are from the International Monetary Fund. In some cases consumer price index data are from sources other than Global Financial Data.

a. Years in brackets are years with missing data. Rates of return are computed on an arithmetic basis using end-of-year values of total-return indexes divided by consumer price indexes. Stock returns computed from stock-price indexes include rough estimates of dividend yields (or use actual dividend yields in some cases). Bill returns are for short-term government bills (maturity of three months or less) or, in some cases, for overnight rates, deposit rates, or central bank discount rates. Bond returns are typically for ten-year government bonds but sometimes for other maturities.

b. Starting date is limited by missing consumer price index data.

c. Data before 1790 are not used. Bond data are for consols up to 1932 and for ten-year government bonds thereafter.

d. Stock-price data are available starting in 1925, but estimates of dividend yields are unavailable.

e. January 1942 stock-price index is used to approximate year-end value for 1941.

the 1920s.[12] The first two data columns show stock and bill returns, where a common sample applies in each case to the two types of returns. The last two data columns show analogous information for bond and bill returns. We emphasize in the present study the comparison between stocks and bills—and, hence, the customary equity premium.

For the seventeen countries with matched stock and bill returns data, the mean real rates of return over long-term samples were 0.0814 for stocks and 0.0085 for bills. (For each country we used a common sample for stock and bill returns.) Thus, the average equity premium was 0.0729. For the fifteen

12. The missing data for this group, involving two to five years each for six countries, are mainly during major wars, for which real rates of return on all three assets were probably sharply negative. This sample selection biases all measured rates of return upward, although the quantitative effect cannot be too large because of the small number of years involved. The effect on computed equity premia is likely to be even smaller.

Table 5. Long-Period Averages of Rates of Return[a]

Country	Stocks-v.-bills comparison			Bonds-v.-bills comparison		
	Start	*Stocks*	*Bills*	*Start*	*Bonds*	*Bills*
OECD countries						
Australia	1876	0.1027 (0.1616)	0.0126 (0.0566)	1870	0.0352 (0.1157)	0.0125 (0.0569)
Belgium	—	—	—	1870	0.0291 (0.1584)[b]	0.0179 (0.1447)[b]
Canada	1916	0.0781 (0.1754)	—	1916	0.0392 (0.1199)	—
Denmark	1915	0.0750 (0.2300)	0.0265 (0.0652)	1870	0.0392 (0.1137)	0.0317 (0.0588)
Finland	1923	0.1268 (0.3155)	0.0128 (0.0935)		—	—
France	1870	0.0543 (0.2078)[c]	–0.0061 (0.0996)[c]	1870	0.0066 (0.1368)	–0.0079 (0.1000)
Germany	1870	0.0758 (0.2976)	–0.0153 (0.1788)	1924	0.0402 (0.1465)	0.0158 (0.1173)
Italy	1906	0.0510 (0.2760)	–0.0112 (0.1328)	1870	0.0173 (0.1879)	0.0046 (0.1191)
Japan	1894	0.0928 (0.3017)	–0.0052 (0.1370)	1883	0.0192 (0.1820)	0.0043 (0.1475)
Netherlands	1920	0.0901 (0.2116)[b]	0.0114 (0.0474)[b]	1881	0.0308 (0.1067)	0.0118 (0.0512)
New Zealand	1927	0.0762 (0.2226)	0.0234 (0.0529)	1926	0.0276 (0.1209)	0.0240 (0.0529)
Norway	1915	0.0716 (0.2842)	0.0098 (0.0782)	1877	0.0280 (0.1130)	0.0204 (0.0709)
Spain	1883	0.0610 (0.2075)[d]	0.0173 (0.0573)[d]	—	—	—
Sweden	1902	0.0923 (0.2347)	0.0180 (0.0719)	1922	0.0292 (0.0941)	0.0176 (0.0448)
Switzerland	1911	0.0726 (0.2107)[e]	0.0083 (0.0531)[e]	1916	0.0218 (0.0717)	0.0065 (0.0545)
United Kingdom	1870	0.0641 (0.1765)	0.0179 (0.0624)	1870	0.0280 (0.1049)	0.0179 (0.0624)
United States	1870	0.0827 (0.1866)	0.0199 (0.0482)	1870	0.0271 (0.0842)	0.0199 (0.0482)

(*continued*)

Table 5. Long-Period Averages of Rates of Return[a] (*Continued*)

	Stocks-v.-bills comparison			Bonds-v.-bills comparison		
Country	*Start*	*Stocks*	*Bills*	*Start*	*Bonds*	*Bills*
Non-OECD countries						
Chile	1895	0.1430 (0.4049)	–0.0094 (0.1776)	—	—	
India	1921	0.0514 (0.2341)[f]	0.0133 (0.0835)[f]	1874	0.0191 (0.1147)	0.0240 (0.0785)
South Africa	1911	0.0890 (0.2006)	—	1911	0.0248 (0.1165)	—
Overall means[g]		0.0814 (0.2449)	0.0085 (0.0880)	—	0.0266 (0.1234)	0.0147 (0.0805)

Sources: See table 4.

a. See notes to table 4. Standard deviations are in parentheses. Columns for stocks and bills, and for bonds and bills, are for common samples with the indicated starting date. End dates are 2006.

b. Missing data for 1945–46.

c. Missing data for 1940–41.

d. Missing data for 1936–40.

e. Missing data for 1914–16.

f. Missing data for 1926–27.

g. Averages of means and standard deviations for all seventeen countries with stock and bill data and all fifteen countries with bond and bill data.

OECD countries in this sample, the average rates of return were 0.0793 for stocks and 0.0093 for bills, with an average equity premium of 0.0699.

Since the stock returns refer to levered equity, the equity premium for unlevered equity would be smaller. For example, with a debt-equity ratio of one-half (roughly that for U.S. nonfinancial corporations in recent years), the predicted premium for unlevered equity would be 0.0729/1.5 = 0.049. Thus, we take as a challenge for the model to explain an unlevered equity premium of around 5 percent a year. This type of challenge is the one taken up long ago by Mehra and Prescott.[13]

The model should also be consistent with observed levels of rates of return, including an average real bill rate of less than 1 percent a year. However, in the model simulations we choose the rate of time preference, ρ, to accord with the observed average level of the real bill rate (taken as a rough estimate of a risk-free rate, although bills are not risk-free). The reasoning is that the main basis for assessing a plausible value of ρ is to consider whether the implied levels of rates of return are sensible. Therefore, matching overall levels of rates of return does not provide a test of the model.

For the fifteen countries (fourteen of which belong to the OECD) with matched bond and bill returns data, the average long-term rate of return on bonds was 0.0266, compared with 0.0147 for bills over common samples. Thus, the average bond-bill premium was 0.0119. The present study does not address the bond-bill premium.

Table 5 also shows the familiar high annual standard deviation of stock returns, which averaged 0.245 for the seventeen countries with matched bill data (0.235 for the fifteen OECD countries). The corresponding average standard deviation for bill returns was 0.088 (0.082 for the fifteen OECD countries). Thus, bill returns exhibited substantial volatility but not nearly as great as that of stocks.

Consumer Expenditure and GDP Disasters

To isolate economic disasters for C and GDP, we first follow the procedure in Barro's 2006 paper by computing peak-to-trough fractional declines that exceed some threshold amount.[14] The earlier study used a lower bound of 0.15, but we broaden this limit here to 0.10. The inclusion of contractions between 0.10 and 0.15 brings in many more events but has only moderate implications for explaining asset returns.

13. See Mehra and Prescott (1985).
14. Barro (2006).

The peak-to-trough method for assessing the size of contractions is reasonable if growth rate shocks are independent and identically distributed (i.i.d.), so that level shocks are permanent. However, the method can be misleading when some shocks to levels are temporary. Later we modify the approach by using one-sided Hodrick-Prescott (HP) filters to attempt to gauge long-run, as opposed to transitory, economic contractions. In ongoing research with Emi Nakamura and Jón Steinsson, we are taking a formal statistical approach that uses the full time series for C and GDP for each country. This approach considers transitional probabilities for movements between normal and crisis regimes and allows for varying degrees of long-term effects of crises on levels of C and GDP.

The full results on measuring C crises are presented in table C1 in appendix C and summarized in table 6. The coverage is twenty-one OECD countries (seventeen with enough data for our subsequent analysis) and fourteen non-OECD countries (seven in our later analysis). For GDP crises, shown in table C2 in appendix C and summarized in table 7, the coverage is twenty-one OECD countries (all used in our subsequent analysis) and eighteen non-OECD countries (fifteen in our later analysis). For the samples used later, the mean size of C contraction (95 events for 24 countries) was 21.9 percent, and the mean size of GDP contraction (152 events for 36 countries) was 20.7 percent.

To highlight some cases, the United States has been comparatively immune to crises, with C declines of 16 percent in 1921 (possibly influenced by the influenza epidemic of 1918–20) and 21 percent during the Great Depression in 1933. GDP declines were 10 percent in 1908 and 1914 (years affected by banking panics[15]), 12 percent in 1921, 29 percent in 1933, and 16 percent in 1947. The last contraction, likely precipitated by the post–World War II demobilization, did not exhibit a consumption decline. For the United Kingdom, the two C crises were during the world wars: 17 percent in both 1918 and 1943. There were no GDP disasters at these times, but GDP did contract after the two wars, by 19 percent in 1921 and 15 percent in 1947.

For France we found three war-related disasters for C: 16 percent in 1871 (Franco-Prussian War), 22 percent in 1915 (World War I), and 58 percent in 1943 (World War II). For GDP there were six contractions, the largest measuring 41 percent in 1944. For Germany there were four C crises: 42 percent in 1918 (World War I), 13 percent in 1923 (German hyperinflation), 12 percent in 1932 (Great Depression), and 41 percent in

15. See Cagan (1965, p. 138).

Table 6. Summary of Consumer Expenditure Disasters by Event or Period and Country Group[a]

Event or period and country group	*No. of events*	*Average fractional decline in C*	*Declines in C by country*
Pre-1914	21	0.16	
OECD	11	0.15	Canada, 0.15, 0.11; Finland, 0.10; France, 0.16; Netherlands, 0.10; Spain, 0.18; Switzerland, 0.19, 0.22, 0.14, 0.14, 0.16
Non-OECD	10	0.16	Argentina, 0.12, 0.28, 0.20, 0.13, 0.12; Brazil, 0.15, 0.16; Peru, 0.12; Taiwan, 0.22, 0.13
World War I	20	0.24	
OECD	14	0.26	Australia, 0.24; Austria, 0.45; Belgium, 0.45; Canada, 0.13; Finland, 0.36; France, 0.22; Germany, 0.42; Netherlands, 0.44; Norway, 0.17; Portugal, 0.22; Spain, 0.13; Sweden, 0.12; Switzerland, 0.11; U.K., 0.17
Non-OECD	6	0.18	Argentina, 0.17; Brazil, 0.11; Chile, 0.32; Malaysia, 0.10; Mexico, 0.25; Singapore, 0.14
1920s	11	0.18	
OECD	6	0.17	Canada, 0.20; Denmark, 0.24; Germany, 0.13; Norway, 0.16; Sweden, 0.13; U.S., 0.16
Non-OECD	5	0.20	Brazil, 0.15; Chile, 0.18; Malaysia, 0.42; Mexico, 0.12; Singapore, 0.13
Great Depression	18	0.21	
OECD	7	0.19	Australia, 0.23; Austria, 0.22; Canada, 0.23; Finland, 0.20; Germany, 0.12; Spain, 0.10; United States, 0.21
Non-OECD	11	0.22	Argentina, 0.19; Brazil, 0.20; Chile, 0.37; Colombia, 0.18; India, 0.22; Malaysia, 0.26; Mexico, 0.31; Peru, 0.14; Singapore, 0.10; Turkey, 0.12; Venezuela, 0.31
Spanish civil war	2	0.29	
OECD	2	0.29	Portugal, 0.12; Spain, 0.46
Non-OECD	0	NA	
Late 1930s	1	0.11	
OECD	0	NA	
Non-OECD	1	0.11	Venezuela, 0.11

(continued)

Table 6. Summary of Consumer Expenditure Disasters by Event or Period and Country Group[a] (*Continued*)

Event or period and country group	*No. of events*	*Average fractional decline in C*	*Declines in C by country*
World War II	23	0.34	
OECD	17	0.34	Australia, 0.30; Austria, 0.44; Belgium, 0.53; Denmark, 0.26; Finland, 0.25; France, 0.58; Germany, 0.41; Greece, 0.64; Italy, 0.29; Japan, 0.64; Netherlands, 0.54; Norway, 0.10; Portugal, 0.10; Spain, 0.14; Sweden, 0.18; Switzerland, 0.17; U.K., 0.17
Non-OECD	6	0.34	Colombia, 0.23; India, 0.13; Malaysia, 0.34; South Korea, 0.39; Taiwan, 0.68; Turkey, 0.30
Post–World War II	38	0.18	
OECD	9	0.14	Denmark, 0.14; Finland, 0.14; Greece, 0.11; Iceland, 0.25, 0.12, 0.11, 0.18; Portugal. 0.10; Spain, 0.13
Non-OECD	29	0.19	Argentina, 0.10, 0.10, 0.16, 0.25; Brazil, 0.16; Chile, 0.14, 0.40, 0.33; Colombia, 0.10; India; 0.18; Malaysia, 0.12, 0.14, 0.12; Mexico, 0.16, 0.11; Peru, 0.18, 0.30; Singapore, 0.16, 0.12; South Korea, 0.37, 0.14; Turkey, 0.11; Uruguay, 0.10, 0.27, 0.22; Venezuela, 0.20, 0.22, 0.32, 0.15

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Calculations are based on appendix table C1. Data for war periods include noncombatants. C represents real per capita personal consumer expenditure.

1945 (World War II). There were also four crises indicated by GDP, the largest a remarkable 74 percent in 1946, reflecting the economic collapse late in World War II.

Many other countries suffered sharp contractions during World War II. For example, C declined in Belgium by 53 percent up to 1942, in Greece by 64 percent up to 1944, in Japan by 64 percent up to 1945, in the Netherlands by 55 percent up to 1944, and in Taiwan by 68 percent up to 1945. Other noteworthy cases for C were the contractions in Spain during its

Table 7. Summary of GDP Disasters by Event or Period and Country Group[a]

Period and country group	*No. of events*	*Average fractional decline in GDP*	*Fractional decline in GDP by country*
Pre-1914	45	0.16	
OECD	19	0.15	Australia, 0.27; Canada, 0.12; Finland, 0.12; France, 0.10, 0.10, 0.13; Greece, 0.11, 0.15, 0.23, 0.15, 0.14, 0.42; Iceland, 0.12; New Zealand, 0.17, 0.11; Spain, 0.12; Switzerland, 0.16; U.S., 0.10, 0.10
Non-OECD	26	0.17	Argentina, 0.19, 0.22, 0.15; Brazi, 0.10, 0.26, 0.14; Chile, 0.11; India, 0.15, 0.10; Malaysia, 0.10; Philippines, 0.16; Singapore, 0.21, 0.34; Sri Lanka, 0.16, 0.14; Taiwan, 0.21, 0.11; Uruguay, 0.27, 0.15, 0.14, 0.20, 0.16, 0.12; Venezuela, 0.24, 0.22, 0.13
World War I	27	0.21	
OECD	14	0.24	Australia, 0.12; Austria, 0.38; Belgium, 0.48; Denmark, 0.16; Finland, 0.35; France, 0.29; Germany, 0.36; Greece, 0.18; Iceland, 0.22; Netherlands, 0.26; New Zealand, 0.11; Norway, 0.15; Sweden, 0.15; Switzerland, 0.19
Non-OECD	13	0.17	Argentina, 0.29; Chile, 0.10, 0.13; India, 0.15; Mexico, 0.12; Philippines, 0.12; Singapore, 0.17, 0.24; South Africa, 0.23; South Korea, 0.11; Sri Lanka, 0.14; Uruguay, 0.28; Venezuela, 0.17
1920s	15	0.18	
OECD	11	0.16	Canada, 0.30; Germany, 0.14; Greece, 0.24; Iceland, 0.16; Italy, 0.22; New Zealand, 0.12; Norway, 0.11; Portugal, 0.11; Sweden, 0.11; U.K., 0.19; U.S., 0.12
Non-OECD	4	0.22	Singapore, 0.39; South Africa, 0.24; Turkey, 0.13; Uruguay, 0.14
Great Depression	22	0.22	
OECD	9	0.21	Australia, 0.22; Austria, 0.24; Belgium, 0.12; Canada, 0.35; France, 0.19; Germany, 0.28; Netherlands, 0.13; Spain, 0.10; U.S., 0.29

(continued)

Table 7. Summary of GDP Disasters by Event or Period and Country Group[a] (*Continued*)

Period and country group	*No. of events*	*Average fractional decline in GDP*	*Fractional decline in GDP by country*
Non-OECD	13	0.23	Argentina, 0.20; Brazil, 0.20; Chile, 0.36; Indonesia, 0.11; Malaysia, 0.19; Mexico, 0.31; Peru, 0.26; Philippines, 0.13; Singapore, 0.41; Sri Lanka, 0.15; Turkey, 0.12; Uruguay, 0.37; Venezuela, 0.16
Spanish civil war	2	0.23	
OECD	2	0.23	Portugal, 0.15; Spain, 0.31
Non-OECD	0	NA	
Late 1930s	3	0.12	
OECD	0	NA	
Non-OECD	3	0.12	Malaysia, 0.12; Singapore, 0.15; South Korea, 0.10
World War II	25	0.36	
OECD	14	0.37	Australia, 0.14; Austria, 0.59; Belgium, 0.45; Denmark, 0.24; Finland, 0.10; France, 0.41; Germany, 0.74; Greece, 0.66; Italy, 0.41; Japan, 0.50; Netherlands, 0.52; Norway, 0.19; Sweden, 0.10; Switzerland, 0.13
Non-OECD	11	0.35	India, 0.12; Indonesia, 0.54; Malaysia, 0.24, 0.36; Philippines, 0.57; South Korea, 0.48; Sri Lanka, 0.21; Taiwan, 0.66; Turkey, 0.40; Uruguay, 0.14; Venezuela, 0.16
Post–World War II	30	0.17	
OECD	6	0.13	Finland, 0.12; Iceland, 0.14; New Zealand, 0.12, 0.10; U.K., 0.15; U.S., 0.16
Non-OECD	24	0.17	Argentina, 0.10, 0.11, 0.14, 0.22; Brazil, 0.11; Chile, 0.24, 0.18; Indonesia, 0.16; Mexico, 0.13; Peru, 0.10, 0.14, 0.32; Philippines, 0.19; Singapore, 0.34, 0.11; South Africa, 0.11, 0.10; South Korea, 0.15; Uruguay, 0.12, 0.24, 0.19; Venezuela, 0.15, 0.30, 0.26

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Calculations are based on appendix table C2. Data for war periods include noncombatants.

civil war, by 46 percent up to 1937, and in Chile during the 1970s military takeover period, by 40 percent up to 1976.

U.S. studies often focus on the severity of the Great Depression; in fact, some researchers gauge disaster probabilities entirely from this single event.[16] One reason for this focus on the Depression is that the United States happened to do well economically during the two world wars, which were major economic disasters for much of the rest of the world, including many OECD countries. However, even if one's concern is limited to forecasting U.S. disasters or studying disaster probabilities as perceived by investors in the United States, it seems plausible that the global experience—particularly of comparable OECD countries—would provide a great deal of information. Our perspective is that U.S. prospects can be gauged much better by consulting the global experience, rather than overweighting the United States' own history, for which the few observed disasters are likely to be dominated by luck.

In a global context, at least since 1870, the most serious economic disaster in terms of incidence and severity of declines in C and GDP was World War II. This event was followed in terms of economic impact by World War I and the Great Depression of the early 1930s—two events with similar overall consequences.

Among the thirty-five countries included for C in appendix table C1, table 6 shows that World War II had twenty-three crises with an average size of 34 percent. (This table includes noncombatant experiences as part of the war periods.) World War I had twenty crises with an average size of 24 percent, and the Great Depression had eighteen crises with an average size of 21 percent. The 1920s had another eleven events, including eight with troughs in 1920–21, with an average size of 18 percent. As already mentioned, the contractions at the start of the 1920s may reflect the influenza epidemic of 1918–20.[17] We also found twenty-one pre-1914 events (for a truncated sample because of missing data) with an average size of 16 percent.

The post–World War II period was remarkably calm for the OECD countries: only nine consumption crises were found, four of which were in Iceland (relating in part to shocks to the fishing industry). The largest crisis outside of Iceland was 14 percent for Finland in the early 1990s (a crisis thought to originate from the changed economic relationship with the former Soviet Union). However, economic crises have not disappeared from

16. See, for example, Chatterjee and Corbae (2007) and Cogley and Sargent (2008).
17. Ursúa (2008).

the world, as is clear from the twenty-nine non-OECD consumption events with an average size of 19 percent. The disasters here include the Latin American debt crisis of the early 1980s, the Asian financial crisis of the late 1990s, and the difficulties in 2001–02 in Argentina related to the collapse of that country's currency board.

Table 7 provides a roughly similar picture for crises gauged by per capita GDP. For the thirty-nine countries included in appendix table C2, World War II had twenty-five events with an average size of 36 percent. World War I had twenty-seven events with a mean size of 21 percent, and the Great Depression had twenty-two cases with an average size of 22 percent. The 1920s had another fifteen events—ten of them with troughs in 1920–21—with a mean size of 18 percent. The pre-1914 period (where GDP events were more plentiful than those for consumer expenditure) showed forty-five events, with an average size of 16 percent. The post–World War II period featured only six events for the OECD; the largest were the post–World War II aftermaths for the United States (16 percent) and the United Kingdom (15 percent). Again, the situation was much less calm outside of the OECD: twenty-four events with an average size of 17 percent.

Consumer Durables

The consumption concept that enters into asset pricing equations would be closer to real consumer expenditure on nondurable goods and services (subsequently referred to as nondurables) than to overall consumer expenditure. That is, one might want to exclude durables outlays or, better yet, include an estimate of rental income on the slowly moving stock of durables. However, except for the OECD countries after World War II (which had few crises), we typically lack the data to divide personal consumer expenditure into durables and nondurables expenditure.

Table C3 in appendix C shows the twenty-eight cases among the C disasters from table C1 for which we have been able to locate data that permit a breakdown in the decline in real personal consumer expenditure into durables and nondurables. Twenty of these cases are in our main sample of ninety-five C crises. Not surprisingly, the proportionate decreases in durables expenditure were typically much larger than those in nondurables. On average for the twenty-eight crises, the proportionate fall in per capita C was 18.3 percent, that in durables was 39.6 percent, and that in nondurables was 15.1 percent. Thus, a substitution of nondurables expenditure for overall consumer expenditure would reduce the mean size of contraction among the twenty-eight cases by about 3 percentage points.

The main reason that the adjustment for durables has only a moderate, though significant, impact is that the share of nominal durables expenditure in total personal consumer expenditure is usually not large, averaging 8.0 percent at the peaks and 5.8 percent at the troughs for the twenty-eight cases considered in table C3.[18] As an extreme example, for the United Kingdom during World War II, the measured durables share fell to only 2.3 percent in 1943 (with household spending on automobiles falling to near zero). But since the durables share of nominal personal consumer expenditure at the peak in 1938 was only 4.9 percent, the adjustment was still only 2.5 percentage points; that is, the proportionate fall in nondurables was 14.4 percent, compared with 16.9 percent for all personal consumer expenditure.

The average durables adjustment of 3 percentage points likely overstates the overall effects. The reason is that we are systematically missing data on the breakdown between durables and nondurables for the larger crises: the mean contraction in C for the twenty-eight cases in table C3 was 18.3 percent, compared with a mean of 21.9 percent for the ninety-five C contractions used in our subsequent analysis. The largest C contractions in table C3 are 46 percent for Spain in 1935–37, 36 percent for Finland in 1913–18, 33 percent for Chile in 1981–85, and 32 percent for Venezuela in 1982–89.

Consider an arithmetic formula for the magnitude of the proportionate change in nondurables—this formula applies when durables and nondurables are both declining, with the size of the fractional decline in durables exceeding that in nondurables:

$$(1) \qquad \left|\frac{\Delta ND}{ND}\right| = \left|\frac{\Delta C}{C}\right| - \left(\frac{D}{ND}\right)\cdot\left[\left|\frac{\Delta D}{D}\right| - \left|\frac{\Delta C}{C}\right|\right],$$

where C is total consumer expenditure, D is durables expenditure, and ND is nondurables expenditure. We have already noted that the size of the adjustment is limited by the modest share of durables in total expenditure—this effect comes through the term D/ND.

An additional effect in equation 1 is that as we consider contractions with larger magnitude for $\Delta C/C$, the difference between the size of $\Delta D/D$ and that of $\Delta C/C$ must, at least eventually, get smaller. For example, the largest possible magnitude of $\Delta D/D$ is one. In this extreme situation, the amount of adjustment in switching to nondurables has to fall as the size of $\Delta C/C$ gets larger (with the adjustment approaching zero as the size of

18. The change in the nominal share of durables from peak to trough depends partly on the relative growth rates of real durables and nondurables and partly on the relative growth rates of prices of durables versus nondurables.

$\Delta C/C$ approaches one). This reasoning suggests that the durables adjustment would tend to be less important (in percentage points) for the larger crises—and these are the ones that matter most for replicating the equity premium in our later analysis. We do see this pattern in appendix table C3: for Spain in 1935–37 the adjustment is from 46.1 percent to 45.0 percent; for Finland in 1913–18 the adjustment is from 36.0 percent to 35.3 percent; and for Venezuela in 1982–89 the adjustment is from 32.0 percent to 29.9 percent. However, for Chile in 1981–85 the adjustment is much larger, from 32.7 percent to 17.9 percent.

In any event, we lack information in most cases on the breakdown of personal consumer expenditure into durables and nondurables. Although we may add a few cases, we will not be able to go much beyond the coverage shown in appendix table C3. Therefore, we apply the rest of our analysis to crises gauged by personal consumer expenditure, C, in appendix table C1, as well as to crises measured by GDP in appendix table C2.

Consumer Expenditure and GDP Disasters Compared

Table 8 matches C and GDP disasters for countries with full data (seventeen OECD and seven non-OECD). We match the C and GDP contractions in appendix tables C1 and C2, respectively, by trough years—either the same or a nearby year. In some cases a contraction by 0.10 or more in C or GDP does not pair up with a decline of at least 0.10 in the other variable (in which case the decline in the other variable does not appear in appendix table C1 or C2). In those cases we enter in table 8 the actual decline in the other variable (where, for a few cases, a negative value means that the variable increased).

Macroeconomists, particularly those familiar with U.S. data, tend to believe that proportionate contractions in consumer expenditure during recessions are typically smaller than those in GDP. Partly this view comes from the Great Depression, and the numbers in appendix tables C1 and C2 bear out this perspective: as an example, the proportionate declines in the United States up to 1933 were 21 percent for C and 29 percent for GDP. The idea that C is relatively more stable than GDP reflects also the general patterns in post–World War II macroeconomic fluctuations, including those in the United States. Since 1954, the standard deviation of the cyclical part of U.S. real GDP was 1.6 percent, compared with 1.2 percent for real consumer expenditure.[19] The main counterpart of the smoother behavior

19. Barro (2008, p. 185).

Table 8. Matched Consumer Expenditure and GDP Contractions[a]

OECD countries					*Non-OECD countries*				
	C		*GDP*			*C*		*GDP*	
Country	*Trough year*	*Size of contraction*	*Trough year*	*Size of contraction*	*Country*	*Trough year*	*Size of contraction*	*Trough year*	*Size of contraction*
Australia	*1918*	0.238	*1918*	0.118	Argentina	1891	0.123	1891	0.189
	1932	0.234	1931	0.221		1898	0.283	1897	0.219
	1944	0.301	*1946*	0.145		1900	0.195	1900	0.147
Belgium	*1917*	0.445	*1918*	0.477		1902	0.127	1902	0.049
	1934	0.092	1934	0.117		1907	0.123	1907	0.025
	1942	0.530	*1943*	0.453		1917	0.172	1917	0.289
Canada	1876	0.152	1878	0.117		1932	0.189	1932	0.195
	1908	0.113	1908	0.078		1959	0.101	1959	0.101
	1915	0.130	*1914*	0.095		*1982*	0.104	*1982*	0.111
	1921	0.196	1921	0.301		1990	0.160	1990	0.141
	1933	0.230	1933	0.348		2002	0.249	2002	0.220
Denmark	*1917*	0.074	*1918*	0.160	Brazil	1905	0.148	1904	0.040
	1921	0.241	1921	0.042		1909	0.157	1908	0.061
	1941	0.261	*1941*	0.239		1919	0.109	1918	0.044
	1948	0.144	1945	0.087		1921	0.147	1921	0.002
Finland	1892	0.102	1892	0.075		1931	0.201	1931	0.201
	1918	0.360	*1918*	0.353		1990	0.163	1992	0.110
	1932	0.199	1932	0.062	Chile	1903	0.048	1903	0.111
	1944	0.254	*1940*	0.103		1915	0.322	1915	0.105
	1993	0.140	1993	0.124		1922	0.181	1919	0.126
France	*1871*	0.158	*1870*	0.095		1932	0.374	1932	0.361
	1878	0.085	1879	0.102		1956	0.136	1956	0.038
	1884	0.085	1886	0.133		*1976*	0.401	*1975*	0.240
	1915	0.215	*1918*	0.289		1985	0.327	1983	0.180

(*continued*)

Table 8. Matched Consumer Expenditure and GDP Contractions[a] (*Continued*)

	OECD countries					*Non-OECD countries*			
	C		*GDP*			*C*		*GDP*	
Country	*Trough year*	*Size of contraction*	*Trough year*	*Size of contraction*	*Country*	*Trough year*	*Size of contraction*	*Trough year*	*Size of contraction*
	1936	0.062	1935	0.187	Mexico	*1916*	0.252	*1915*	0.119
	1943	0.580	*1944*	0.414		1924	0.118	1924	0.032
Germany	*1918*	0.425	*1919*	0.357		1932	0.311	1932	0.258
	1923	0.127	1923	0.135		1988	0.161	1988	0.128
	1932	0.121	1932	0.280		1995	0.113	1995	0.080
	1945	0.412	*1946*	0.736	Peru	1914	0.118	1914	0.019
Italy	1919	0.026	1920	0.221		1932	0.140	1932	0.258
	1945	0.286	*1945*	0.413		1979	0.179	1979	0.104
Japan	*1945*	0.639	*1944*	0.503		1983	0.075	1983	0.136
Netherlands	1893	0.098	1893	0.062		1992	0.300	1992	0.325
	1918	0.440	*1918*	0.258	S. Korea	1920	0.066	1919	0.111
	1935	0.045	1934	0.129		*1939*	0.068	*1939*	0.104
	1944	0.545	*1944*	0.525		*1945*	0.387	*1945*	0.480
Norway	*1918*	0.169	*1918*	0.148		*1952*	0.371	*1951*	0.151
	1921	0.161	1921	0.110		1998	0.143	1998	0.078
	1944	0.100	*1944*	0.193	Taiwan	*1905*	0.219	*1905*	0.214
Portugal	1919	0.215	1918	0.086		1911	0.127	1911	0.114
	1928	0.062	1928	0.109		*1945*	0.684	*1945*	0.662
	1936	0.121	1936	0.148					
	1942	0.104	1945	0.048					
	1976	0.098	1975	0.085					

Spain	1896	0.182	1896	0.119
	1915	0.128	1918	0.038
	1930	0.101	1933	0.096
	1937	0.461	*1938*	0.313
	1945	0.145	1945	0.084
	1949	0.131	1949	0.013
Sweden	1917	0.115	1918	0.150
	1921	0.132	1921	0.108
	1945	0.182	1941	0.095
Switzerland	1872	0.190	1870	0.052
	1878	0.225	1879	0.161
	1883	0.142	1883	0.065
	1886	0.141	1887	0.003
	1888	0.157	1887	0.003
	1918	0.108	1918	0.191
	1945	0.173	1942	0.126
United Kingdom	*1918*	0.167	*1918*	–0.022
	1921	0.005	1921	0.192
	1943	0.169	*1943*	–0.014
	1948	0.001	1947	0.148
United States	1908	0.037	1908	0.105
	1915	0.046	1914	0.095
	1921	0.164	1921	0.118
	1933	0.208	1933	0.290
	1947	0.001	1947	0.165

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. C represents real per capita personal consumer expenditure; GDP represents real per capita GDP. This table includes only the seventeen OECD countries and the seven non-OECD countries that are in our full samples for personal consumer expenditure, C, and GDP. Contractions of 0.10 or more come from tables C1 and C2 (with additions from underlying data for cases where C or GDP contractions were of magnitude less than 0.10). Contractions are matched by trough years (the same or nearby). Italics for trough year indicate participation as war combatant.

of C than of GDP was sharply fluctuating investment. That is, the steep declines in investment during U.S. recessions, including the Great Depression, partly buffered the decreases in consumer expenditure.[20] This buffering could also apply, in principle, to the current account balance; that is, a procyclical current account would moderate fluctuations in consumer spending (and investment) relative to those in GDP. However, in the post-1954 period, the ratio of the U.S. current account balance to GDP was actually weakly countercyclical.[21]

From a theoretical standpoint (and despite the validity of the permanent-income hypothesis), it is not inevitable that consumption would fluctuate proportionately by less than GDP. These patterns depend on whether the underlying macroeconomic shocks impinge more on investment demand or on desired saving. This balance depends, in turn, on the permanence of the shocks and whether they operate primarily as income effects or as shifts to the productivity of capital. In a simple AK model with i.i.d. shocks to the growth rate of productivity, A, consumption and GDP would always have the same proportionate variations.

An important consideration during wartime is the sharp increase in government purchases for the military. This expansion of government spending decreases C (and investment) for a given GDP.[22] In our data many of the C and GDP crises—and a disproportionate share of the larger crises—feature these wartime expansions of government spending. In such circumstances C would tend to decline proportionately by more than GDP.

Table 9, based on the matching of contractions shown in table 8, covers 112 contractions overall, 70 for OECD countries and 42 for non-OECD countries. Of the 112 contractions, 31 featured participation of the country as a war combatant and 81 did not (the label "nonwartime" in table 9 includes noncombatants during major wars). In the eighty-one nonwartime cases, the average proportionate decrease in C was slightly greater than that in GDP: 14.6 percent versus 12.9 percent (12.6 percent versus 12.4 percent for the OECD countries). In the thirty-one wartime cases, the margin was greater: 31.8 percent versus 27.2 percent (32.0 percent versus 27.6 percent for the OECD countries).

20. This pattern is stronger for consumption measured by expenditure on nondurables and services, that is, when expenditures on consumer durables are grouped with investment.

21. Barro (2008, p. 429).

22. The declines in consumption and investment could be moderated by falls in the current account balance. However, the option of borrowing from abroad tends to be severely limited during a global conflict. Moreover, even in localized conflicts, combatants are likely to be cut off from international borrowing.

Table 9. Means and Relative Timing of Matched Consumer Expenditure and GDP Contractions[a]

			Trough of C contraction occurred		
Events	*Mean C contraction*	*Mean GDP contraction*	*In same year as GDP contraction*	*Before GDP contraction*	*After GDP contraction*
OECD countries					
All (70 contractions)	0.190	0.174	35	19	16
Wartime (23)	0.320	0.276	10	9	4
Nonwartime (47)	0.126	0.124	25	10	12
Non-OECD countries					
All (42 contractions)	0.199	0.159	31	1	10
Wartime (8)	0.311	0.260	5	0	3
Nonwartime (34)	0.173	0.135	26	1	7
Full sample					
All (112 contractions)	0.194	0.168	66	20	26
Wartime (31)	0.318	0.272	15	9	7
Nonwartime (81)	0.146	0.129	51	11	19

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Means and timing are for the matched contractions listed in table 8.

In terms of timing patterns, table 9 shows for the full sample of 112 crises that 66 have the same trough years for C and GDP. The trough year for C comes later in twenty-six cases, whereas that for GDP comes later in twenty cases. Thus, at least in the annual data, there is no clear pattern as to whether C or GDP reaches its trough first during crises. If we consider only wartime cases, fifteen of the thirty-one have the same trough year, whereas C reaches its trough later in seven and GDP reaches its trough later in nine. Thus, there is also no clear result on the timing pattern during wars.

One concern is that the apparent excess of the average size of C contractions over GDP contractions might reflect greater measurement error in the C data. In future formal statistical analysis of the C and GDP time series, we will allow for measurement error that might differ across countries, over time, and between the C and GDP data. For now we can get some idea about the role of measurement error by redoing the analysis using trend values of log(C) and log(GDP) calculated from HP filters. We use a conventional smoothing parameter for annual data of 100. Unlike in the standard setup, we use one-sided filters; that is, we consider only current and past values at each point in time when estimating "trends." (This procedure avoids the implication that people knew in advance of a coming destructive war or depression, so that they knew that a major decline in trend C or GDP was about to happen.) Instead of computing proportionate peak-to-trough decreases in C or GDP during crises, we calculate here the proportionate peak-to-trough decreases in the HP trend values. This procedure downplays short-lived contractions and tends to count only the more persistent declines. It also tends to filter out downturns that are merely a response to a previous upward blip in C or GDP. Most important in the present context, the HP filter tends to eliminate "crises" that reflect mainly temporary measurement error in C and GDP.

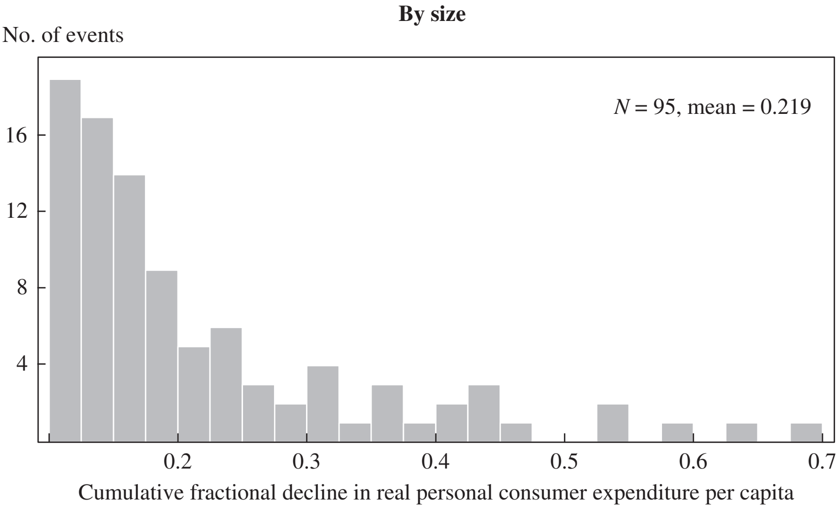
The HP filtering procedure substantially reduces the estimated number of disasters, from 95 to 43 for C and from 152 to 70 for GDP. The full results are presented in tables C4 and C5 in appendix C. We matched the C and GDP crises, as before, and found thirty nonwartime pairs (seventeen in OECD countries and thirteen in non-OECD countries) and twenty-three wartime pairs (nineteen in OECD countries and four in non-OECD countries), the wartime pairs indicated by italics in tables C4 and C5. In the nonwartime sample, the average size of C decline was 12.0 percent, compared with 14.0 percent for GDP (8.8 percent and 13.4 percent, respectively, for the OECD countries). In the wartime sample, the mean size of C decline was 28.9 percent, compared with 23.8 percent for GDP (27.4 percent and 21.7 percent, respectively, for the OECD countries). Thus, the HP-filtered data generate wartime patterns that are similar to those found before: the average C decline was larger than that for GDP. However, the findings for nonwartime samples are reversed, with the average C decline smaller than that for GDP. Thus, overall, the main robust finding is that C tends to fall proportionately more than GDP during wartime crises. The relative magnitude of decline during nonwartime crises is less clear.

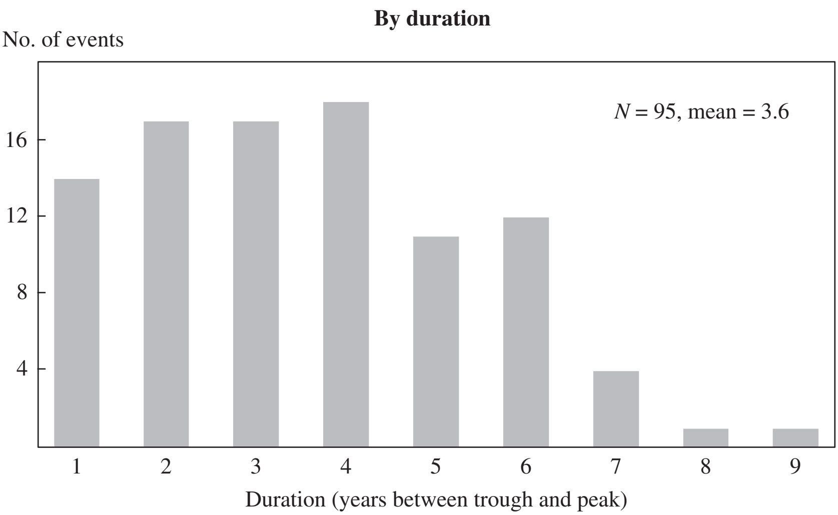
Disaster Probability and the Frequency Distribution of Disaster Sizes

This section considers the sample of countries with essentially complete annual time series since before 1914. We use twenty-four countries (including seventeen OECD countries) on per capita consumer expenditure, C, and thirty-six countries (including twenty-one OECD countries) on per capita GDP.[23] For the C sample of twenty-four countries, we isolated ninety-five disasters (appendix table C1). The top panel of figure 1

23. We include Greece and the Philippines in the GDP sample. Although GDP data are missing for Greece in 1944 and for the Philippines in 1941–45, we can compute the peak-to-trough GDP declines during World War II in each case: 66 percent for Greece from 1939 to 1942 and 57 percent for the Philippines from 1939 to 1946.

Figure 1. Distributions of Consumer Expenditure Disasters by Size and Duration[a]





Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. The sample is our main sample of ninety-five personal consumption expenditure disasters from appendix table C1.

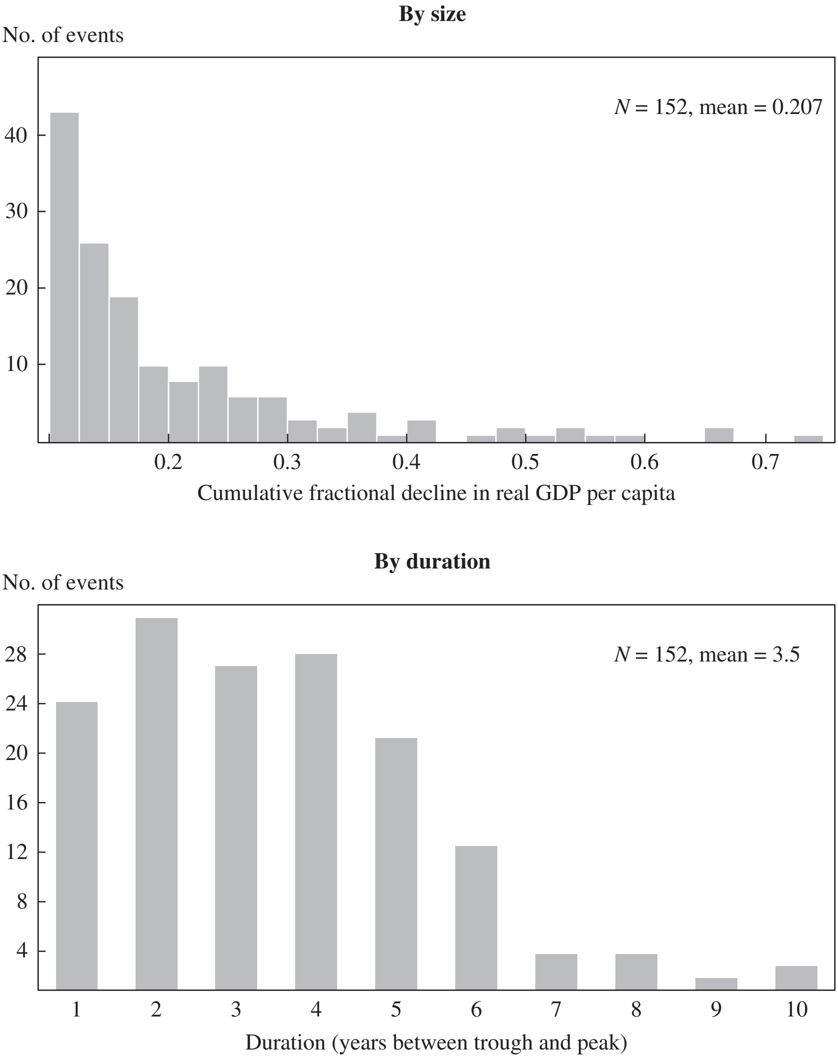
plots the frequency distribution of these C declines. The bottom panel shows the frequency distribution of the duration of these disasters (gauged, in each case, by the number of years from "peak" to "trough"). The average size was 22 percent, and the average duration was 3.6 years. For the GDP sample of thirty-six countries, we found 152 disasters (appendix table C2). The top panel of figure 2 plots the frequency distribution of these GDP declines, and the bottom panel shows the frequency distribution of the disaster durations. The average size was 21 percent, and the average duration was 3.5 years. Appendix figures D1 and D2 show the frequency distribution graphs for C and GDP corresponding to the HP-filtered data. The mean disaster sizes are very similar to the nonfiltered cases (22 percent for GDP and 23 percent for C), but average durations are longer because of the smoothing procedure (6.4 years for GDP and 6.3 years for C).

In our subsequent simulation of a model of the equity premium, using the disaster data to calibrate the model, the results depend mainly on the probability of disaster, p, and the frequency distribution of the proportionate disaster size, b. With substantial risk aversion, the key aspect of the size distribution is not so much the mean of b but, rather, the fatness of the tails, that is, the likelihood of extremely large disasters.

Suppose that there are two states, normalcy and disaster. With probability p per year (taken here to be constant over time and across countries), the economy shifts from normalcy to disaster. With another probability π per year (also constant over time and across countries), the economy shifts from disaster to normalcy. As mentioned before, we found 95 disasters for C and 152 for GDP. Also as noted before, we measured disaster years by the interval between peak and trough for each event. This calculation yields 343 disaster years for C and 530 disaster years for GDP. The total number of annual observations is 2,963 for C and 4,653 for GDP. Therefore, the number of normalcy years is 2,620 for C and 4,123 for GDP. We estimate p as the ratio of the number of disasters to the number of normal years. This calculation yields $p = 0.0363$ for C and 0.0369 for GDP.[24] We estimate π as the ratio of the number of disasters (all of which eventually ended) to the number of disaster years. This computation gives $\pi = 0.277$ for C and 0.287 for GDP. Therefore, whether we gauge by C or by GDP, we can think of disasters as starting with a probability of around 3.6 percent a year and ending with a probability of about 28 percent a year.

24. The main reason that these disaster probabilities exceed those in Barro (2006) is the inclusion of disaster sizes between 0.10 and 0.15. If we consider only disasters of 0.15 or greater, the probabilities are $p = 0.0218$ for C and 0.0192 for GDP.

Figure 2. Distributions of GDP Disasters by Size and Duration[a]



Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. The sample is our main sample of 152 GDP disasters from appendix table C2.

The frequency distributions for disaster size, *b,* shown for C and GDP, respectively, in the upper panels of figures 1 and 2, turn out to be well approximated by Pareto or power-law forms. These representations have been found to apply to an array of economic and physical phenomena, including amounts of stock-price changes and sizes of cities and firms.[25] We plan to work out the application of power-law distributions to disaster sizes in future research.

A Lucas-Tree Model of Rates of Return

The estimates of p and the b distribution can be matched with rates of return determined in a representative-agent Lucas-tree setting.[26] Our theoretical framework, summarized briefly here, follows that in a forthcoming paper by Barro, which extends his 2006 paper to use the Epstein-Zin-Weil (EZW) form of consumer preferences.[27] That is, we allow for two distinct preference parameters: γ, the coefficient of relative risk aversion, and θ, the reciprocal of the intertemporal elasticity of substitution (IES).

We set up the model, for convenience, in terms of discrete periods. However, the formulas derived later apply as the length of the period approaches zero. The log of real GDP evolves exogenously as a random walk with drift:

$$\log\left(Y_{t+1}\right) = \log\left(Y_t\right) + g + u_{t+1} + v_{t+1}. \quad (2)$$

The first random term, u_{t+1}, is i.i.d. normal with mean zero and variance σ^2. This term reflects "normal" economic fluctuations due, for example, to productivity shocks. The parameter $g \geq 0$ is a constant that reflects exogenous productivity growth. Population is constant, so Y_t represents per capita GDP as well as the level of GDP.

The second random term, v_{t+1}, picks up rare disasters, as in Rietz's earlier work and Barro's 2006 paper.[28] In these rare events, output and consumption jump down sharply. The probability of a disaster is the constant $p \geq 0$ per unit of time. In a disaster, output and consumption contract by the fraction b, where $0 < b < 1$. The distribution of v_{t+1} is given by

25. See Mandelbrot (1963), Fama (1965), and Gabaix (1999).
26. Lucas (1978).
27. Epstein and Zin (1989); Weil (1990).
28. Rietz (1988); Barro (2006).

$$\text{probability } 1 - p\text{: } v_{t+1} = 0$$
$$\text{probability } p\text{: } v_{t+1} = \log(1 - b).$$

The disaster size, *b,* follows some probability distribution, which we gauge by the empirical densities shown in figures 1 and 2.

In the baseline Lucas-tree setting—a closed economy with no investment and no government purchases—the representative agent's consumption, C_t, equals output, Y_t.[29] Given the processes that generate u_{t+1} and v_{t+1}, the expected growth rate of C_t and Y_t, denoted by g^*, is given by

$$g^* = g + (1/2)\sigma^2 - p \cdot \mathrm{E}(b), \tag{3}$$

where E(b) is the expected value of b. (Note that we have allowed for disasters but not for "bonanzas.")

A key simplification, which allows for closed-form solutions, is that the shocks u_{t+1} and v_{t+1} in equation 2 are i.i.d.; that is, they represent permanent effects on the level of output, rather than transitory disturbances to this level. An important part of our ongoing research is to reassess this i.i.d. assumption, in particular to allow for transitory effects from disasters, such as wars and financial crises. (Another important extension, needed to match the observed volatility of stock prices and rates of return, is to allow for time variation in the uncertainty parameters, particularly the disaster probability, p.)

In general, EZW preferences do not yield closed-form solutions for asset pricing equations. However, Barro shows that with i.i.d. shocks (as in the present model), the first-order optimizing conditions generate asset pricing equations of familiar form:[30]

$$C_t^{-\gamma} = \left(\frac{1}{1+\rho^*}\right) \cdot \mathrm{E}_t\left(R_t \cdot C_{t+1}^{-\gamma}\right), \tag{4}$$

where R_t is the one-period gross return on any asset. This specification differs from the standard power-utility model ($\gamma = \theta$) in that, first, the exponent on consumption is the negative of the coefficient of relative risk aversion,

29. We can readily incorporate wartime-related government purchases, G_t, which do not substitute for C_t in household utility but do create a wedge between Y_t and C_t. In this case an increase in G_t amounts to a decrease in productivity. Results on asset returns are similar in an AK model with endogenous investment and stochastic (i.i.d.) depreciation shocks; see Barro (forthcoming). In this setting, a disaster amounts to a large-scale destruction of Lucas trees.

30. Barro (forthcoming).

γ (not θ), and second, the effective rate of time preference, ρ^*, differs from the usual rate of time preference, ρ, when $\gamma \neq \theta$. The formula for ρ^* is

$$\rho^* = \rho - (\gamma - \theta) \cdot \left\{ g^* - (1/2) \cdot \gamma\sigma^2 - \left(\frac{p}{\gamma - 1} \right) \cdot \left[\mathrm{E}(1-b)^{1-\gamma} - 1 - (\gamma - 1) \cdot \mathrm{E}(b) \right] \right\}, \tag{5}$$

where E is the expectations operator and g^* is the expected growth rate given in equation 3.

The formulas for the expected rate of return on equity (unlevered claims to Lucas trees), r^e, and the risk-free rate, r^f, can be derived from equation 4, given the process that generates Y_t and C_t in equation 2. The results are

$$r^e = \rho^* + \gamma g^* - (1/2) \cdot \gamma \cdot (\gamma - 1) \cdot \sigma^2 - p \cdot \left[\mathrm{E}(1-b)^{1-\gamma} - 1 - (\gamma - 1) \cdot \mathrm{E}(b) \right] \tag{6}$$

$$r^f = \rho^* + \gamma g^* - (1/2) \cdot \gamma \cdot (\gamma + 1) \cdot \sigma^2 - p \cdot \left[\mathrm{E}(1-b)^{-\gamma} - 1 - \gamma \cdot \mathrm{E}(b) \right]. \tag{7}$$

Hence, the equity premium can be expressed as

$$r^e - r^f = \gamma\sigma^2 + p \cdot \mathrm{E}\left\{ b \cdot \left[(1-b)^{-\gamma} - 1 \right] \right\}, \tag{8}$$

which depends only on γ and the uncertainty parameters (σ, p, and the distribution of b). The first term, $\gamma\sigma^2$, is negligible and corresponds to the no-disaster equity premium of Mehra and Prescott.[31] The second term brings in disasters and is proportional to the disaster probability, p. The disaster size, b, enters as the expectation of the product of b (the proportionate decline in consumption) and the proportionate excess of the "marginal utility of consumption"[32] in a disaster state, $[(1 - b)^{-\gamma} - 1]$. This second term tends to be large.

The formulas for rates of return and the equity premium in equations 6 through 8 depend on a number of assumptions. The baseline model assumes that property rights in assets are perfectly maintained; in particular, there

31. Mehra and Prescott (1985).

32. This interpretation would be precise for power utility ($\gamma = \theta$).

are no possibilities for default on stocks or risk-free claims. The analysis can be extended to allow for partial defaults during crises.[33] Aside from formal repudiation of claims, default can involve erosion of the real value of nominal claims through surprise jumps in the price level. This type of default tends to apply to government bills and bonds (which are typically denominated in nominal terms), rather than stocks. If one interprets the "risk-free" claim as a government bill, then a higher probability of default on bills, conditional on a crisis, lowers the equity premium in a revised version of equation 8.

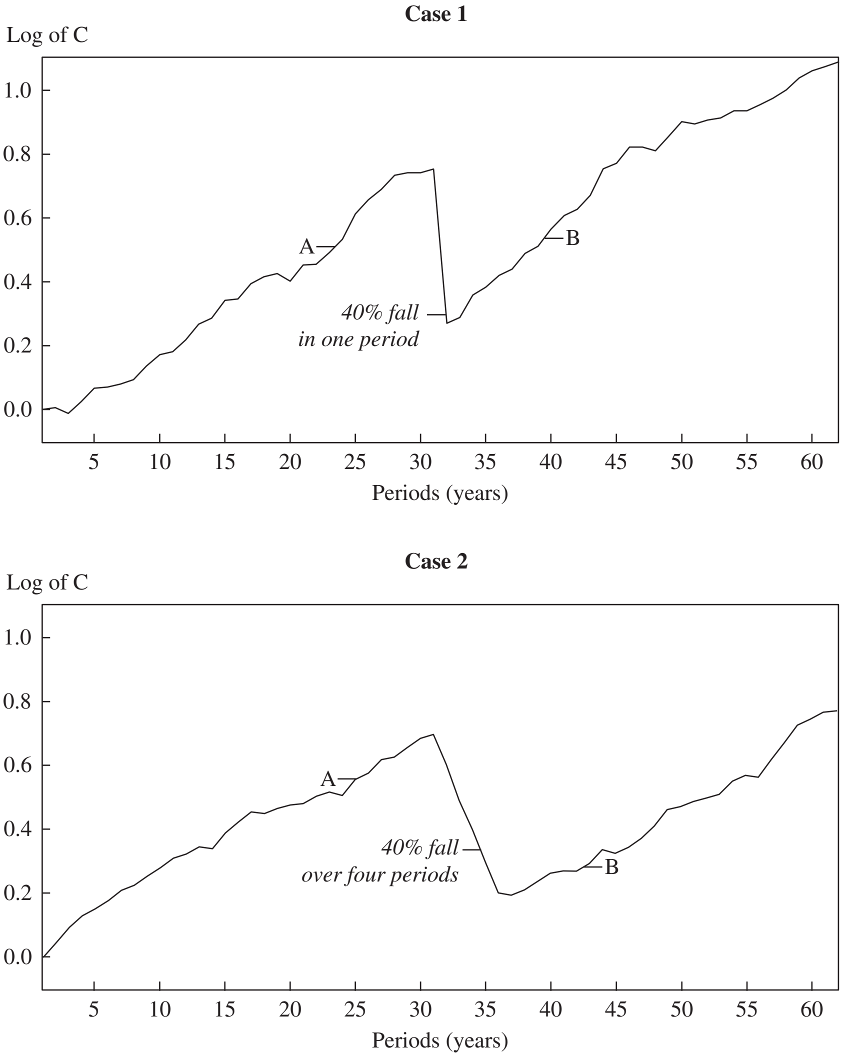
The model also neglects government rationing of consumption during crises, notably wars. Rationing can be viewed as a tax on consumption in crisis states. The more effective the system, in the sense of precluding black markets, the higher the effective tax rate on consumption beyond some rationed quantity; thus, a fully enforced rationing system has an infinite tax rate at the margin. (In practice, the situation is complicated because the rationing and hence the tax are likely to be temporary, lapsing once the crisis is over.) Rationing can be viewed as a form of partial default on assets, as above, but one that applies equally to gross returns on stocks and bills. Therefore, although rationing tends to lower the equity premium in an extended version of equation 8, the effects are weaker than those from crisis-contingent defaults that apply only to bills.

Another issue for empirical implementation is that the model does not deal with the duration of disaster states; a disaster is a jump that takes place in one period, which amounts to an instant of time. Our research with Nakamura and Steinsson will deal explicitly with the time evolution of the economy during disaster states. For present purposes we assume that the important aspect of a disaster is the cumulative amount of contraction, *b,* which we gauge empirically by the numbers shown for C and GDP, respectively, in appendix tables C1 and C2. That is, we assume that, for a given cumulative decline, the implications for the equity premium do not depend a great deal on whether this decline occurs in an instant or, more realistically, is spread out over time.

To illustrate our assumption, figure 3 depicts two possible time paths for the log of C. Each case has two normalcy intervals, denoted A and B. These paths reflect growth at 0.025 per year and (different) realizations of normal shocks with a standard deviation, σ, of 0.02 per year—these parameters apply in our subsequent simulations. In each case a single disaster event with a cumulative fractional decline in C by 0.4 happens to occur

33. See Barro (2006).

Figure 3. Paths of Consumption with Different Durations of Crises[a]



Source: Authors' calculations.

a. In case 1 a crisis entails a 40 percent decline in C over one period. In case 2 a crisis entails a 40 percent decline in C stretched over four periods. The normalcy periods (A and B in each panel) are generated by assuming mean growth of 0.025 per year with normally distributed shocks that have a standard deviation of 0.02 per year. The paths shown, meant only to be illustrative, reflect different realizations of random numbers in each case.

in the middle of the sample. We are unsure at present how to model disaster states that last for more than an instant. The mean growth rate is likely to be much lower than normal, and the volatility is likely to be much higher than normal. In figure 3 the only difference between the two cases is that the fractional decline by 0.4 for the disaster in case 1 occurs over one period (which could be one year or one second), whereas that in case 2 stretches over four periods. The graphs assume, unrealistically, that crises have the usual amount of volatility—that is, normal shocks with $\sigma = 0.02$ per year.

Our key assumption is that the determination of expected rates of return during normalcy periods (A and B in the two panels of figure 3) is roughly the same whether disasters look like case 1 or case 2. This conclusion holds in an extension of the model pursued in Barro's 2006 paper,[34] which assessed the effects of variations in the period length T. (This extension was feasible in a model with i.i.d. growth shocks.) In that setting T represents the fixed duration of a disaster. Variations in T between zero and 5 years did not have much impact on the implied equity premium (measured per year).

In practice, the normalcy rates of return would not be exactly the same in cases 1 and 2 of figure 3. For example, case 2 implies low, perhaps negative short-term risk-free rates during crises and, therefore, capital gains on longer-term risk-free bonds when a crisis starts. This pattern has implications for the term structure of risk-free rates during normal times. However, a different specification—one where disasters entail higher than usual chances of default on bonds—predicts capital losses, rather than gains, on longer-term bonds when a crisis occurs. Because of this ambiguity, we are unable at this stage to go beyond our assumption that cases 1 and 2 are approximately the same for the equity premium.

Simulating the Lucas-Tree Model

We now simulate the Lucas-tree model by viewing the Euler condition in equation 4 as applying to a representative agent at the country level. That is, we neglect the implications of imperfect markets and heterogeneous individuals within countries. However, we also assume that markets are not sufficiently complete internationally for equation 4 to apply to the representative agent in the world. In future work we will assess how the analysis applies to multiple-country regions, rather than country by country.

In applying equation 4 to the determination of each country's asset returns, we neglect any implications from international trade in goods and

34. Barro (2006, section V).

assets; that is, we effectively treat each country as a closed economy. With this perspective, we can view each country-period observation as providing independent information about the relationship between macroeconomic shocks and asset returns. In particular, this independence may be approximately right despite the clear common international dimensions of crises—most obviously from wars but also from financial crises, disease epidemics, and natural resource shocks.

We apply the full historical information on disaster probability and sizes to the simulation at each point in time. Thus, we implicitly assume that the underlying parameters are fixed over time and across countries and are known from the outset to the representative agent in each country. We therefore neglect learning about disaster parameters.[35]

We focus on the model's implications for the expected rate of return on equity, r^e, and the risk-free rate, r^f, and hence for the equity premium. As it stands, the model is inadequate for explaining the volatility of asset prices, including stock prices. For example, the model unrealistically implies a constant price-dividend ratio and a constant risk-free rate. The most promising avenue for extending the model to fit these features—including the high volatility of stock returns—is to allow for shifting uncertainty parameters, notably the disaster probability, p. This possibility is explored in a recent paper by Xavier Gabaix; his results suggest that the extended model can explain volatility patterns without much affecting the implications for expected rates of return, including the equity premium. In a related vein, Ravi Bansal and Amir Yaron have pursued the consequences of shifting expected growth rates, g^*.[36]

The calibrations of the model follow those in the forthcoming paper by Barro. We set the expected normal growth rate, g, at 0.025; the standard deviation of normal fluctuations, σ, at 0.02; and the reciprocal of the intertemporal elasticity of substitution, θ, at 0.5.[37] These choices of parameters either do not affect the equity premium (g and θ) or have a negligible impact (σ). The rate of time preference, ρ, also does not affect the equity premium. However, ρ (along with g, σ, and θ) affects levels of rates of return, including the risk-free rate, r^f (see equations 6 and 7). Given the lack of useful outside information on ρ, we set ρ^* in equation 7 to generate $r^f = 0.01$—roughly the long-run average across countries of real rates of

35. This issue is stressed by Weitzman (2007).

36. Gabaix (2008); Bansal and Yaron (2004).

37. For a discussion of the choice of θ, including the problematic nature of estimates computed from macroeconomic time series, see Barro (forthcoming).

return on bills from table 5.[38] Then ρ takes on the value needed to satisfy equation 5.

The calibrations for the disaster probability, p, and the frequency distribution of disaster sizes, b, use our multicountry study of disaster events. We can then determine the value of γ needed in equation 8 to replicate an unlevered equity premium of around 0.05—the long-run average across countries implied by the data in table 5. Since we always have $r^f = 0.01$, an unlevered equity premium of 0.05 corresponds to an expected rate of return on unlevered equity, r^e, of 0.06.

Table 10 reports results of our simulation for crises gauged by C, and table 11 for those gauged by GDP. For baseline cases, which encompass 95 observations of C crises and 152 observations of GDP crises, a coefficient of relative risk aversion, γ, of 3.5 gets the simulated results into the right ballpark for the observed equity premium: specifically, $r^e = 0.059$ in the C case and 0.067 in the GDP case. The respective rates of time preference, ρ, are 0.045 and 0.052, and the corresponding effective rates of time preference, ρ*, are 0.029 and 0.037.

The results are sensitive to the choice of γ. For example, the second lines of tables 10 and 11 show that if $\gamma = 3.0$, the values for r^e fall to 0.042 in the C case and 0.045 in the GDP case.

The results are not very different if the sample encompasses only the OECD countries, in which case the number of C disasters falls from 95 to 57, and the number of GDP disasters falls from 152 to 75. The equity premium is still in the right ballpark with $\gamma = 3.5$ (or slightly higher for C crises).

The results do not change greatly if we truncate the b distribution to eliminate smaller crises. Tables 10 and 11 show the results when, instead of $b \geq 0.10$, we admit only $b \geq 0.15$, $b \geq 0.20$, $b \geq 0.30$, or $b \geq 0.40$. Even when $b \geq 0.40$, which leaves only eleven C crises and fourteen GDP crises, r^e is still at 0.047 in the case of C and 0.054 in the case of GDP. Thus, the larger crises are crucial for getting the equity premium into the right ballpark with a "reasonable" amount of risk aversion, such as $\gamma = 3.5$.

This reasoning also applies when we examine nonwartime samples, a selection that eliminates the biggest crises from the sample. (We define "war" as applying only to active combatants.) For C crises, the consideration of a nonwartime sample—which retains sixty-six of the original

38. Real rates of return on treasury bills and similar assets are not risk-free and tend particularly to be lower than normal during crises that involve high inflation (see the section on "Asset Returns during Crises" below). Thus, r^f may be lower than 0.01. However, pegging to a lower value of r^f would not affect our analysis of the equity premium.

Table 10. Results of the Simulated Model Based on Consumer Expenditure Disasters[a]

Specification	No. of disasters	No. of disaster-years	Probabilities[c]		Moments of disaster size[d]			Time preference[e]		Rate of return[f] r^e
			p	π	$E(b)$	$E(1-b)^{-\gamma}$	$E(1-b)^{1-\gamma}$	ρ	ρ^*	
Baseline[b]	95	343	0.0363	0.277	0.219	3.88	2.34	0.045	0.029	0.059
$\gamma = 3.0$	95	343	0.0363	0.277	0.219	2.96	1.90	0.029	0.008	0.042
OECD	57	214	0.0286	0.266	0.223	3.87	2.37	0.034	0.007	0.048
Non-OECD	38	129	0.0604	0.295	0.214	3.89	2.29	0.080	0.100	0.095
$b \geq 0.15$	59	252	0.0218	0.234	0.278	5.28	2.92	0.042	0.018	0.057
$b \geq 0.20$	36	163	0.0129	0.221	0.345	7.41	3.75	0.038	0.007	0.054
$b \geq 0.30$	20	99	0.0070	0.202	0.431	11.25	5.17	0.035	–0.003	0.051
$b \geq 0.40$	11	60	0.0038	0.183	0.506	16.90	7.07	0.031	–0.015	0.047
Nonwartime	66	208	0.0240	0.317	0.168	2.01	1.63	0.004	–0.051	0.016
Nonwartime, $\gamma = 9$	66	208	0.0240	0.317	0.168	7.70	5.87	0.037	–0.038	0.053
HP-filtered	43	271	0.0167	0.159	0.232	3.68	2.35	0.016	–0.030	0.030
HP-filtered, $\gamma = 4.5$	43	271	0.0167	0.159	0.232	6.18	3.68	0.034	–0.012	0.050

Source: Model simulations by the authors.

a. Unless otherwise specified, the coefficient of relative risk aversion, γ, is set at 3.5; and the threshold for the disaster size, b, at 0.10. Calibrated parameters common to all specifications are as follows: expected normal growth rate $g = 0.025$; standard deviation of normal fluctuations $\sigma = 0.02$; reciprocal of intertemporal elasticity of substitution $\theta = 0.5$, as discussed in the text. The risk-free rate r^f is 0.01 in all cases.

b. Sample consists of all C disasters for the twenty-four included countries from table C1 in appendix C.

c. p is the estimated probability per year of moving from normalcy to disaster, and π the estimated probability per year of moving from disaster to normalcy.

d. $E(b)$ is the mean disaster size; $E(1-b)^{-\gamma}$ and $E(1-b)^{1-\gamma}$ are, respectively, the mean values of these key determinants of the equity premium, from equation 8 in the text.

e. ρ is the rate of time preference and ρ^* is the effective rate of time preference given in equation 5; values are chosen to generate $r^f = 0.01$ in equation 7.

f. Overall expected rate of return on unlevered equity, from equation 6.

Table 11. Results of the Simulated Model Based on GDP Disasters[a]

Specification	No. of disasters	No. of disaster-years	Probabilities		Moments of disaster size			Time preference		Rate of return r^e
			p	π	$E(b)$	$E(1-b)^{-\gamma}$	$E(1-b)^{1-\gamma}$	ρ	ρ^*	
Baseline[b]	152	530	0.0369	0.287	0.207	4.03	2.31	0.052	0.037	0.067
$\gamma = 3.0$	152	530	0.0369	0.287	0.207	2.99	1.86	0.032	0.010	0.045
OECD	75	263	0.0287	0.285	0.221	4.96	2.60	0.057	0.039	0.073
Non-OECD	77	267	0.0509	0.288	0.194	3.13	2.04	0.043	0.033	0.057
$b \geq 0.15$	83	320	0.0192	0.259	0.278	6.08	3.09	0.048	0.022	0.063
$b \geq 0.20$	54	229	0.0122	0.236	0.338	8.31	3.90	0.045	0.014	0.061
$b \geq 0.30$	24	115	0.0053	0.209	0.453	15.32	6.23	0.041	0.001	0.057
$b \geq 0.40$	14	69	0.0031	0.203	0.532	23.13	8.63	0.038	–0.007	0.054
Nonwartime	112	370	0.0261	0.303	0.168	2.02	1.64	0.005	–0.048	0.017
Nonwartime, $\gamma = 9$	112	370	0.0261	0.303	0.168	7.91	6.01	0.042	–0.018	0.059
HP-filtered	70	446	0.0174	0.160	0.224	4.08	2.42	0.022	–0.022	0.036
HP-filtered, $\gamma = 4.0$	70	446	0.0174	0.160	0.224	5.55	3.09	0.035	–0.008	0.050

Source: Model simulations by the authors.

a. See the notes to table 10 for discussion and definitions.

b. Sample consists of all GDP disasters for the thirty-six included countries from table C2 in appendix C.

ninety-five disasters—yields $r^e = 0.016$. For GDP crises, with 112 of the original 152 disasters retained, the result is $r^e = 0.017$. Getting into the right ballpark here for the equity premium requires a much higher coefficient of relative risk aversion, γ. For example, tables 10 and 11 show that $\gamma = 9$ yields $r^e = 0.053$ for C and 0.059 for GDP.

As discussed before, we redid the analysis using trend values of log(C) and log(GDP) calculated from HP filters. As already noted, this method captures in an informal way the idea that crises may have less than permanent effects on levels of C and GDP. Tables 10 and 11 show that the HP filtering reduces the number of C disasters from 95 to 43 and of GDP disasters from 152 to 70. Correspondingly, the estimated disaster probabilities fall from 0.0363 to 0.0167 for C and from 0.0369 to 0.0174 for GDP. However, the size distributions of the crises are not so different from the baseline cases. For C crises the mean of b is 0.232, rather than 0.219, and for GDP the mean is 0.224, rather than 0.207. Hence, the HP filtering decreases the number of disasters but slightly raises the average size, contingent on the occurrence of a disaster.

If we again use a coefficient of relative risk aversion, γ, of 3.5, the HP filtering lowers the computed r^e to 0.030 for the C case and to 0.036 for the GDP case. However, γ does not have to increase very much to restore a reasonable equity premium. For example, for C crises, $\gamma = 4.5$ yields $r^e = 0.050$, whereas for GDP crises, $\gamma = 4$ yields $r^e = 0.050$.

In terms of broad patterns, the results based on C in table 10 deliver results for the equity premium that are similar to those based on GDP in table 11. On the one hand, this finding suggests a certain robustness, in that the results are not sensitive to measurement differences in these two main macroeconomic aggregates. On the other hand, it means that fitting the equity premium does not depend on our efforts in measuring consumer expenditure and thereby getting closer to measures of consumption.

Overall, the simulations in tables 10 and 11 show that the model delivers reasonable equity premia with "plausible" coefficients of relative risk aversion for a variety of specifications. The main lack of robustness applies to elimination of the biggest crises from the sample, for example, by removing the war-related crises.

Asset Returns during Crises

In our Lucas-tree model of asset returns, crises feature downward jumps in C and GDP at a point in time. More realistically, they fall gradually during crises of varying lengths, as suggested by figure 3. In our empirical analysis, we approximated the crisis declines in C and GDP by cumulative fractional amounts over peak-to-trough intervals, as shown in appendix tables C1 and C2 and figures 1 and 2. Now we carry out a preliminary analysis that considers observed returns during crises on stocks and bills.

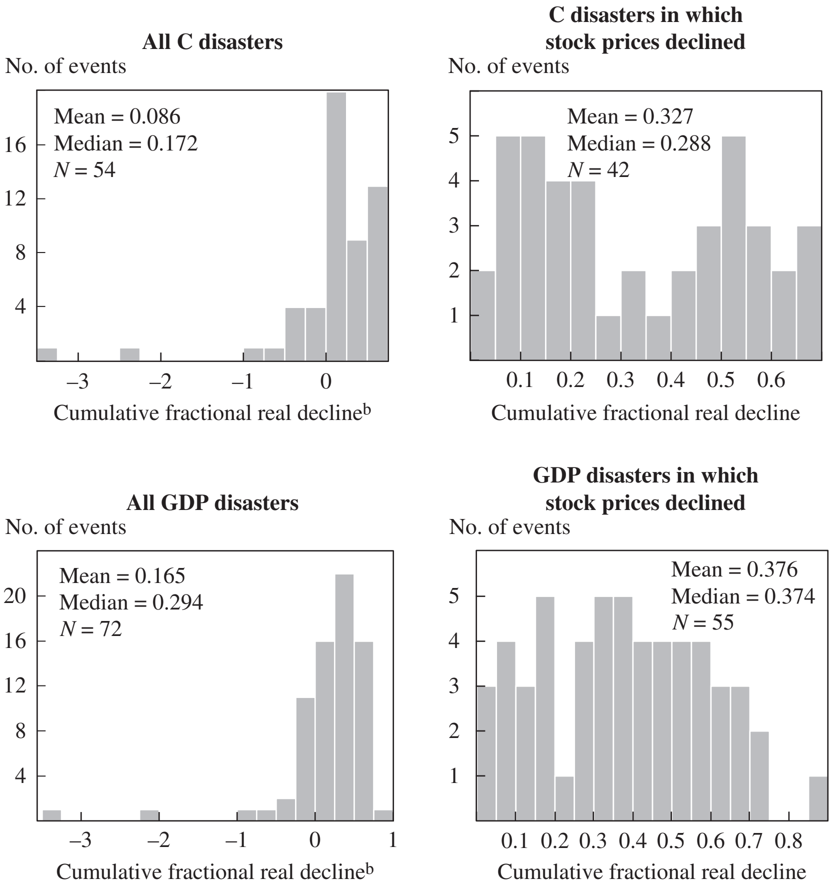
Stock Returns during Crises

In the theory, real stock prices jump down discretely at the start of a crisis. More realistically, stock prices would fall each time negative information hits the financial markets. Since we are conditioning on crises that cumulate to at least a 10 percent fall in C or GDP, the crises typically feature more than one adverse piece of news (or, rather, more negative than positive news). Thus, the stock-price declines tend also to be spread out during the crises. By analogy to our procedure for measuring decreases in C and GDP, we measure the crisis changes in stock prices by cumulative fractional amounts. Specifically, the real stock-price falls shown in appendix tables C1 and C2 are the total fractional declines from the end of the year before the peak to the end of the year before the trough. (Negative values indicate stock-price increases.) This procedure omits changes in stock prices during the trough year, when the financial markets would likely be influenced by information indicating that the crisis had ended.

Data on real stock prices are available for only a subset of the C and GDP crises: 54 of the 95 C crises (appendix table C1) and 72 of the 152 GDP crises (table C2). The majority of these crises show declines in real stock prices: in forty-two of the fifty-four C events (78 percent) and fifty-five of the seventy-two GDP events (76 percent). Figure 4 shows the size distribution of real stock-price declines during crises (where negative values correspond to stock-price rises). The left-hand panels show the full distributions, and the right-hand panels consider only the events with stock-price decreases. The left-hand panels have two outliers with very large price increases: Argentina in the late 1980s and Chile in the mid-1970s. In these situations, periods of economic contraction were accompanied by major contemporaneous or prospective reforms that were viewed favorably by the stock markets.[39] To admit the possibility of stock-price increases during crises into the model, we would have to expand the

39. An analogous situation is the C crisis in Venezuela in the late 1980s (see appendix table C1), which, however, is not included in the sample currently being considered.

Figure 4. Distributions of Real Stock-Price Declines during Consumer Expenditure and GDP Disasters[a]



Source: See table 4.

a. The sample for consumer expenditure, C, disasters is the 54 of 95 cases for included countries from table C1 with data on stock-price changes. The sample for GDP disasters is the 72 of 152 cases for included countries from table C2 with data on stock-price changes. We exclude cases in which missing data cause the period for stock-price changes to deviate from that for the declines in C or GDP.

b. Negative numbers indicate increases in real stock prices.

framework to allow for shocks to parameters, such as the expected growth rate, g^*, or the disaster probability, p.

The mean and median of fractional stock-price declines were 0.086 and 0.172, respectively, for C crises and 0.165 and 0.294 for GDP crises. Conditioning on cases of stock-price decrease in the right-hand panels of figure 4 shows roughly uniform shapes for the frequency distributions in the range of sizes between zero and 0.7.[40] In this range the mean and the median of stock-price declines were 0.327 and 0.288, respectively, for C crises and 0.376 and 0.374 for GDP crises.

In tables 10 and 11 we simulated the underlying asset pricing model using the observed distributions of C and GDP crises. The underlying assumption was that the size of the fractional stock-price decline (for unlevered equity) during a crisis equaled the size of the fractional decline, b, in C or GDP. We can instead simulate the model by using the actual stock-price changes during crises, as shown in appendix tables C1 and C2 and in figure 4. Since these stock returns refer to levered equity, these calculations apply to expected returns on levered equity.

The asset pricing condition in equation 4 involves the term $E[R_t \cdot (1 - b)^{-\gamma}]$, where R_t is the gross real stock return during crises, and b is the fractional decline in C or GDP during crises. This expression is difficult to calculate accurately because stock-price changes are highly volatile, particularly during crises.[41] In table 12 we compute this term in four alternative ways. First, we measure contractions by either C or GDP, and second, we use either the full distributions of stock-price changes (the left-hand panels of figure 4) or the truncated distributions that consider only stock-price declines (the right-hand panels). This last choice is more consistent with our model and may also lessen the effects from measurement error.

The calculations using the full distributions of stock-price changes do not accord well with observed long-term average returns on levered equity of around 0.081 (from table 5). If we use $\gamma = 3.5$, as before, the simulations in table 12 deliver an overall mean rate of return on levered equity of 0.029 based on C crises and 0.031 based on GDP crises. The results fit better if we use the truncated distributions, which eliminate cases of stock-price increase during crises. The simulated mean rate of return on levered equity is then 0.075 based on C crises and 0.034 based on GDP crises. Given the wide range of results, we cannot, at this stage, reach firm conclusions from our attempts to simulate the model using observed stock-price changes during crises.

40. Recall that the samples are selected by considering C or GDP declines of 0.10 or more. We could instead select the sample by considering real stock-price declines of 0.10 or more. Our conjecture is that the size distributions would then look like power-law functions, as in figures 1 and 2.

41. An additional difficulty is the imperfect matching of the timing of stock-price changes with the timing of the declines in C or GDP. In our data, stock-price changes are from the end of the year before the peak to the end of the year before the trough. The changes in C or GDP are from the peak year to the trough year, with C and GDP representing annual flows for each year.

Table 12. Results of the Simulated Model Using Actual Stock-Price Changes during Crises[a]

	C crises		*GDP crises*	
	All crises with stock data	*Crises with stock-price decreases only*	*All crises with stock data*	*Crises with stock-price decreases only*
No. of observations	54	42	72	55
Coefficient of relative risk aversion γ	3.5	3.5	3.5	3.5
Effective time-preference rate ρ^*	0.029	0.029	0.037	0.037
Normal growth rate g	0.025	0.025	0.025	0.025
$(1 + g)^{-\gamma}$	0.917	0.917	0.917	0.917
Disaster probability p	0.0363	0.0363	0.0369	0.0369
Stock returns[b]				
Overall mean $E(R_t - 1)$ (from table 5)	0.0814	0.0814	0.0814	0.0814
Mean of crisis sample $E(R_t - 1)$	−0.0864	−0.3272	−0.1655	−0.3759
Mean of crisis sample $E[R_t \cdot (1 - b)^{-\gamma}]$	3.446	1.964	3.545	3.235
Model simulation				
Implied noncrisis[c] $E(R_t - 1)$	0.035	0.090	0.038	0.050
Implied overall mean[d] $E(R_t - 1)$	0.029	0.075	0.031	0.034

Source: Authors' calculations.

a. The parameters γ, ρ^*, g, and p come from tables 10 and 11. Stock-price changes during crises are reported in tables C1 and C2. The four crisis samples used are C crises with data on stock-price changes ($N = 54$), C crises with stock-price decreases ($N = 42$), GDP crises with data on stock-price changes ($N = 72$), and GDP crises with stock-price decreases ($N = 55$).

b. "Mean of crisis sample $E(R_t - 1)$" is the mean for each crisis sample of the fractional change in real stock prices. "Mean of crisis sample $E[R_t \cdot (1 - b)^{-\gamma}]$" is the mean for each crisis sample of the interaction between (1 + fractional change in real stock prices) and $(1 - b)^{-\gamma}$, where b is the fractional decline in C or GDP.

c. Based on the following approximate formula, derived from equations 2 through 4 in the text (neglecting the effects from normal fluctuations, σ):

$$1 + \rho^* \approx (1 + g)^{-\gamma} \cdot \left\{ p \cdot \mathrm{E}\left[R_t \cdot (1 - b)^{-\gamma} \right]_{|crisis} + (1 - p) \cdot (\mathrm{E}R_t)_{|noncrisis} \right\}.$$

d. Based on the formula $E(R_t) = p \cdot (ER_t)_{|\text{crisis}} + (1 - p) \cdot (ER_t)_{|\text{noncrisis}}$.

Bill Returns during Crises

In the Lucas-tree model, the risk-free rate is the same in normal times as in a crisis, which lasts an instant of time. The same pattern would apply to the expected real rate of return on short-term bills—the type of claim considered in table 5—if we introduce a constant probability of default or, for nominal claims, a time-invariant process for inflation.

Table 13. Bill Returns and Inflation Rates during Crises[a]

	C crises			GDP crises		
Item	*N*	*Mean*	*Median*	*N*	*Mean*	*Median*
Real rate of return on bills	58	−0.051	−0.023	73	−0.052	−0.021
Inflation rate	87	1.13	0.066	123	0.961	0.069

Source: Authors' calculations.

a. The results apply to the crisis samples used in the main analysis: 95 C crises from table C1 and 152 GDP crises from table C2. Data for real rates of return on bills and inflation rates are for the subsamples that also have data on bill returns or inflation rates, as indicated in tables C1 and C2. The cells show means and medians of real rates of return on bills and inflation rates for these subsamples.

Observed returns on short-term bills deviate from these predictions. Table 13 shows means and medians for real bill returns during the C and GDP crises in appendix tables C1 and C2. (The bill returns for each crisis are mean values from the peak year to one year before the trough year.) These results apply to the main samples (95 C crises and 152 GDP crises) when data are also available on bill returns (58 for C crises and 73 for GDP crises). The average real bill return during crises was between −2 percent and −5 percent a year, depending on whether a C or a GDP sample is used and on whether the mean or the median is considered. Hence, the average crisis return was below the long-term average of around 1 percent shown in table 5.

There are two main issues to consider. The first is whether a substantially negative number, such as −2 percent to −5 percent a year, is a good measure of expected real bill returns during crises. A major question here concerns inflation. The second is whether our analysis of the equity premium would be much affected if the expected real return on bills during crises were substantially negative. Since the second issue is more fundamental, and we think the answer is no, we consider that question first.

One possible reason for a low equilibrium expected real bill return during crises, suggested by figure 3, is that crisis states last for more than an instant, and the mean growth rate of C in these states is negative. (A supporting reason, not shown in figure 3, is that volatility tends to be unusually high in crisis states.) In these cases the risk-free rate and the expected real bill return would be unusually low in crises. However, the key issue for the equity premium is not the low level of the real bill return during crises (caused by a low expected growth rate or some other factor) but, rather, whether the incidence of a crisis imposes substantial real capital losses on bills. Recall that bills correspond, empirically, to claims with maturity of three months or less. Although the crisis-induced changes in the real value of these claims are hard to measure accurately, substantial real capital losses can arise only if there are jumps in the price level or literal defaults on bills. Absent these effects, the pricing of bills in normal times (and, hence, the equity premium) would not be much influenced by the prospect of low equilibrium real bill returns during crises.[42] In contrast, for long-term bonds, changes in real capital values at the onsets of crises may be substantial and would have to be compared with those on stocks. Thus it would be useful to analyze the crisis experiences of the ten-year government bonds included in table 5. However, the measurement of crisis-induced changes in real bond values will be challenging.

A different point is that the computed averages of real bill returns during crises may understate expected real returns because of influences from inflation. Crises do feature higher than usual inflation rates: table 13 shows that the median inflation rates were 6.6 percent for C crises and 6.9 percent for GDP crises, compared with 4.2 percent for long samples for all countries taken together.[43] Hence, one possible explanation for the low average real bill return during crises is that the greater incidence of high inflation corresponds to high unanticipated inflation and, thereby, to a shortfall of realized real returns on nominally denominated bills from expected returns. A shortcoming of this argument is that it requires inflation to be systematically underestimated during crises (which are presumably recognized contemporaneously).

A second possibility is that the reported nominal yields at times of high inflation systematically understate the true nominal returns and, therefore, lead to underestimates of the real returns. The reason is the understatement of the implications of compounding for calculating true nominal returns.[44]

42. An analogous result holds for paper currency. The expected real return on currency would be low during a crisis if the expected inflation rate were high. However, absent jumps in the price level or literal defaults, currency held in normal times would still provide good protection against crisis-induced stock-market crashes.

43. The inflation rate for each crisis in tables C1 and C2 is the mean value from the peak year to one year before the trough year.

44. As an example, Peru's crisis in 1987–92 featured very high inflation. In 1989 the price level increased by a factor of 29. The International Monetary Fund's *International Financial Statistics* (IFS) reports, on a monthly basis, nominal deposit yields for 1989 averaging 1,100 percent a year. The IFS staff tell us that an annual rate of 1,100 percent means that the nominal value of funds held as deposits would rise over a year by a factor of 12. This nominal return, in conjunction with the inflation experience, produces a real rate of return for Peru in 1989 of –0.58 per year. Suppose, alternatively, that a nominal yield of 1,100 percent means that returns are compounded monthly at a rate of 92 percent (= 1,100/12) per month. In this case the nominal value would rise over a year by a factor of 2,500, implying an astronomically positive real rate of return. The point is that when the inflation rate is high, compounding errors of this type have large implications for calculated real rates of return—and we think that these errors are regularly in the direction of understating true returns.

We think that this issue is quantitatively important, and we are attempting to improve our calculations in this regard.

Plans for Further Research

We plan in future research to expand the twenty-four-country sample for C and the thirty-six-country sample for GDP. Promising candidates are Malaysia and Singapore, both of which have gaps in the data around World War II. Also promising are Russia back to the pre–World War I tsarist period, and Turkey back to the times of the Ottoman Empire, for which we currently have data since 1923. We are also considering Ireland, particularly whether we can isolate macroeconomic data for the territory of the Republic of Ireland from U.K. statistics for the period preceding Irish independence in 1922. We plan also to reexamine the pre-1929 U.S. data, focusing on the Civil War years.

We will try to go further in measuring the division of personal consumer expenditure between durables versus nondurables and services. Appendix table C3 shows the data that we have been able to compile thus far for crisis periods. We may also attempt to add data on government consumption. A key issue here is the separation of military outlays from other forms of government consumption expenditure.

We plan to construct time series for C and GDP per capita at the levels of regions that include multiple countries: the OECD, Western Europe, Latin America, Asia, the "world," and so on. These regional aggregates can be relevant when countries are integrated through financial and other markets. There are tricky aspects of this exercise involving changes in country borders, and we are working on this issue. Once we have these superaggregate variables, we will examine C and GDP crises at regional levels.

In joint work with Rustam Ibragimov, we will use the method of Gabaix and Ibragimov to estimate the distribution of disaster sizes, b, within a power-law context.[45] Preliminary analysis shows good results when treating the transformed variable $1/(1 - b)$ as subject to a power-law density function with exponent α. With these results we can compute the key expectations that enter into the theoretical model, such as $E(1 - b)^{-\gamma}$, as functions of γ and α. Preliminary results suggest that the estimated α, around 5, is consistent with a finite value of $E(1 - b)^{-\gamma}$, when γ is around 3.5. With these results, we can redo the simulation of the model using the fitted density function for b, rather than the observed histogram.

45. Gabaix and Ibragimov (2007).

We are working with Emi Nakamura and Jón Steinsson on a formal statistical model of the evolution of consumer expenditure and GDP. We will use the full time series on C and GDP to estimate the probability of disaster (possibly time-varying), the evolution of economic contractions during disaster states, the probability of return to normalcy, and the long-run effects of disasters on levels and growth rates of C and GDP. We will also allow for trend breaks in growth rates, as well as for some differences in uncertainty parameters across countries and over time.

We are working with Emmanuel Farhi and Xavier Gabaix on a different approach to measuring time-varying disaster probabilities. Our plan is to use U.S. data since the early 1980s on prices of stock-index options to gauge changing market perceptions of the likelihood of substantial adverse shocks. In addition to considering the equity premium, we will apply this analysis to the bond-bill premium, which we found to be about 1 percent a year.

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APPENDIX A

Table A1. Main Differences between Maddison's GDP Data and Data Used in This Paper

Country	*Focus period*	*Maddison (updated version)*	*Our approach*
Argentina	Late 19th century (1870–1900)	Benchmark values provided only for 1870 and 1890; apparently calculated by assuming same growth rates as in 1900–13.	Used various sources, including recently published series based on sectoral output for earlier decades (including agriculture, mining, manufacturing, energy, construction, trade, transports, and services). Sufficient coverage allows starting the series in 1875.
Austria	World War II (1944–46)	Indicated source does not contain figure for 1945; estimation procedure is undisclosed.	Estimated growth rates for 1944–46 using a weighted average of indexes of industrial production and livestock production (the latter as proxy for the agricultural sector); estimates were constrained to fit the growth rate between benchmark values provided in the original source.
	19th–20th centuries	Adjusts the series to present-day boundaries of Austria.	Followed the criterion explained in the text for territorial adjustment; output measures corresponding to the Austro-Hungarian Empire were used up to 1918 and to Austria from then onward.
Brazil	19th–20th centuries (1850–90)	Presents a linear trend for 1870–90 (divergence with respect to source is unexplained). Missing 1851–69.	Constructed a continuous series starting in 1850 combining various sources, among them the most recent revision of Brazilian GDP for the 20th century that is currently available, which differs from the earlier estimates used in Maddison's series.
Belgium	World War I (1914–19)	Assumed to move in tandem with France.	Estimated based on the weighted movement in production of carbon, cast iron, steel, and proxies for agricultural output in the form of available cattle and imported malt for breweries. Trends were matched with productivity data in the carbon industry, number of metallurgical facilities in operation, and unemployment figures.
	World War II (1939–47)	Assumed to move in tandem with France.	Estimated based on benchmark values constructed using data on industrial activity indexes and production of carbon, steel, and electricity, in combination with transports data. When industrial data were missing, information on railroads, vehicles, and transportation of merchandise and passengers, among other communications indicators, were weighted to connect benchmark values.

Colombia	1901–12	Series interpolated with average movement in Brazil and Chile.	Used actual GDP estimates for Colombia starting from 1905 and constructed from the production side.
Denmark	19th–20th centuries	Starts 1820; territorial adjustment to eliminate impact of North Schleswig.	Chose a different combination of sources (series starts in 1818). Territorial adjustment to follow criterion explained in main text.
France	19th–20th centuries (World Wars I and II)	Series interpolated between 1913 and 1920 based on figures of industrial and agricultural output (assuming services remained stable); interpolated between 1938 and 1949 using information from a separate report on national income.	A different set of sources was chosen so as to have GDP measures consistent with the private consumption series that would be built in parallel. More recent and revised measures of the evolution of output during the world wars were preferred. These are refinements of the official series produced by the French Institute of Statistics and Economics.
Germany	World War II (1944–46)	Assumes 1945 value lay midway between 1944 and 1946 values; figures for these two years are linked from originally unconnected sources.	Used level-comparable anchor values for 1944 and 1946. Estimated changes for 1945 and 1946 based on recently published data on industrial production for West and East Germany, in combination with data on agricultural output (crops and livestock).
	19th–20th centuries	Baseline series is adjusted to fit borders in three points in time.	Followed the criterion explained in the text for territorial adjustment: smooth pasting of per capita growth rates during transition years of separation and unification.
Greece	19th–20th centuries (1914–20)	Five benchmark values are given for 1820–1921 (missing 1914–20). Apparently, as in an older but continuous version of Maddison's series, these benchmarks are assumed to follow the aggregate for Eastern Europe.	Used a continuous and longer time series based on new estimates developed by a group of researchers from the Centre for Planning and Economic Research together with the historical archives of the National Bank of Greece, based on output in primary, secondary, and tertiary activities; sectoral weights; price deflators; and measures of money supply.

(*continued*)

Table A1. Main Differences between Maddison's GDP Data and Data Used in This Paper (*Continued*)

Country	*Focus period*	*Maddison (updated version)*	*Our approach*
	World War II (1938–50)	Mismatch with indicated source, which seems to contain only benchmark values for 1938 and 1947; estimation procedure for the years in between is undisclosed.	Estimated values between the two benchmark years by appropriately weighting data on industrial production and agricultural production (including crops and animals), which were calibrated to match the observed evolution of aggregate GDP during overlapping years. Absolute lack of data does not allow building an estimate for 1944.
Iceland	19th–20th centuries	Not considered separately but as part of an aggregate of countries whose pre-1950 growth rates are assumed to equal the averages of larger Western European countries.	Considered as a separate country; combined sources to construct a continuous series starting in 1870.
India	19th century	Presents continuous series starting in 1884.	Constructed a different series combining various sources that allow starting in 1872.
Indonesia	World War II (1942–48)	Missing figures.	Built estimates following an indicators approach based on weighted movements in the following sectors: food and crops, mining, construction and housing, trade and services, public administration, and oil and gas. Estimates were constrained to match actual GDP growth rates for surrounding years.
Italy	19th–20th centuries	Uses previous estimates based on older official statistical series.	Constructed a series with the same starting date but a different combination of sources, some of which are recent revisions of the older statistical figures used in Maddison's series and are supported in richer estimates of industry, agriculture, and services.

Japan	World War II (1945)	Apparently, 1945 value is assumed to be half of 1944.	Used the more recent consensus figures showing a decline in output of approximately 50 percent spread over both 1945 and 1946.
Malaysia	20th century	Series starts in 1911, missing 1943–46. Territorial adjustment to fit figures to present-day Malaysia.	Extended the series back to 1900 using recently published revisions of older series corresponding to Malaya.
Mexico	Revolution period (1911–20)	Uses linear interpolation as done in another source.	Constructed estimates based on weighted changes in services, agriculture, and industry (including mining, energy, and manufacturing). For each of these sectors, we built subsector-weighted indexes using an array of data from national statistical abstracts and various academic works on the revolution. (Maddison's population series is a linear interpolation between 1910 and 1920, a procedure that yields incorrect measures of per capita output. We used a population series that accords with the more likely demographic changes during this period.)
	1896–99	Missing.	Covered with official GDP figures.
Netherlands	19th–20th centuries (World Wars I and II)	Starts continuous series in 1820; covers war years with undisclosed aggregate measures.	Constructed new series with the purpose of extending the series further back into the past, being explicit about proxies used as measures of GDP, and taking advantage of new revisions to older series. In particular, deflated measures of gross domestic income were used to extend the series to the early years of the 19th century. In the absence of a GDP aggregate, world war years were covered with figures corresponding to net national product.
Singapore	Early 20th century	Continuous series starts in 1950. Benchmark for 1913 is provided, apparently based on the assumption that per capita GDP moved proportionately to that of Malaysia.	Used newly generated series of GDP starting in 1900 (but missing the period 1940–49), based on estimation of all demand-side components of GDP.

(*continued*)

Table A1. Main Differences between Maddison's GDP Data and Data Used in This Paper (*Continued*)

Country	*Focus period*	*Maddison (updated version)*	*Our approach*
South Africa	20th century	Presents data starting in 1950.	Extended the series back to 1911.
South Korea	Early 19th century and war periods (1941–53)	Older estimates; mismatches with indicated sources for the war years; undisclosed estimation procedure.	Used results from recent research to cover the first half of the 20th century. Constructed estimates for World War II period based on sectoral output in agriculture, forestry, fishery, mining, manufacturing, and services. Weighted indexes for each of these subsectors were constructed mainly from primary Korean statistical abstracts. For the Korean War years, we used statistical data from the United Nations.
Sweden	19th–20th centuries	Source from an older study; series starts in 1820.	Extended the series back to 1800 using recently published figures compatible with revised official data and covering the two centuries.
Switzerland	World War I to 1920s (1914–29)	Uses a baseline source that proxies output with moving averages of railroad transport volume for 1914–24 (combined with industrial production for 1925–29). Adjustments to match movements in another source are not detailed.	Reestimated GDP figures for this period following an indicators approach using a wider set of variables: private consumption (in turn estimated for 1851–1948 from quantities of consumption items and expenditure shares), expenditures of the confederation, exports, imports, freight traffic on railways, gross consumption of energy, industrial production, number of new residences, number of stock companies, and capital at year end of stock companies. Whenever necessary, a consumer price index (built for purposes of the private consumption series) was used as deflator.

	19th–20th centuries	Adjustments based on a combination of sources, not fully explained.	Preferred to construct a new series accounting for specific details, for example, the use of an actual GDP deflator, available for the earlier part of the series starting in 1851, and the use of net national product to cover the lack of a GDP measure during 1930–48.
Taiwan	War periods (1939–49)	Covers 1939–45 with older estimates and 1945–49 by assuming equal percentage growth for each of these years.	Used recently published series based on revised national accounts statistics for the 20th century. This new source presents constant price series based on different deflating methods, all of which show different patterns than older estimates.
United Kingdom	19th–20th centuries	Uses various sources; makes assumptions related to territorial adjustments to present-day boundaries.	Although patterns do not change markedly, we chose a different concatenation of sources. Some of these are themselves “compromise” series of earlier estimates; official sources for post–World War II data.
United States	19th–20th centuries	Provides five benchmark figures for 1820–70.	Restricted the series to start in 1869 with the estimates from Balke and Gordon (1989) through 1929; followed by National Income and Product Accounts figures from the Bureau of Economic Analysis up to 2006. Although estimates for earlier years are available from a new edition of the *Historical Statistics of the United States,* we believe these figures warrant further analysis, especially those corresponding to the Civil War period.
Venezuela	19th century (1884–99)	Discards data from the source for pre-1900 decades.	Started the series in 1884 using GDP estimates based on a wide coverage of sectors, including agriculture, commerce, finances, government, and transports.

Sources: Maddison (2003) and Internet updates (www.ggdc.net/maddison) through May 2008; for details on our sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

APPENDIX B

Real Consumption and GDP per Capita by Country

Figure B1. Real Personal Consumer Expenditure and GDP per Capita in OECD Countries[a]

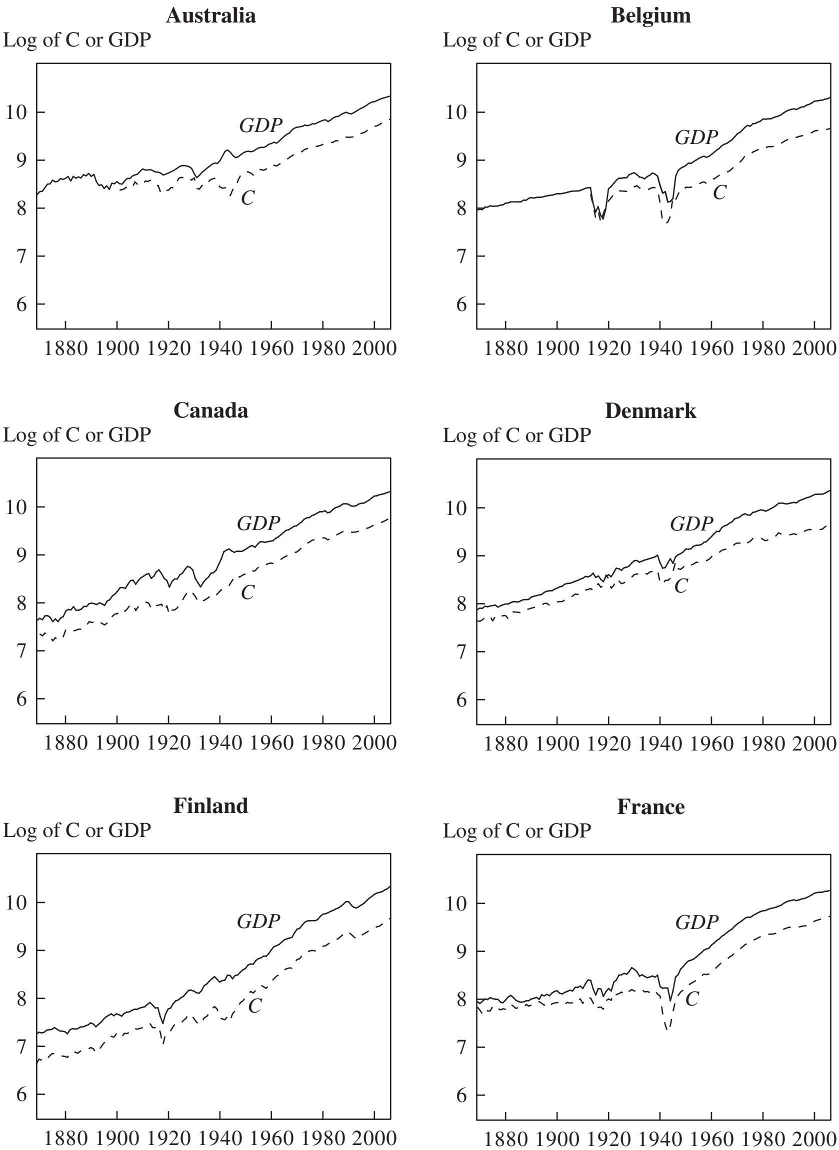
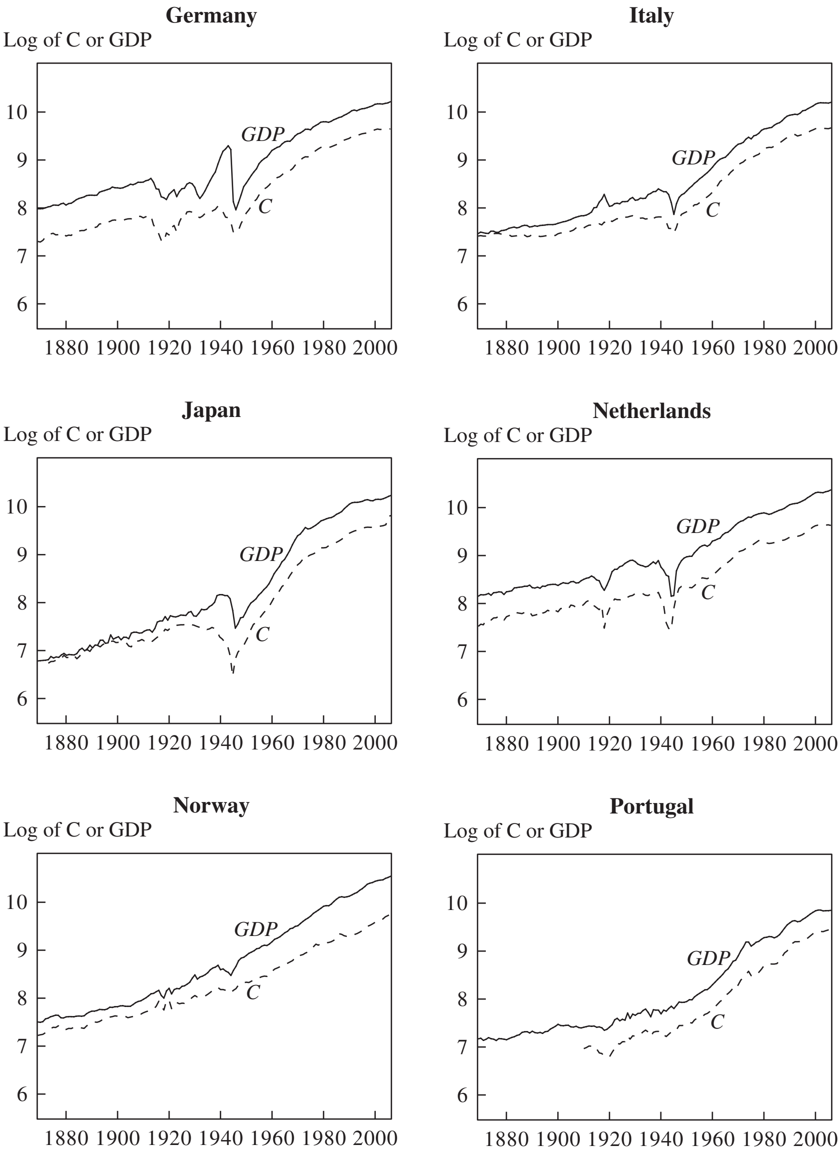
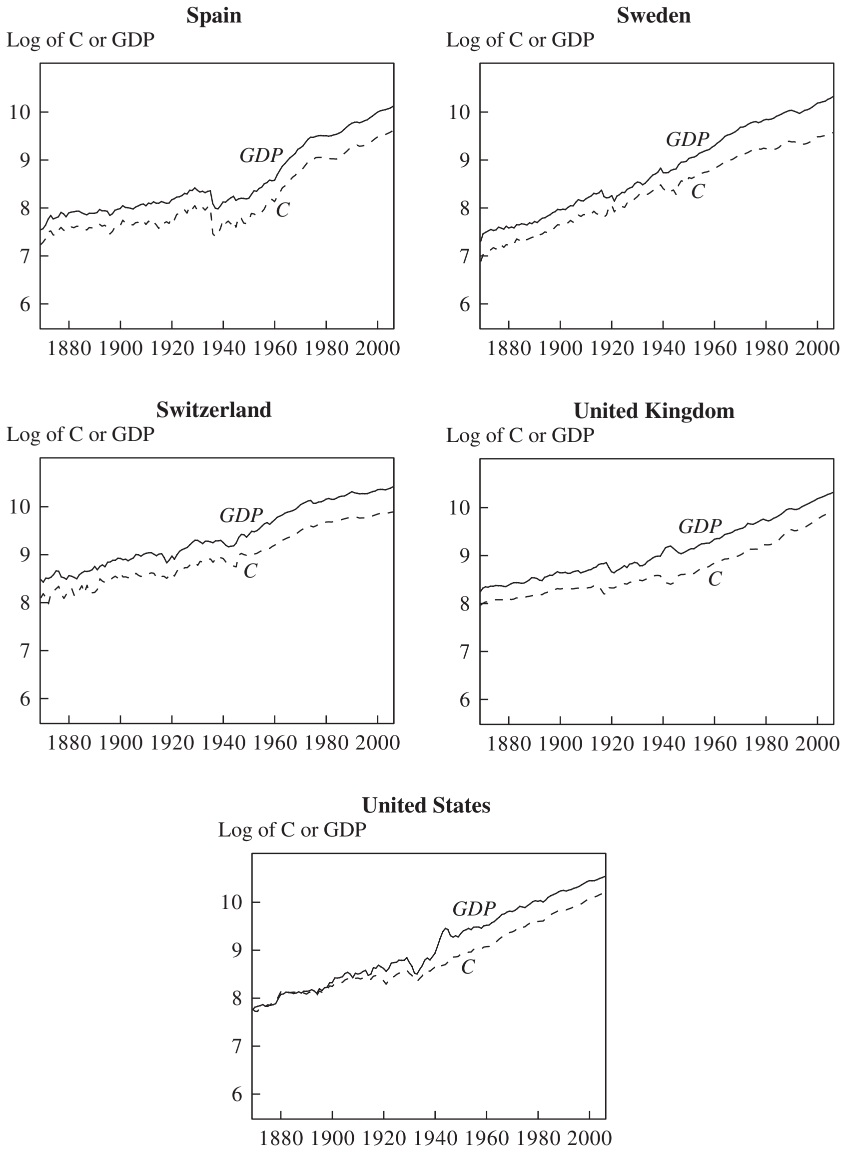


Figure B1. Real Personal Consumer Expenditure and GDP per Capita in OECD Countries[a] (*Continued*)



(*continued*)

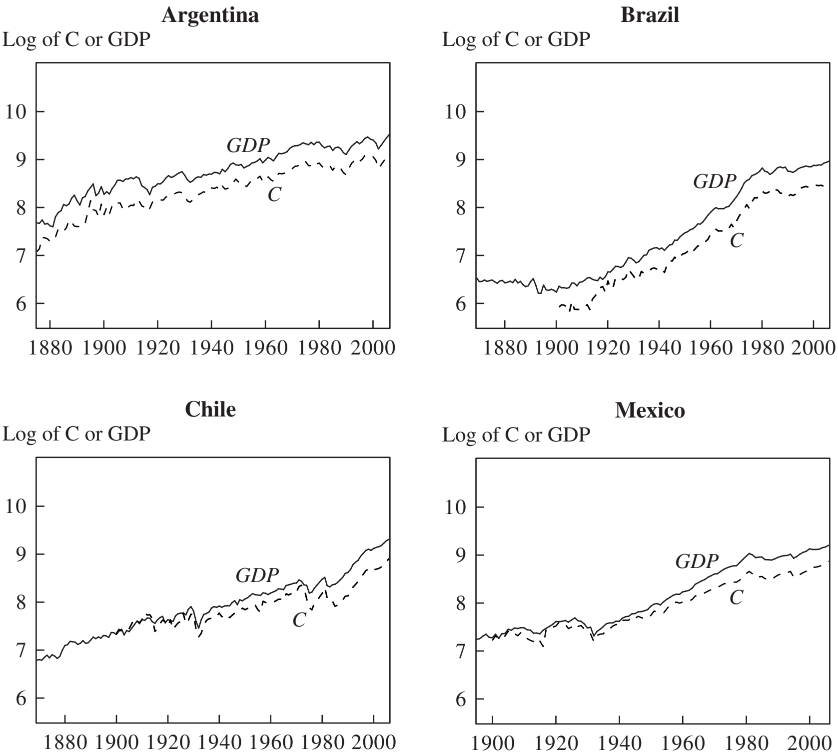
Figure B1. Real Personal Consumer Expenditure and GDP per Capita in OECD Countries[a] (*Continued*)



Source: Authors' construction; for details on sources see www.economics.harvard.edu/faculty/barro/data_sets_barro.

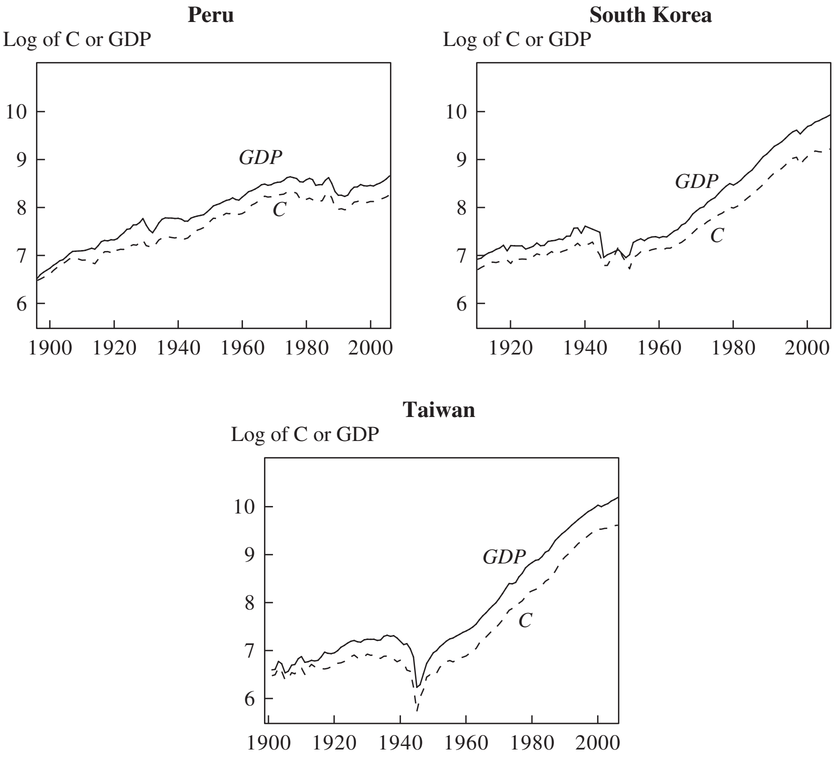
a. Log scale ranges from 5.5 to 11.0 ($245 to $59,900, respectively, in 2000 U.S. dollars). Series start in 1869 or later depending on data availability.

Figure B2. Real Personal Consumer Expenditure and GDP per Capita in Non-OECD Countries[a]



(*continued*)

Figure B2. Real Personal Consumer Expenditure and GDP per Capita in Non-OECD Countries (*Continued*)



Source: Authors' construction; for details on sources see www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Log scale ranges from 5.5 to 11.0 ($245 to $59,900, respectively, in 2000 U.S. dollars). Series start in 1869 or later depending on data availability.

APPENDIX C

Characteristics of Consumption and GDP Disasters

Table C1. Consumption Disasters

Country	Disaster period: Trough[a]	Disaster period: Peak	Decline in consumer expenditure per capita[b]	Stock-price decline[c]	Rate of return on bills[d]	Inflation rate[d]
OECD countries						
Australia	*1918*	1913	0.238	0.144	–0.008	0.036
	1932	1927	0.234	0.069	0.086	–0.032
	1944	1938	0.301	0.225	–0.024	0.041
Austria[e]	*1918*	1913	0.451	—	0.034	0.019
	1933	1929	0.217	0.533	0.071	–0.004
	1947	1938	0.438	—	—	—
Belgium	*1917*	1913	0.445	—	–0.160	0.353
	1942	1937	0.530	—	–0.024	0.034
Canada	1876	1873	0.152	—	—	–0.023
	1908	1906	0.113	—	0.014	–0.046
	1915	1912	0.130	—	0.022[f]	0.034
	1921	1918	0.196	0.210	—	0.104
	1933	1929	0.230	0.650	—	–0.054
Denmark	1921	1919	0.241	0.502	–0.113	0.201
	1941	1939	0.261	0.336	–0.120	0.193
	1948	1946	0.144	0.040	0.005	0.025
Finland	1892	1890	0.102	—	—	—
	1918	1913	0.360	—	–0.194[g]	0.389[g]
	1932	1928	0.199	0.207	0.115	–0.041
	1944	1938	0.254	0.168	–0.067	0.122
	1993	1989	0.140	0.620	0.092	0.045
France	*1871*	1864	0.158	0.212	0.027	0.007
	1915	1912	0.215	0.171	0.031	0.006
	1943	1938	0.580	—	–0.121	0.162
Germany	*1918*	1912	0.425	0.539	–0.101	0.186
	1923	1922	0.127	0.654	–0.970	34.5
	1932	1928	0.121	0.562	0.109	–0.035
	1945	1939	0.412	–0.366	0.000	0.020
Greece[e]	*1944*	1938	0.636	0.442[h]	–0.442	4.65
	1946	1945	0.113	—	—	—
Iceland[e]	1952	1947	0.250	—	—	0.202
	1969	1967	0.118	—	—	0.108
	1975	1974	0.107	—	—	0.515
	1993	1987	0.176	—	0.060[i]	0.144
Italy	*1945*	1939	0.286	0.429	–0.236	1.02
Japan	*1945*	1937	0.639	0.457	–0.066	0.101
Netherlands	1893	1889	0.098	—	–0.013	0.038
	1918	1912	0.440	—	–0.013	0.060
	1944	1939	0.545	–0.506	–0.050	0.069
New Zealand[e]	*1944*	1939	0.224	0.089	–0.009	0.031

(*continued*)

Table C1. Consumption Disasters (*Continued*)

Country	*Disaster period*		*Decline in consumer expenditure per capita*[b]	*Stock-price decline*[c]	*Rate of return on bills*[d]	*Inflation rate*[d]
	Trough[a]	*Peak*				
Norway	*1918*	1916	0.169	–0.035	–0.212	0.326
	1921	1919	0.161	0.536	–0.032	0.094
	1944	1939	0.100	–0.222	–0.062	0.090
Portugal	1919	1913	0.215	—	—	—
	1936	1934	0.121	–0.434	0.044	0.010
	1942	1939	0.104	0.084	–0.058	0.110
	1976	1974	0.098	—	–0.136	0.242
Spain	1896	1892	0.182	–0.088	0.079	–0.024
	1915	1913	0.128	0.065	0.021	0.026
	1930	1929	0.101	0.090	0.027	0.028
	1937	1935	0.461	0.238[j]	–0.051	0.058
	1945	1940	0.145	–0.079	–0.021	0.107
	1949	1946	0.131	0.014	–0.029	0.075
Sweden	1917	1913	0.115	0.095	–0.014	0.074
	1921	1920	0.132	0.251	0.052	0.019
	1945	1939	0.182	0.173	–0.030	0.059
Switzerland	1872	1870	0.190	—	—	—
	1878	1876	0.225	—	—	—
	1883	1881	0.142	—	—	–0.018
	1886	1885	0.141	—	—	–0.059
	1888	1887	0.157	—	—	0.010
	1918	1912	0.108	0.475	–0.031	0.088
	1945	1939	0.173	0.382	–0.052	0.074
United Kingdom	*1918*	1915	0.167	0.490	–0.117	0.188
	1943	1938	0.169	0.123	–0.032	0.047
United States	1921	1917	0.164	0.584	–0.071	0.139
	1933	1929	0.208	0.631	0.093	–0.064
Non-OECD countries						
Argentina	1891	1887	0.123	—	—	0.080
	1898	1895	0.283	—	—	0.030
	1900	1899	0.195	—	—	–0.096
	1902	1901	0.127	—	—	0.059
	1907	1906	0.123	—	—	0.025
	1917	1912	0.172	—	—	0.047
	1932	1928	0.189	—	—	–0.028
	1959	1958	0.101	—	—	0.507
	1982	1980	0.104	0.575	0.516	1.09
	1990	1987	0.160	–3.264	–0.249	18.3
	2002	1998	0.249	0.401	0.090	–0.009
Brazil	1905	1902	0.148	—	—	–0.029
	1909	1906	0.157	—	—	0.023
	1919	1918	0.109	—	—	0.123
	1921	1920	0.147	—	—	0.099
	1931	1928	0.201	—	—	–0.037
	1990	1984	0.163	–0.271	—	6.42

Table C1. Consumption Disasters (*Continued*)

Country	Disaster period Trough[a]	Peak	Decline in consumer expenditure per capita[b]	Stock-price decline[c]	Rate of return on bills[d]	Inflation rate[d]
Chile	1915	1911	0.322	0.125	0.021	0.069
	1922	1918	0.181	0.154	0.011	0.085
	1932	1929	0.374	0.538	0.063	0.007
	1956	1954	0.136	–0.315	–0.410	0.775
	1976	1972	0.401	–2.470	–0.516	3.47
	1985	1981	0.327	0.684	0.165	0.191
Colombia[e]	1932	1929	0.181	0.263	—	–0.090
	1943	1939	0.228	–0.053	—	0.041
	1999	1997	0.099	0.043	0.095	0.172
India[e]	*1942*	1932	0.217	–0.814	0.003	0.016
	1946	1943	0.130	–0.305	–0.053	0.086
	1950	1947	0.177	0.504	–0.025	0.038
Malaysia[e]	1916	1914	0.096	—	—	—
	1920	1917	0.425	—	—	—
	1932	1929	0.258	—	—	—
	1947	1938	0.336	—	—	—
	1952	1951	0.118	—	—	0.164
	1986	1984	0.145	0.434	0.036	0.014
	1998	1997	0.124	0.533	0.036	0.029
Mexico	*1916*	1909	0.252	—	—	0.031[k]
	1924	1921	0.118	—	—	–0.074
	1932	1926	0.311	0.406[m]	—	–0.025
	1988	1981	0.161	–0.148	0.024	0.852
	1995	1994	0.113	0.147	0.075	0.071
Peru	1914	1907	0.118	—	—	—
	1932	1929	0.140	0.105	—	–0.043
	1979	1975	0.179	0.325	—	0.437
	1992	1987	0.300	0.519	–0.522	24.8
Singapore[e]	1916	1910	0.145	—	—	—
	1920	1918	0.127	—	—	—
	1931	1928	0.104	—	—	—
	1951	1949	0.159	—	—	0.098
	1959	1956	0.117	—	—	0.013
South Korea	*1945*	1942	0.387	—	—	—
	1952	1949	0.371	—	—	1.68
	1998	1997	0.143	0.458	0.072	0.066
Taiwan	*1905*	1903	0.219	—	—	0.076
	1911	1910	0.127	—	—	0.082
	1945	1936	0.684	—	—	0.148
Turkey[e]	1932	1929	0.120	—	—	–0.031
	1946	1938	0.298	—	—	0.215
	2001	2000	0.108	0.565	–0.078	0.390
Uruguay[e]	1965	1960	0.099	—	—	0.274
	1984	1981	0.267	—	—	0.338
	2002	1998	0.219	—	—	0.054

(*continued*)

Table C1. Consumption Disasters (*Continued*)

Country	*Disaster period*		*Decline in consumer expenditure*	*Stock-price*	*Rate of return*	*Inflation*
	Trough[a]	*Peak*	*per capita*[b]	*decline*[c]	*on bills*[d]	*rate*[d]
Venezuela[e]	1933	1930	0.311	0.074	—	–0.060
	1936	1935	0.107	–0.069	—	–0.058
	1952	1948	0.203	0.103	–0.025	0.048
	1964	1957	0.223	0.329	0.020	0.016
	1989	1982	0.320	–3.493	–0.048	0.183
	2003	1993	0.147	0.690	–0.043	0.421

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Italics indicate that the country was a current participant in an external or internal war.

b. Decline in real personal consumer expenditure per capita by 0.1 or greater, expressed as a cumulative fraction from peak year to trough year.

c. Decline in real stock prices, expressed as cumulative fractions from the end of the year preceding the peak to the end of the year preceding the trough (unless the timing is indicated otherwise because of missing data). Negative numbers indicate increases in real stock prices.

d. Mean values from the peak year to one year before the trough year (unless the timing is indicated otherwise because of missing data).

e. Not included in the analysis for the consumer expenditure sample.

f. 1913–14. g. 1915–17. h. 1937–40. i. 1988–92. j. 1934–35. k. 1909–13. m. 1929–31.

Table C2. GDP Disasters

Country	*Disaster period*		*Decline in GDP per capita*[b]	*Stock-price decline*[c]	*Rate of return on bills*[d]	*Inflation rate*[d]
	Trough[a]	*Peak*				
OECD countries						
Australia	1895	1889	0.271	0.067	0.085	–0.050
	1918	1910	0.118	0.188	–0.020	0.045
	1931	1926	0.221	0.179	0.061	–0.013
	1946	1943	0.145	–0.167	0.007	0.005
Austria	*1918*	1912	0.381	—	0.031	0.022
	1933	1929	0.235	0.533	0.071	–0.004
	1945	1941	0.587	—	—	—
Belgium	*1918*	1913	0.477	—	–0.225	0.492
	1934	1930	0.117	0.451	0.070	–0.052
	1943	1937	0.453	–0.764	–0.033	0.045
Canada	1878	1874	0.117	—	—	–0.020
	1921	1917	0.301	0.393	—	0.115
	1933	1928	0.348	0.558	—	–0.041
Denmark	*1918*	1914	0.160	0.132[f]	–0.045	0.128
	1941	1939	0.239	0.336	–0.120	0.193
Finland	1881	1876	0.120	—	—	—
	1918	1913	0.353	—	–0.194[g]	0.389[g]
	1940	1938	0.103	0.142	0.017	0.024
	1993	1989	0.124	0.620	0.092	0.045
France	*1870*	1868	0.095	—	—	–0.011
	1879	1874	0.102	—	—	–0.002
	1886	1882	0.133	0.296	0.028	0.000
	1918	1912	0.289	0.395	–0.055	0.117
	1935	1929	0.187	0.535	0.068	–0.039
	1944	1939	0.414	—	–0.147	0.197
Germany	*1919*	1913	0.357	0.736	–0.125	0.214
	1923	1922	0.135	0.654	–0.970	34.5
	1932	1928	0.280	0.562	0.109	–0.035
	1946	1943	0.736	0.068	–0.009	0.028
Greece	1872	1868	0.106	—	—	—
	1877	1873	0.152	—	—	—
	1891	1888	0.233	—	—	—
	1897	1896	0.151	—	—	—
	1901	1899	0.144	—	—	—
	1913	1911	0.419	—	—	—
	1919	1918	0.177	—	–0.553	1.38
	1923	1921	0.238	—	–0.203	0.369
	1942	1939	0.660	0.448[h]	–0.331	4.31
Iceland	1883	1881	0.125	—	—	—
	1918	1913	0.221	—	—	0.206
	1920	1919	0.157	—	—	0.114
	1952	1948	0.139	—	—	0.235
Italy	1920	1918	0.221	0.374	–0.101	0.195
	1945	1939	0.413	0.429	–0.236	1.02
Japan	*1944*	1940	0.503	0.239	–0.026	0.054

(*continued*)

Table C2. GDP Disasters (*Continued*)

Country	*Disaster period*		*Decline in GDP per capita*[b]	*Stock-price decline*[c]	*Rate of return on bills*[d]	*Inflation rate*[d]
	Trough[a]	*Peak*				
Netherlands	*1918*	1913	0.258	—	–0.021	0.070
	1934	1929	0.129	0.582	0.057	–0.032
	1944	1939	0.525	–0.506	–0.050	0.069
New Zealand	1879	1878	0.174	—	—	—
	1909	1907	0.110	—	—	—
	1918	1911	0.107	—	—	0.040
	1927	1925	0.117	—	0.057	0.009
	1948	1947	0.119	0.003	–0.061	0.081
	1951	1950	0.097	–0.049	–0.068	0.089
Norway	*1918*	1916	0.148	–0.035	–0.212	0.326
	1921	1920	0.110	0.447	–0.117	0.194
	1944	1939	0.193	–0.222	–0.062	0.090
Portugal	1928	1927	0.109	—	—	—
	1936	1934	0.148	–0.434	0.044	0.010
Spain	1896	1892	0.119	–0.088	0.079	–0.024
	1933	1929	0.096	0.464	0.061	–0.009
	1938	1935	0.313	0.238[i]	–0.035	0.098
Sweden	1918	1916	0.150	0.169	–0.185	0.323
	1921	1920	0.108	0.251	0.052	0.019
	1941	1939	0.095	0.349	–0.071	0.104
Switzerland	1879	1875	0.161	—	—	—
	1918	1912	0.191	0.475	–0.031	0.088
	1942	1939	0.126	0.308	–0.080	0.105
United Kingdom	1921	1918	0.192	0.321	–0.069	0.130
	1947	1943	0.148	–0.269	0.003	0.006
United States	1908	1906	0.105	0.365	0.019	0.041
	1914	1913	0.095	0.160	0.034	0.020
	1921	1918	0.118	0.293	–0.057	0.125
	1933	1929	0.290	0.631	0.093	–0.064
	1947	1944	0.165	–0.061	–0.062	0.076
Non-OECD countries						
Argentina	1891	1889	0.189	—	—	0.284
	1897	1896	0.219	—	—	0.069
	1900	1899	0.147	—	—	–0.096
	1917	1912	0.289	—	—	0.047
	1932	1929	0.195	—	—	–0.002
	1959	1958	0.101	—	—	0.507
	1982	1980	0.111	0.575	0.516	1.09
	1990	1988	0.141	–3.430	–0.355	26.6
	2002	1998	0.220	0.401	0.090	–0.009
Brazil	1887	1884	0.105	—	—	–0.020
	1893	1891	0.262	—	—	0.248
	1900	1895	0.135	—	—	0.033
	1931	1928	0.201	—	—	–0.037
	1992	1987	0.110	0.358	—	10.8

Table C2. GDP Disasters (*Continued*)

Country	*Disaster period*		*Decline in GDP per capita*[b]	*Stock-price decline*[c]	*Rate of return on bills*[d]	*Inflation rate*[d]
	Trough[a]	*Peak*				
Chile	1903	1902	0.111	0.015	0.022	0.055
	1915	1912	0.105	0.185	0.000	0.090
	1919	1918	0.126	–0.018	0.103	–0.014
	1932	1929	0.361	0.538	0.063	0.007
	1975	1971	0.240	–2.081	–0.479	2.67
	1983	1981	0.180	0.499	0.296	0.151
Colombia	None					
India	1877	1875	0.154	—	—	–0.065
	1896	1894	0.100	—	0.120	–0.060
	1918	1916	0.146	—	0.004	–0.061
	1948	1943	0.117	0.073	–0.058	0.082
Indonesia	1933	1930	0.114	0.406	—	–0.186
	1945	1940	0.545	—	—	0.044
	1999	1997	0.158	0.681	–0.066	0.440
Malaysia[e]	1904	1902	0.100	—	—	—
	1935	1929	0.193	—	—	—
	1937	1936	0.117	—	—	—
	1941	1939	0.235	—	—	—
	1947	1942	0.361	—	—	—
Mexico	*1915*	1909	0.119	—	—	0.031[j]
	1932	1926	0.314	0.406[k]	—	–0.025
	1988	1981	0.128	–0.148	0.024	0.852
Peru	1932	1929	0.258	0.105	—	–0.043
	1979	1975	0.104	0.325	—	0.437
	1983	1981	0.136	0.879	—	0.728
	1992	1987	0.325	0.519	–0.522	24.8
Philippines	1904	1903	0.158	—	—	0.234
	1915	1913	0.116	—	—	–0.109
	1935	1929	0.134	—	—	–0.038
	1946	1939	0.572	—	—	—
	1985	1982	0.187	0.736	–0.050	0.285
Singapore[e]	1904	1902	0.214	—	—	—
	1913	1910	0.337	—	—	—
	1916	1915	0.174	—	—	—
	1920	1917	0.235	—	—	—
	1927	1925	0.389	—	—	—
	1932	1929	0.412	—	—	—
	1938	1937	0.151	—	—	—
	1952	1950	0.345	—	—	0.192
	1957	1956	0.113	—	—	0.033
South Africa	1917	1912	0.229	0.139	—	0.031
	1920	1919	0.239	–0.200	—	0.009
	1987	1981	0.113	–0.156	0.006	0.147
	1993	1989	0.102	0.028	0.032	0.140
South Korea	1919	1918	0.111	—	—	—
	1939	1938	0.104	—	—	—

(*continued*)

Table C2. GDP Disasters (*Continued*)

Country	*Disaster period*		*Decline in GDP per capita*[b]	*Stock-price decline*[c]	*Rate of return on bills*[d]	*Inflation rate*[d]
	Trough[a]	*Peak*				
	1945	1940	0.480	—	—	—
	1951	1949	0.151	—	—	0.492
Sri Lanka	1878	1870	0.158	—	—	—
	1886	1883	0.141	—	—	—
	1923	1913	0.138	—	—	—
	1932	1929	0.147	—	—	—
	1946	1942	0.211	—	—	0.147
Taiwan	*1905*	1903	0.214	—	—	0.076
	1911	1910	0.114	—	—	0.082
	1945	1936	0.662	—	—	0.148
Turkey[e]	1927	1926	0.134	—	—	0.033
	1932	1931	0.122	—	—	–0.025
	1945	1939	0.395	—	—	0.283
Uruguay	1875	1872	0.269	—	—	—
	1881	1878	0.153	—	—	—
	1887	1886	0.140	—	—	–0.054
	1890	1888	0.202	—	—	0.181
	1901	1896	0.156	—	—	0.045
	1905	1904	0.122	—	—	–0.081
	1915	1912	0.280	—	—	0.057
	1920	1919	0.142	—	—	0.099
	1933	1930	0.367	—	—	–0.005
	1943	1939	0.139	—	—	0.033
	1959	1957	0.118	—	—	0.190
	1984	1981	0.236	—	—	0.338
	2002	1998	0.186	—	—	0.054
Venezuela	1892	1890	0.235	—	—	—
	1897	1893	0.225	—	—	—
	1907	1903	0.134	—	—	—
	1916	1913	0.167	—	—	0.025[m]
	1933	1930	0.162	0.074	—	–0.060
	1942	1939	0.155	–0.134	—	–0.003
	1961	1957	0.152	0.270	0.007	0.020
	1985	1977	0.295	0.616	–0.005	0.121
	2003	1993	0.259	0.690	–0.043	0.421

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Italics indicate that the country was a current participant in an external or internal war.

b. Decline in real GDP per capita by 0.1 or greater, expressed as a cumulative fraction from peak year to trough year.

c. Decline in real stock prices, expressed as a cumulative fraction from the end of the year preceding the peak to the end of the year preceding the trough (unless the timing is indicated otherwise because of missing data). Negative numbers indicate increases in real stock prices.

d. Mean values from the peak year to one year before the trough year (unless the timing is indicated otherwise because of missing data).

e. Not included in the analysis for the GDP sample.

f. 1914–17. g. 1915–17. h. 1938–40. i. 1934–35. j. 1909–13. k. 1929–31. m. 1914–15.

Table C3. Declines in Consumer Durables during Consumption Crises[a]

	Share of nominal durables in nominal consumer expenditure per capita				*Proportionate decline in real consumer expenditure per capita*		
	Trough		*Peak*				
Country	*Year*	*Share*	*Year*	*Share*	*Consumer expenditure*[b]	*Durables*	*Nondurables and services*
OECD countries							
Canada	1933	0.054	1929	0.085	0.230	0.507	0.201
Finland	1892	0.029	1890	0.042	0.102	0.132	0.101
	1918	0.010	1913	0.017	0.360	0.655	0.353
	1932	0.013	1928	0.030	0.199	0.636	0.182
	1944	0.019	1938	0.038	0.254	0.634	0.237
	1993	0.072	1989	0.138	0.140	0.512	0.062
Iceland	1969	0.101	1967	0.133	0.118	0.321	0.087
	1975	0.134	1974	0.181	0.107	0.340	0.043
	1993	0.102	1987	0.183	0.176	0.529	0.053
Portugal	1976	0.092	1974	0.101	0.098	0.195	0.091
Spain	1896	0.020	1892	0.018	0.182	0.063	0.185
	1915	0.020	1913	0.034	0.128	0.405	0.109
	1930	0.045	1929	0.057	0.101	0.238	0.090
	1937	0.022	1935	0.034	0.461	0.642	0.450
	1945	0.023	1940	0.019	0.145	−0.206	0.153
	1949	0.025	1946	0.027	0.131	0.170	0.127
United Kingdom	1918	0.040	1915	0.037	0.167	0.198	0.166
	1943	0.023	1938	0.049	0.169	0.649	0.144
United States	1921	0.094	1917	0.094	0.164	0.227	0.158
	1933	0.076	1929	0.119	0.208	0.501	0.169
Non-OECD countries							
Chile	1985	0.060	1981	0.098	0.327	0.695	0.179
Colombia	1999	0.088	1997	0.110	0.099	0.314	0.060
Mexico	1995	0.070	1994	0.082	0.113	0.340	0.077
South Korea	1998	0.063	1997	0.089	0.143	0.363	0.096
Turkey	2001	0.150	2000	0.195	0.108	0.315	0.056
Venezuela	1964	0.042	1957	0.079	0.223	0.581	0.184
	1989	0.047	1982	0.073	0.320	0.643	0.299
	2003	0.076	1993	0.081	0.147	0.478	0.105
Overall means		0.058		0.080	0.183	0.396	0.151

a. This table shows the universe of consumption crises considered in table C1 for which we have been able to break down the decline in real personal consumer expenditure per capita into durables, on the one hand, and nondurables and services, on the other. The latter category should be closer to "consumption." Of the twenty-eight consumer expenditure crises for which the necessary data are available, twenty are included in our main sample of ninety-five crises in table C1.

b. From table C1.

Table C4. Consumption Disasters Gauged by One-Sided Hodrick-Prescott Filters[a]

Country	*Disaster period*		*Decline in real personal consumer expenditure per capita*
	Trough[b]	*Peak*	
OECD countries			
Australia	1920	1913	0.202
	1935	1928	0.167
	1945	1938	0.215
Belgium	*1944*	1938	0.505
Canada	1923	1913	0.166
	1935	1930	0.136
Denmark	*1943*	1939	0.202
Finland	*1919*	1913	0.201
	1933	1929	0.105
	1944	1939	0.181
France	1874	1864	0.104
	1918	1913	0.185
	1944	1934	0.530
Germany	*1920*	1913	0.384
	1947	1940	0.356
Iceland[c]	1995	1988	0.096
Italy	*1946*	1940	0.221
Japan	*1936*	1928	0.123
	1946	1937	0.515
Netherlands	*1919*	1913	0.264
	1944	1934	0.487
Norway	None		
Portugal	None		
Spain	*1939*	1929	0.416
Sweden	1945	1940	0.106
Switzerland	1945	1940	0.142
United Kingdom	*1918*	1915	0.109
	1944	1939	0.160
United States	1934	1929	0.136
Non-OECD countries			
Argentina	1933	1929	0.141
	1990	1980	0.168
	2004	2000	0.149
Brazil	1992	1985	0.158
Chile	1917	1913	0.198
	1933	1930	0.247
	1978	1973	0.320
	1987	1981	0.157
Colombia[c]	1945	1941	0.095
India[c]	*1942*	1933	0.184
Malaysia[c]	1922	1917	0.297
	1934	1930	0.141

Table C4. Consumption Disasters Gauged by One-Sided Hodrick-Prescott Filters[a] (*Continued*)

	Disaster period		*Decline in real personal consumer expenditure per capita*
Country	*Trough*[b]	*Peak*	
Mexico	*1916*	1909	0.194
	1934	1926	0.240
	1988	1982	0.115
Peru	1914	1909	0.095
	1985	1976	0.205
	1993	1988	0.229
Singapore[c]	1916	1910	0.103
South Korea	*1947*	1942	0.325
	1952	1949	0.127
Taiwan	*1947*	1937	0.578
Turkey[c]	1946	1940	0.222
Uruguay[c]	1985	1981	0.189
	2004	2000	0.134
Venezuela[c]	1933	1930	0.499
	1971	1961	0.148
	1990	1982	0.331

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Analysis is based on one-sided Hodrick-Prescott filters for the logarithm of real consumer expenditure per capita, using a conventional smoothing parameter of 100. Declines are expressed as cumulative fractions from peak year to trough year.

b. Italics indicate that the country was a current participant in an external or internal war.

c. Not included in the analysis for the consumer expenditure sample.

Table C5. GDP Disasters Gauged by One-Sided Hodrick-Prescott Filters

	Disaster period		
Country	*Trough*	*Peak*	*Decline in real GDP per capita*
Australia	1897	1891	0.255
	1920	1913	0.109
	1933	1928	0.163
Austria	*1920*	1913	0.346
	1936	1930	0.226
	1947	1943	0.455
Belgium	*1919*	1913	0.436
	1935	1930	0.108
	1945	1938	0.426
Canada	1922	1917	0.191
	1935	1930	0.250
Denmark	*1943*	1939	0.165
Finland	*1919*	1914	0.225
France	*1919*	1913	0.208
	1938	1930	0.180
	1945	1939	0.310
Germany	*1920*	1913	0.321
	1933	1929	0.172
	1949	1944	0.663
Greece	1872	1862	0.200
	1898	1888	0.174
	1917	1912	0.260
	1945	1939	0.626
Iceland	1921	1915	0.189
Italy	*1946*	1940	0.267
Japan	*1949*	1943	0.439
Netherlands	*1919*	1914	0.174
	1935	1930	0.128
	1945	1939	0.426
New Zealand	1888	1879	0.116
	1933	1925	0.125
Norway	*1945*	1939	0.115
Portugal	None		
Spain	*1939*	1930	0.316
Sweden	1921	1916	0.131
Switzerland	1883	1876	0.110
	1919	1912	0.132
	1944	1934	0.127
United Kingdom	1923	1918	0.143
	1949	1944	0.109
United States	1934	1929	0.221
Non-OECD countries			
Argentina	1918	1912	0.248
	1934	1929	0.135
	1990	1980	0.201
	2003	1999	0.113

Table C5. GDP Disasters Gauged by One-Sided Hodrick-Prescott Filters (*Continued*)

Country	*Disaster period* — *Trough*	*Disaster period* — *Peak*	*Decline in real GDP per capita*
Brazil	1900	1891	0.175
Chile	1933	1930	0.201
	1977	1972	0.170
India	*1950*	1943	0.103
Indonesia	*1947*	1941	0.517
Malaysia[c]	1941	1931	0.184
Mexico	*1915*	1910	0.105
	1934	1926	0.243
Peru	1933	1929	0.137
	1985	1976	0.142
	1993	1987	0.269
Philippines	1988	1983	0.171
Singapore[c]	1916	1911	0.212
	1928	1925	0.153
	1932	1930	0.178
South Africa	1994	1984	0.156
South Korea	*1952*	1942	0.486
Sri Lanka	1923	1914	0.107
Taiwan	*1947*	1938	0.594
Turkey[c]	1945	1940	0.276
Uruguay	1901	1896	0.112
	1917	1913	0.176
	1935	1930	0.210
	1967	1957	0.169
	1986	1981	0.171
	2003	2000	0.105
Venezuela	1901	1895	0.109
	1963	1958	0.101
	1989	1979	0.298
	2003	1993	0.157

Source: Authors' construction; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. Analysis is based on one-sided Hodrick-Prescott filters for the logarithm of real GDP per capita, using a conventional smoothing parameter of 100. Declines by 0.1 or greater are expressed as cumulative fractions from peak year to trough year.

b. Italics indicate that the country was a current participant in an external or internal war.

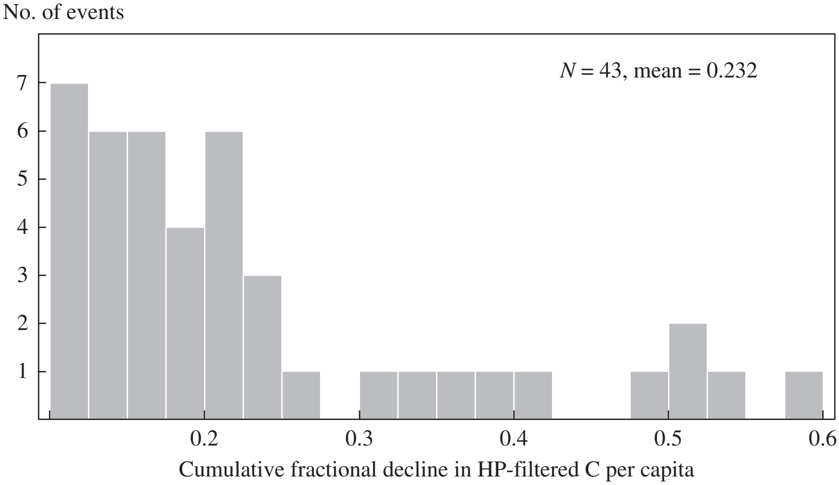
c. Not included in the analysis for the GDP sample.

APPENDIX D

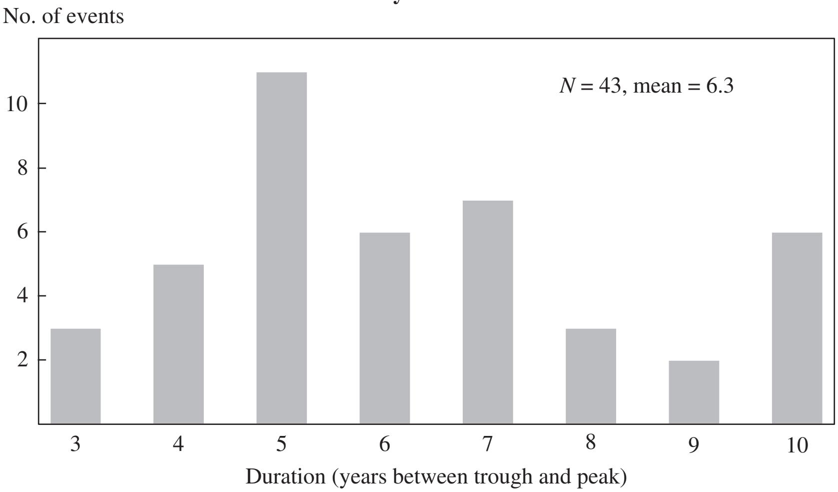
Distributions of Disasters Using Hodrick-Prescott-Filtered Data

Figure D1. Distributions of Consumer Expenditure Disasters by Size and Duration, One-Sided HP-Filtered[a]

By size



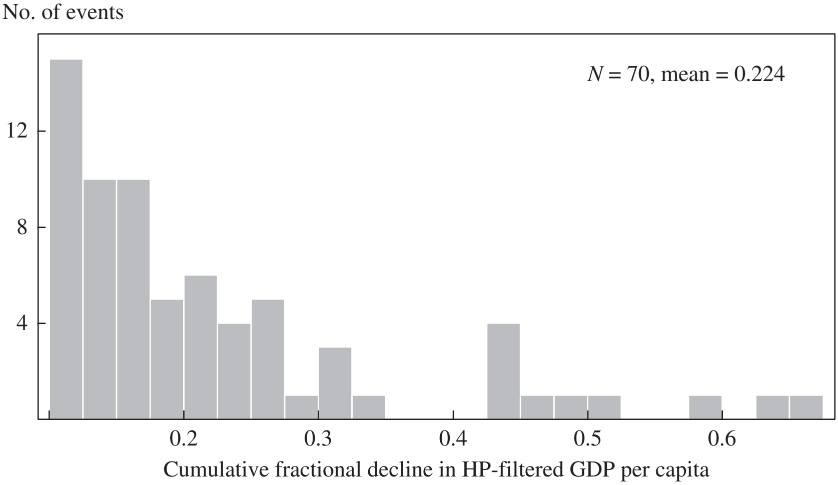
By duration

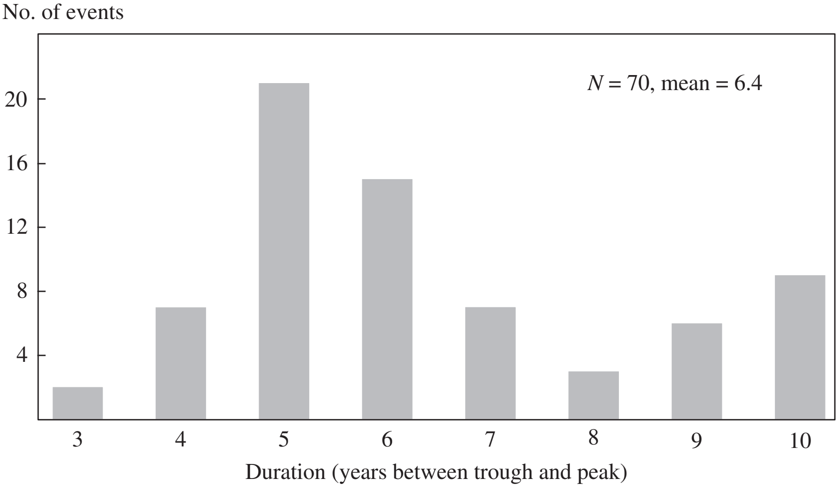


Source: Authors' calculation; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. The sample is the forty-three personal consumption expenditure disasters listed in table C4 in appendix C.

Figure D2. Distributions of GDP Disasters by Size and Duration, One-Sided HP-Filtered[a]





Source: Authors' calculation; for details on sources and procedures see the online appendix at www.economics.harvard.edu/faculty/barro/data_sets_barro.

a. The sample is the seventy GDP disasters listed as in the sample in table C5 in appendix C.

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Comments and Discussion

COMMENT BY

OLIVIER J. BLANCHARD Even if one is not deeply interested in the equity premium puzzle, this paper by Robert Barro and José Ursúa will prove extremely useful. Understanding the economic implications of disasters, whether natural or man-made, is both essential and fascinating. Like the celebrated Barro-Lee growth dataset, the dataset that the authors have carefully put together for this project will be widely used. I had fun playing with it, and so will others.

I shall organize my comments around two points. The first is that macroeconomic crises—what the authors call consumption and GDP disasters—come in very different forms, with different implications for output, consumption, and rates of return on bills, bonds, and stocks. The second is that if the focus is on the equity premium, and if one takes seriously the claim that the authors have now provided a representative sample of disasters, then looking at the determination of the equity premium through the lens of the Lucas model does not seem the best way to proceed.

THE MANY INCARNATIONS OF CONSUMPTION DISASTERS What I was most struck by, looking at the consumption disasters identified and documented by the authors, was how different these disasters in fact were one from another. As I went through the list, it became fairly clear that the disasters should be put in different boxes. Here is a tentative breakdown.

Wars on one's own soil. For obvious reasons, a war on one's own soil leads to a large decline in output and consumption. Part of the country is occupied by the enemy, and production in the rest is seriously disrupted.

I thank Antoine Bozio for information about the French stock market, Pedro Portugal for information about the Portuguese stock market, and the authors for providing me with their data.

The stock market, if it remains open, does poorly. Depending on the extent of rationing, inflation may be high; real bill returns are likely to be low.

A good example is France during World War II. From 1937 to 1944, output per capita in France decreased by 51 percent (using log differences); not until 1947 did it return to its 1937 level. From 1938 to 1943, consumption per capita decreased by 86 percent (this seems extremely large); not until 1949 did it return to its 1938 level.[1]

The German invasion closed the stock market. It reopened under the Vichy regime, but, not surprisingly, volume remained very low during the war.[2] (This raises the issue of what one should assume for stock returns when the market is closed. Could one reasonably argue that if one cannot sell one's stock, the rate of return in such years is −100 percent?) Leaving 1940 and 1941 aside, the average yearly rate of return on stocks from 1938 to 1947 was −10 percent.

Despite widespread rationing, average inflation in France during the war was high. From 1938 to 1944, annual inflation as measured by the consumer price index averaged 18.7 percent, leading to large negative bill and bond returns. (Rationing also raises the issue of whether it makes sense to use the first-order condition of consumers. This condition relies on a thought experiment in which a larger return on the asset allows one to increase consumption at the margin, but such an increase may not feasible under rationing.) As is often the case, the immediate postwar period was associated with a burst of inflation, leading to even larger negative bill and bond returns. Inflation from 1945 to 1948 averaged 58.7 percent, and bill and bond returns were negative and very large.

Wars on foreign soil. Wars on foreign soil have a very different economic profile. With the increase in defense spending, output is likely to increase, but its composition is likely to change drastically. Whether through rationing or through other means, consumption is likely to fall. After the initial bad news that a war is imminent, the stock market, pushed by defense stocks, is likely to do well. Depending on the form of rationing and the extent of forced saving, inflation is likely to rise, while nominal rates of return are kept low, leading to negative real bond returns.

The standard example here is the United States during World War II. From 1941 to 1945, U.S. output per capita grew by 34 percent. Consumption per capita dipped by 3 percent from 1941 to 1942 but was still 5 percent

1. All the numbers on GDP, consumption, and stock and bond returns cited in this comment are from the Barro-Ursúa database.

2. The authors assume that it was closed during both 1940 and 1941. My French historian friends tell me that it was closed only for a few weeks in 1940.

higher in 1945 than in 1941. The small consumption decrease in 1942 is not large enough to make the authors' "consumption disaster" list. Interestingly (and I return to this below), the United States does make the "GDP disaster" list in the 1940s, but, perhaps surprisingly, for the period 1944 to 1947, which includes the first two postwar years. The reason is the return of the U.S. economy from the wartime boom to a more normal level of output.

With the boom and the increase in defense spending, U.S. stock returns were high during the war. From 1941 to 1945, annual stock returns averaged 12 percent; from 1942 to 1945, they averaged 20.9 percent. Despite price controls, inflation ran at an average 5 percent a year from 1941 to 1945. Coupled with very low nominal interest rates aimed at limiting the burden of increasing government debt, the result was negative rates of return on government bonds. As in France, the immediate aftermath of the war was characterized by a burst of inflation, which reached 18 percent in 1946, leading to large negative returns on nominal assets.

Civil wars. Civil wars offer yet another pattern of co-movements among output, consumption, and stock and bond returns. A leftist revolution, for example, may lead to an initial shift in income distribution and an initial increase in consumption, followed later by lower output and lower consumption. Companies are likely to be nationalized, and stock returns are likely to suffer. Loss of government revenue is likely to lead to rapid money growth, high inflation, and large losses on nominal assets.

Portugal provides a nice example. In 1974, after a long dictatorship and the loss of Portugal's colonies, a bloodless coup put leftist colonels in charge. Political and economic turmoil ensued, together with large-scale nationalization of firms. Although output decreased marginally from 1973 to 1974, consumption increased by 7 percent (one may, however, reasonably question whether the consumption of stockholders increased as well). The measured labor share of income exceeded 100 percent of GDP, and so it is no great surprise that both output and consumption declined in the following years. Not until 1978 did they exceed their 1973 level.

Not surprisingly, the Portuguese stock market did not do well. The market was closed from April 1974 to February 1977. Measured stock returns were negative and large in 1978. But bill returns did not fare much better. Inflation averaged 20 percent a year from 1974 to 1978 and remained above 20 percent until 1985. Nominal interest rates were substantially lower, implying large negative real returns.

Other types of crisis, and some implications. One could go on. Another box would include fiscal crises. Fiscal crises accompanied by hyperinflations are likely to feature low output and low consumption. Stock returns may be dismal, but so are bill and bond returns. Here the German hyperinflation of 1923 is the obvious example. During this consumption disaster, as defined by the authors' dates, stock prices declined by 65.4 percent. But the real rate of return on bills was –97 percent. Another box would include banking crises, such as that in Finland in the early 1990s, and so on.

In going through these cases, I have done what Barro and Ursúa precisely do not want us to do. I have tried to think about each data point and told a specific story. The authors' interest is in general patterns and the use of a large sample of disasters to uncover them. This makes sense, however, only if all these disasters are realizations from the same underlying process. This seems unlikely. Conditioning on the probability of a war at home will not imply the same set of conditional correlations as conditioning on a war fought abroad; they imply very different patterns of correlations. And if the probabilities of these different events vary across countries and time, the implications of an unconditional approach are likely to be misleading.

To take an example, and venturing further than I should, it is likely that in the United States the probability of a war at home (say, the explosion of an atomic bomb) has decreased with the end of the cold war (conventional terrorism, including the use of "dirty" bombs, is unlikely to create disasters on the same scale). But one may argue that the probability of a war abroad has increased. One may also argue that the probabilities of a hyperinflation or a financial crisis have changed substantially over time. If this is the case, then the unconditional equity premium derived by the authors is likely to be misleading.

DO WE NEED THE LUCAS-TREE MODEL? Having collected their data, Barro and Ursúa analyze the data through the lens of a Lucas-tree model, augmented for a small annual probability of disaster à la Thomas Rietz. This requires them to estimate the probability of a disaster, p, and the size of the relative consumption disaster, b.

I do not understand why the authors force themselves to look at the data through this particular straightjacket. Doing so forces them to choose dates for the start and the end of each disaster, to ignore the length of the disaster, to make assumptions about returns on bills, and so on. The way in which they map the data onto the inputs of the model is sensible, and given the mapping constraint, they do the best job that one can, but the results are sometimes surprising. The choice, for example, of a peak-to-trough fractional decline larger than 10 percent as a criterion for consumption or GDP disasters seems perfectly reasonable. But it leads, for example, to defining a consumption disaster for France from 1938 to 1943, even though consumption remained below its 1938 value until 1949. (Recall that the high inflation and very low bill returns occurred from 1945 to 1948, thus after the authors' consumption disaster, but before consumption returned to its prewar level. This may be relevant to the way one thinks about asset pricing.) It also leads to defining a GDP disaster for the United States from 1944 to 1947, which might have come as a surprise to participants at the time. Given a mechanical rule, one has to accept the discipline of the rule, and the consequences. The question is whether the rule is needed.

The motivation for using the Lucas-Rietz model until now was twofold. The first was to clarify the potential role of low-probability events in asset pricing; the model is at just the right level between simplicity and complexity to give nontrivial insights. The second was that researchers lacked even a representative sample, much less a universe, of disasters to analyze. Thus one could not be too ambitious in describing correlations during crises, and the simple p and b approach seemed properly humble and transparent.

The point of this paper is, however, to provide a much larger sample, indeed the universe of consumption disasters that one can hope to measure. In this case I see no reason not to go back to asset pricing formulas that rely only on the first-order intertemporal condition of consumers with no additional assumptions. As is well known, this simplified condition can be written, for any asset, as

$$E(R) = \left[\frac{1}{E(M)}\right][1 - \text{cov}(M, R)],$$

where M is the marginal rate of substitution between consumption today and consumption in the next period, R is the gross rate of return on the asset—stocks, bills, or bonds—over the same period, and E(.) is a conditional expectation.

Given a specification of utility and thus of the marginal rate of substitution, that condition can be used to compute conditional or unconditional required returns on stocks, bills, and bonds and the implied equity premium. This computation does not require taking a stand on starting and ending dates for consumption disasters, nor does it require treating bills as riskless. It deals naturally with issues of disaster length, which are central to the computation in the Lucas-Rietz framework. It allows one to explore how the bursts of inflation that often follow consumption disasters are relevant to the equity premium. In short, it seems to simplify the task and to get around a number of the issues that arise under the current formalization. I hope the authors explore this route in the future.

COMMENT BY

GEORGE M. CONSTANTINIDES An important contribution of this paper by Robert Barro and José Ursúa is the compilation of a comprehensive database of real growth in consumption per capita for twenty-four countries and in GDP per capita for thirty-six, with data for some countries dating back to 1870. This database builds upon and greatly expands an earlier one by Angus Maddison on GDP growth and is, in its own right, an invaluable resource for future research.[1]

The paper's second contribution is to employ this database to revisit and expound on earlier investigations by Thomas Rietz and by Barro himself in understanding the role of rare but major economic disasters in the equity premium and the risk-free rate puzzles.[2] My discussion focuses on the latter contribution.

The equity premium puzzle, to use the term coined by Rajnish Mehra and Edward Prescott,[3] originally referred to the inability of the standard neoclassical economic theory to reconcile the historically large realized premium of stock market returns over the risk-free interest rate with its low covariability with aggregate consumption growth.[4] By now it is recognized that the challenge is actually a *dual puzzle* of the historical equity premium being too high (the equity premium puzzle) and the risk-free rate being too low (the risk-free rate puzzle), relative to the model predictions. The

1. Angus Maddison, *The World Economy: Historical Statistics* (Paris: Organization for Economic Cooperation and Development, 2003).

2.Thomas A. Rietz, "The Equity Risk Premium: A Solution," *Journal of Monetary Economics* 22, no. 1 (1988): 117–31; Robert J. Barro, "Rare Disasters and Asset Markets in the Twentieth Century," *Quarterly Journal of Economics* 121, no. 3 (2006): 823–66. Related papers include Jean-Pierre Danthine and John B. Donaldson, "Non-Falsified Expectations and General Equilibrium Asset Pricing: The Power of the Peso," *Economic Journal* 109, no. 458(1999): 607–35; Xavier Gabaix, "Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-finance," working paper, New York University, 2007; Christian Julliard and Anisha Ghosh, "Can Rare Events Explain the Equity Premium Puzzle?" working paper, London School of Economics, 2008; and Rajnish Mehra and Edward C. Prescott, "The Equity Premium: A Solution?" *Journal of Monetary Economics* 22, no. 1 (1988): 133–36.

3. Rajnish Mehra and Edward C. Prescott, "The Equity Premium: A Puzzle," *Journal of Monetary Economics* 15, no. 2 (1985): 145–61.

4. Early references include Sanford J. Grossman and Robert J. Shiller, "The Determinants of the Variability of Stock Market Prices," *American Economic Review* 71, no. 2 (1981): 222–27; Lars Peter Hansen and Kenneth J. Singleton, "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models," *Econometrica* 50, no. 5 (1982): 1269–86; and Philippe Weil, "The Equity Premium Puzzle and the Risk-Free Rate Puzzle," *Journal of Monetary Economics* 24, no. 3 (1989): 401–21.

research agenda has subsequently been expanded to encompass a number of empirical regularities in the prices of capital assets that are at odds with the predictions of standard economic theory, notably that the returns of various subclasses of financial assets are too large, too variable, and too predictable.[5] Several generalizations of essential features of the model have been proposed to mitigate its poor performance.[6]

In particular, Rietz entertained the possibility that rare but major economic disasters cause a large decline in consumption per capita. In theory, the prospect of such disasters gives rise to a significant equity premium, while leaving the risk-free rate low because of the precautionary demand for savings. Rietz calibrated economies that matched both the moments of the time-series process of consumption growth and the unconditional mean of the equity premium and the risk-free rate. He pointed out that the size of the annual (negative) consumption growth at the onset of an economic disaster needed to resolve the puzzle in his calibrated economies is of the same order of magnitude as the (negative) consumption growth *over the entire Great Depression.* He also pointed out that the model explains only a small fraction of the equity premium if one calibrates the annual (negative) consumption growth at the onset of an economic disaster to *annual* consumption growth over the Great Depression.[7] Rietz's model fell by the wayside until recently revived by Barro.[8]

The thesis in that paper and in the present one is that a more careful calibration of the model implies that major economic disasters explain most

5. This extensive literature is reviewed in a collection of essays edited by Rajnish Mehra, *Handbooks in Finance: Handbook of the Equity Risk Premium* (Amsterdam: Elsevier, 2008); in textbooks by John Y. Campbell, Andrew W. Lo, and A. Craig MacKinlay, *The Econometrics of Financial Markets* (Princeton University Press, 1997) and by J. H. Cochrane, *Asset Pricing* (Princeton University Press, 2005); and in several articles, including John Y. Campbell, "Consumption-Based Asset Pricing," in *Handbook of the Economics of Finance,* vol. IB: *Financial Markets and Asset Pricing,* edited by George M. Constantinides, Milton Harris, and Rene Stulz, Handbooks in Economics vol. 21 (Amsterdam: North-Holland, 2003); John H. Cochrane and Lars Peter Hansen, "Asset Pricing Explorations for Macroeconomics," *NBER Macroeconomics Annual* 7 (1992): 115–65; George M. Constantinides, "Rational Asset Prices," *Journal of Finance* 57, no. 4 (2002): 1567–91; and Rajnish Mehra and Edward C. Prescott, "The Equity Premium in Retrospect," in *Handbook of the Economics of Finance,* vol. IB: *Financial Markets and Asset Pricing.*

6. These include idiosyncratic income shocks in incomplete markets; alternative assumptions about preferences; distorted beliefs and learning; market imperfections; liquidity risk; better understanding of data problems such as limited participation of consumers in the stock market; temporal aggregation; regime shifts; and the survival bias of the U.S. capital market.

7. Barro, "Rare Disasters and Asset Markets in the Twentieth Century." See also the discussion in Mehra and Prescott, "The Equity Premium: A Solution?"

8. Barro, "Rare Disasters and Asset Markets in the Twentieth Century."

of the observed equity premium. Barro and Ursúa's central argument is that one should calibrate the consumption decrease over the first year of the disaster to the measured cumulative consumption decrease from peak to trough of the disaster period. They motivate this approach with the observation that the incidence of negative shocks to consumption growth increases upon the onset of the economic disaster. Although I recognize the validity of their observation, I explain below why I disagree with their calibration and conclude that a correctly calibrated model, such as that of Rietz, explains only a small fraction of the observed premium.

Before I describe the specifics of the authors' model and discuss it in detail, let me explain in broad terms why I disagree with their central argument. I begin, as they do, with the standard neoclassical economic model, as adapted in finance. In a single-good economy, the representative consumer chooses consumption plan $\{C_t\}_{t=0,1,\ldots}$, subject to a budget constraint, and maximizes expected utility $E_0\left[\sum_{t=0}^{\infty}\beta^t C_t^{1-\gamma}\right]$ with a constant relative risk aversion coefficient γ and a subjective discount factor β.[9] Let $R^j_{t,t+1}$ be the total return on the j^{th} asset from time t to time $t + 1$. If (C_t, C_{t+1}) is the optimal consumption plan at times t and $t + 1$, then the feasible consumption plan $(C_t - \delta, C_{t+1} + \delta R^j_{t,t+1})$ maximizes expected utility with respect to δ at $\delta = 0$, where δ is saving in period t. This variational argument leads to the standard Euler equation of consumption between times t and $t + 1$,

$$E_t\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} R^j_{t,t+1}\right] = 1, \tag{1}$$

as in the authors' equation 4.

Suppose that time t signifies the onset of an economic disaster. Then the Euler equation between times t and $t + 1$ depends on the conditional distribution of consumption growth at time t, C_{t+1}/C_t, between times t and $t + 1$ and on total return, $R^j_{t,t+1}$, between times t and $t + 1$. Note that this derivation remains valid even if the consumption growth series, C_{t+1}/C_t, C_{t+2}/C_{t+1}, . . . , is autocorrelated.

9. Barro and Ursúa also entertain Epstein and Zin preferences; see Larry G. Epstein and Stanley E. Zin, "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis," *Journal of Political Economy* 99, no. 2 (1991): 263–86. Their Euler equation 4 holds with Epstein-Zin preferences only if consumption shocks are i.i.d. However, Barro and Ursúa assume that upon the onset of an economic disaster, the shocks are correlated. For their Euler equation 4 to remain valid, it is necessary to limit discussion to utility $\sum_{t=0}^{\infty}\beta^t C_t^{1-\gamma}$.

By contrast, Barro and Ursúa argue that upon the onset of an economic disaster, annual consumption growth over the peak-to-trough period of the disaster is highly autocorrelated and that one should replace one-year consumption growth, C_{t+1}/C_t, in the standard Euler equation with the measured cumulative consumption decrease from peak to trough, for example, C_{t+4}/C_t for a four-year decline, as

$$\text{(2)} \qquad E_t\left[\beta\left(\frac{C_{t+4}}{C_t}\right)^{-\gamma} R^j_{t,t+1}\right] = 1.$$

This is the Euler equation that Barro and Ursúa implicitly apply upon the onset of an economic disaster. They provide no formal derivation of equation 2, and I believe that this equation is incorrect. In a technical sense, this Euler equation concentrates and magnifies the effect of an economic disaster and thus generates a much higher premium than equation 1 does (an observation made earlier by Rietz).

The correct version of the Euler equation with the measured cumulative consumption decrease from peak-to-trough (four-year) consumption growth, C_{t+4}/C_t, is

$$\text{(3)} \qquad E_t\left[\beta\left(\frac{C_{t+4}}{C_t}\right)^{-\gamma} R^j_{t,t+4}\right] = 1.$$

This equation states that the Euler equation on four-year consumption growth addresses the four-year return.

As I will show later, the authors' baseline consumption case (the first row in their table 10) says that their model of economic disasters generates a premium of 0.059 − 0.01, or 4.9 percent, over 3.6 years. However, the historical equity premium over a holding period of 3.6 years is approximately 3.6 × 6 percent = 21.6 percent.[10] Thus, the authors' model of economic disasters explains 4.9 ÷ 21.6 ≈ 0.227, or less than a quarter, of the historical equity premium.

Let me now turn to the authors' formal model. Each year the economy is in either a normal state (N) or a disaster state (D). The sequence of states at the annual frequency is a Markov chain. The transition probability in one year from N to D is p (and that from N to N is $1 - p$); the transition probability in one year from D to N is π (and that from D to D is $1 - \pi$).

10. See, for example, George M. Constantinides, "Rational Asset Prices," *Journal of Finance* 57 (August 2002): 1567–91, for estimates of the historical equity premium.

One easily calculates the unconditional probability of a year being in state N as $P_N = \pi/(\pi + p)$ and that of being in state D as $P_D = p/(\pi + p)$. The annual probability of the onset of a disaster is $\pi \times p/(\pi + p)$, and the expected length of a disaster is π^{-1} years.

In their baseline case, Barro and Ursúa observe that the sample mean length of disasters is 3.6 years. Therefore, I set $\pi = (3.6)^{-1} = 0.278$, which agrees with their value of 0.277 in table 10. They observe 343 disaster years out of a total of 2,963 years across countries. Therefore, I set the unconditional probability of a disaster year as $P_D = p/(\pi + p) = 343/2{,}963 = 0.1158$, which, combined with $\pi = 0.278$, gives $p = 0.0364$. This value of p is approximately equal to the authors' value of 0.0363 in table 10. Thus, the authors and I are in agreement regarding the calibration of the Markov chain in the baseline case.[11]

Note that the Markov chain and its calibration already accommodate the observation that the incidence of consumption growth shocks is highly correlated during a disaster: whereas the unconditional probability of a disaster year is $P_D = 0.1158$, the probability conditional on the previous year being a disaster year is $1 - \pi = 1 - 0.278 = 0.722$. I argue later on that Barro and Ursúa double-count this correlation.

Barro and Ursúa assume the following process for *annual* consumption growth:

$$\log C_{t+1} - \log C_t = g + u_{t+1} + \upsilon_{t+1}, \tag{4}$$

where u_{t+1}, υ_{t+1} are i.i.d., $u_{t+1} \sim N(0, \sigma^2)$, $\upsilon_{t+1} = 0$ if $t + 1$ is a normal year, and $\upsilon_{t+1} = \log(1 - b)$ if $t + 1$ is a disaster year. If t is a normal year, then the probability that $t + 1$ is a normal year is $1 - p$, and the probability that it is a disaster year is p; if t is a disaster year, then the probability that $t + 1$ is a normal year is π, and the probability that it is a disaster year is $1 - \pi$. Thus, Barro and Ursúa model annual consumption growth as a process that is *not* i.i.d., contrary to their claim: "However, Barro shows that with i.i.d. shocks (as in the present model), the first-order optimizing conditions generate asset pricing equations of familiar form."

Barro and Ursúa set the probability that $u_{t+1} = \log(1 - b)$ equal to $p = 0.0363$ in the baseline. Recall, however, that p was earlier defined as the transition probability in one year from N to D. The probability that $\upsilon_{t+1} = \log(1 - b)$ should be set equal to the *unconditional* probability of a disaster year, $P_D = p/(\pi + p) = 0.1158$.

11. Note that this calibration does not account for estimation error and, in particular, the correlation of economic disasters across countries.

A critical issue is the *size* of the *annual* consumption growth shock in a disaster year, $\upsilon_{t+1} = \log(1 - b)$. Barro and Ursúa assume that the peak-to-trough shock occurs in the first year of a disaster. This assumption is not supported by the data over the two primary consumption disaster periods in the United States, 1917–21 and 1929–33. Over 1917–21, the arithmetic annual total real consumption growth, $[(C_{t+1}/C_t) - 1] \times 100$, is −2.6 percent, −3.7 percent, −4.6 percent, and −6.4 percent in 1917–18, 1918–19, 1919–20, and 1920–21, respectively.[12] The most important feature of these data is that the consumption decline in the first year of the disaster period is the smallest annual decline over the 1917–21 period and accounts for only a fraction of the total consumption decline. Likewise, over the period 1929–33 the arithmetic annual total consumption growth, $[(C_{t+1}/C_t) - 1] \times 100$, is −6.4 percent, −3.9 percent, −9.5 percent, and −2.8 percent in 1929–30, 1930–31, 1931–32, and 1932–33, respectively. As before, the consumption decline in the first year of the disaster period accounts for only a fraction of the total consumption decline. Similar observations apply to data on nondurables consumption. These observations do not support the authors' calibration that treats the peak-to-trough consumption decline as if it occurs in the first year of the disaster period.

Given the above observations and the Markovian nature of the authors' model, I proceed to calibrate the fractional decline in annual consumption b if the end of the year is a disaster year. The expected cumulative peak-to-trough consumption ratio is

$$(5) \qquad E\left[\sum_{n=1}^{\infty} \pi(1-\pi)^{n-1}(1-b_1)(1-b_2)\ldots(1-b_n)\right] = \sum_{n=1}^{\infty} \pi(1-\pi)^{n-1}\left(1-\bar{b}\right)^n = \frac{\pi\left(1-\bar{b}\right)}{1-(1-\pi)\left(1-\bar{b}\right)}.$$

For this calculation I rely on the authors' assumption that the shocks $(1 - b_1)$, $(1 - b_2)$, . . . , $(1 - b_n)$ are i.i.d.

12. In private communication, the authors kindly provided the data for total consumption growth and nondurables consumption growth over 1917–21 and 1929–33. I draw similar conclusions by using consumption data on nondurables and services from John Campbell's website (www.economics.harvard.edu/faculty/campbell) and by using consumption data from Robert Shiller's website (www.econ.yale.edu/~shiller/data.htm) that include durables in the definition of consumption.

In the authors' baseline case, they assume that the expected cumulative trough-to-peak consumption ratio is $1 - 0.219 = 0.781$. Setting $\pi(1 - \bar{b})/[1 - (1 - \pi)(1 - \bar{b})] = 0.781$ and $\pi = 0.278$, I obtain $1 - \bar{b} = 0.928$. As a back-of-the-envelope calculation, note that with the sample mean length of disasters being 3.6 years, the expected cumulative trough-to-peak consumption ratio is roughly $(0.928)^{3.6} = 0.764$, which is very close to 0.781.

Barro and Ursúa assume for convenience that "equity" or the "stock market" is the claim to the future consumption stream. Effectively, they assume that the capitalized value of future labor income is either zero or included in "equity." This assumption conveniently allows one to bypass the need to specify the conditional return distribution on the equity. Although this assumption is counterfactual, it is a common assumption in the early literature on the equity premium and I leave it at that.

Barro and Ursúa state the Euler equation of consumption between dates t and $t + 1$ for the equity return and the risk-free rate in their equations 6 and 7, respectively. I take the difference of these equations and obtain the premium as follows:

$$(6) \qquad r^e - r^f = \gamma\sigma^2 + p\left[\mathrm{E}(1-b)^{-\gamma} - \mathrm{E}(1-b)^{1-\gamma} - \mathrm{E}b\right].$$

If b were constant, equation 6 would simplify to $r^e - r^f = \gamma\sigma^2 + p\{b[\mathrm{E}(1 - b)^{-\gamma} - 1]\}$. This is the same as equation 8 in the paper. However, the authors do not assume that b is constant, and therefore their equation 8 is incorrect.

Even after this correction, another correction needs to be made in my own equation 6. Based on my discussion above, I correct equation 6 by replacing p with $p/(\pi + p)$, the unconditional probability of a disaster state at the end of the year, and state it as follows:

$$(7) \qquad r^e - r^f = \gamma\sigma^2 + \frac{p}{(\pi + p)}\left[\mathrm{E}(1-b)^{-\gamma} - \mathrm{E}(1-b)^{1-\gamma} - \mathrm{E}b\right].$$

As I argued above, $1 - b$ should be thought of as the one-year consumption ratio in disaster years and not as the cumulative trough-to-peak consumption ratio in these years. Since I do not have the moments for $\mathrm{E}(1 - b)^{-\gamma}$ and $\mathrm{E}(1 - b)^{1-\gamma}$ either over one year or over the cumulative trough-to-peak period, I do a calibration in the special case where b is constant. The point of this exercise is to demonstrate that the authors' approach and mine yield results that differ by an order of magnitude, when in both cases b is treated as constant. In both cases I set $\gamma = 3.5$, $p = 0.0363$, and $\pi = 0.278$ and suppress the term $\gamma\sigma^2$, as the authors do.

First, I consider the authors' approach. When I set $1 - b = 0.781$, equation 7 yields an annual equity premium $r^e - r^f = 0.0348$. By contrast, when I set $1 - b = 0.928$, which I argued is the correct way to think about the annual shock in a disaster state, equation 7 yields an annual equity premium $r^e - r^f = 0.0025$. Although both numbers are small because I have suppressed uncertainty about b for reasons of convenience, the point is that the premium 0.0025 is less than one-tenth of the premium 0.0348. I recommend that the authors provide the annual moments for $E(1 - b)^{-\gamma}$ and $E(1 - b)^{1-\gamma}$ and repeat the above comparison without the assumption that b is constant.

As I argued above, there is an alternative and intuitive way to make the same point. I finesse the controversial issue as to whether the entire shock to consumption occurs in the year of onset of the disaster or is distributed over all years of the disaster, by choosing the length of one period in the model to be 3.6 years instead of one year. In this case it does not matter which year during the disaster period is the year in which consumption drops. Then the baseline case in the authors' table 10 says that their model of economic disasters generates a premium of 0.059 − 0.01, or 4.9 percent, over 3.6 years. However, the historical equity premium over a holding period of 3.6 years is, as noted above, approximately $3.6 \times 6 = 21.6$ percent, which again is less than a quarter of the historical equity premium.

Barro and Ursúa do not provide empirical evidence to support giving special status to one year as the length of time over which the entire shock to consumption occurs upon the onset of a disaster. Had they instead picked one month as the critical period, the modified calibration above would predict a one-month premium of 4.9 percent, which is almost ten times the historical one-month premium of $6/12 = 0.5$ percent.

I have argued that Barro and Ursúa do not deliver a convincingly calibrated model of economy-wide disasters that explains a substantial fraction of the historically observed equity premium. The reason is that the *annual* drop in consumption during these disasters is too small to explain the premium, even after allowing for the fact that the incidence of negative shocks to consumption growth increases upon the onset of an economic disaster. The authors' device of attributing the entire peak-to-trough drop in consumption to the year of onset of the disaster is simply counterfactual and double-counts the increased incidence of negative shocks to consumption growth after the onset of the disaster. In a recent empirical study, Christian Julliard and Anisha Ghosh find that economy-wide disasters, along the lines of Barro's 2006 paper and the present one, do not explain the cross section of asset returns.[13]

There is, however, an alternative interpretation of economic disasters, namely, as periods where the incidence of large negative *idiosyncratic* income shocks increases *at the household level.*[14] These shocks may largely wash out at the aggregate level and may not even show up in aggregate consumption data. Nevertheless, these shocks potentially play a major role in the pricing of financial assets through the household Euler equations of consumption, provided they are persistent and uninsurable. Given that markets provide grossly incomplete consumption insurance, models that account for these shocks show promise for understanding the source of the equity premium and of the premia of subclasses of financial assets.

GENERAL DISCUSSION Robert Hall commented on the history of the equity premium literature, starting with Lars Peter Hansen and Kenneth Singleton's 1983 paper on the temporal behavior of asset returns. He suggested that one could measure the progress of this literature by the plausibility of the coefficient of relative risk aversion required to match the equity premium. Papers such as this one tend either to overestimate the relative risk aversion coefficient or to fail to explain the equity premium. He suggested that the authors' relative risk aversion coefficient of 3.5 was unreasonably high.

William Brainard noted that international portfolio diversification is substantial and has fluctuated greatly since the late nineteenth century. The authors' assumption that economies are closed greatly simplifies the analysis but may bias the results. For example, it presumably overstates the risk

13. Julliard and Ghosh, "Can Rare Events Explain the Equity Premium Puzzle?" working paper, London School of Economics, 2008.

14. Such models were suggested by Mehra and Prescott in an early draft of their 1985 paper, "The Equity Premium: A Puzzle," working paper, Carnegie-Mellon University, 1980; and by N. Gregory Mankiw, "The Equity Premium and the Concentration of Aggregate Shocks," *Journal of Financial Economics* 17, no. 1 (1986): 211–19. George M. Constantinides and Darrell Duffie, "Asset Pricing with Heterogeneous Consumers," *Journal of Political Economy* 104, no. 2 (1996): 219–40, introduced such a model in an intertemporal economy. Alon Brav, George M. Constantinides, and Christopher C. Geczy, "Asset Pricing with Heterogeneous Consumers and Limited Participation: Empirical Evidence," *Journal of Political Economy* 110, no. 4 (2002): 793–824, provided empirical support for the model. See also Tom Krebs, "Testable Implications of Consumption-Based Asset Pricing Models with Incomplete Markets," *Journal of Mathematical Economics* 40, no. 1–2 (2004): 191–206.

faced by a typical investor and therefore understates the degree of risk aversion required to rationalize observed risk premia.

Christopher Sims observed that high rates of risk aversion may not be needed to explain asset pricing paradoxes. Instead, it is possible that disasters follow different probability distributions. Because these events are so rare, however, it is difficult to measure this with confidence. The authors' figure 1 caps the disaster size at 70 percent, but it is unclear whether the distribution tapers off slowly toward this maximum or falls off sharply. These two behaviors have wildly different implications for asset pricing. Therefore, experimenting with different probability distributions would be useful.

William Nordhaus cited research on the probability distributions of other war statistics, such as the number of fatalities, and suggested that consumption shocks might be similarly distributed. He said that these variables seem to follow Cauchy distributions, which is problematic because standard estimation techniques then do not work: variances and means are infinite. Nordhaus also noted that the authors assumed that disasters led to permanent level shifts in consumption, and this applied even to cases of large wars. The authors' figures suggested trend reversion following each of the major wars, so the consumption shock would be overestimated under the assumption of a permanent shock.

Lawrence Summers pointed out that consumption and asset returns in many of the countries in this dataset are highly correlated during major crisis periods such as World War II. He questioned the value of including highly correlated observations, which may not add any more information than, say, dividing North and South Carolina into separate observations in a U.S. dataset.

Summers also wondered whether the Euler equation makes sense during wars: consumption is rationed, so the marginal utility of income cannot be inferred from observed consumption. Similarly, in periods of financial crisis, international capital flows and exchange rate movements can make it difficult to accurately assess the behavior of asset markets. For example, during the Mexican financial crisis of 1995, the peso collapsed but the Mexican stock market appeared to rally. The reason was that the stock market was priced in dollars, and because the peso was falling faster than stock prices, the dollar value of stocks increased. Stock prices may therefore have provided an inaccurate description of what was happening in Mexican asset markets during this period. David Romer wondered whether asset returns were measured accurately during periods of hyperinflation, and whether the authors had been successful in dealing with periods of default. A few observations where the rate of return on government bonds was close to minus 100 percent might affect the picture dramatically.