Appendix 1: Underlying Data

Pre-World War I Indices

There are five different stock price indices available for the pre-World War I German stock market.

The index that covers the earliest time period is that of Däbritz, reprinted in Donner (1934). From 1925 on, Däbritz was the director of the *Institut für Konjunkturforschung* "West" in Cologne. As part of his business cycle research program, he calculated ratios of share value to registered capital over the period 1856-1870 for a relatively small number of publicly-traded companies.

There are two major shortcomings in Däbritz's index from our perspective. The first is that it is not a portfolio index at all. Instead, Däbritz's index is an average of ratios of market to par value for the corporations in the index. This means, first, that changes in the index are not capital gains or losses on a portfolio: the index value jumps when a new stock is added or an old stock dropped from the sample. Second, Däbritz did not collect any index of the dividends paid or the average yield on the stocks that make up his index.

The first of the pre-World War I indices ranked by the date of its composition is that of Dermietzel (1906). Dermietzel sought to advance the literature on the determinants of corporate profitability that had been started by Körösy (1901). He collected company specific dividend and share price statistics for German corporations between 1876 and 1902. Dermietzel (1906) himself, following his model Körösy, reports as his primary statistic the absolute value of all shares of all companies on the exchange. Dermietzel also reports the par values of the companies'

registered capital, and so his index can be converted into an index of price relative to par value of a definition similar to that of Däbritz.

The Dermietzel index covered a very large sample of more than one hundred companies by the end of the nineteenth century. Even at its beginning in 1876, it still covered more than forty companies.

A slightly later study by Albert (1910) contains yet a third index, once more not a "portfolio" index but instead a ratio of market to par values. Albert's index is an average of individual stock price series for eleven companies over the period 1895 to 1908.

Albert's series is itself derivative. He compiled his tables from two sources. From 1895-1899 he averaged monthly numbers in Neumann's share price tables for the Berlin exchange. From 1900-1908 he used Conrad's article "Volkswirtschaftliche Chronik" in the *Handwörterbuch der Staatswissenschaften*.[1]

The first of the true portfolio indices ranked by date of composition was constructed by Wagemann and published in the *Wochenberichte* of his *Institut für Konjunkturforschung* in 1929. He was the founder (in 1925) of the Berlin *Institut für Konjunkturforschung*—a different "Institute for Business Cycle Research" than the *Institut für Konjunkturforschung* "West" of which Däbritz was head. Däbritz's institute was a largely independent but formally subsidiary branch of Wagemann's. Wagemann's organization was a Berlin-based non-profit, "free think-tank" for business cycle research. It was supported by the Weimar Republic's ministries and by private industry. It shared many of its personnel with the National Statistical Bureau, the *Statistisches*

[1]The companies in Albert's sample are the Gelsenkirchener Bergbau, Harpener Bergbau (coal), Bochumer Gußstahl, Königs- und Laurahütte (steel), Berliner Maschinen bau Gesellschaft (machinery), Hamburg-Amerika Paket Fracht, Norddeutscher Lloyd (shipping), Stettiner Vulkan (shipbuilding), the Deutsche Bank, and the Diskonto Kommandite Gesellschaft (banking).

Reichsamt.[2] Wagemann's principal interest, however, was not so much in tracking the stock market as in capturing short-run fluctuations that would be useful for predicting the course of the business cycle.

The second of the true portfolio indices is that of Donner (1934). Donner (1934) is certainly the most ambitious German contribution to the international debate on the causes of stock market fluctuations that sprang up after the 1929 crash. He seeks to determine the economic causes of German stock market fluctuations, thus following the track of Prion (1929). Donner put together a monthly index covering the period from January 1870 to December 1913 by taking averages weighted by their market capitalizations of stock price changes. His work was published by Wagemann in the Quarterly Supplements to the reports of his *Institut für Konjunkturforschung*.

Donner takes pains to purge his index of the effects of new share issues, and of the inclusion and exclusion of companies. Donner excludes from his calculations of month-to-month price changes any company that issues new shares (and, more likely than not, offers them at below market values to existing shareholders), is added to the index, or drops out of the index.

Donner's indices are superior to those of his contemporaries both from the point of view of coverage and from the point of view of the sophistication of their construction. The earlier indices compiled by Albert and others were simple calculations of the total market value of shares or of averages of share prices across companies.[3] Unlike Donner

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[2]Wagemann compares his Institut für Konjunkturforschung with similar institutions in the United States—like the Harvard Economic Service, Wesley Clair Mitchell's National Bureau of Economic Research, the Institute of Economics in Washington (a piece of what was to become Brookings), and the Russian "Business Cycle Service" run by Kondratieff before his arrest and execution under Stalin. Unlike the Americans, whom Wagemann characterized as "engineers," or the Russians, whom he called "astronomers," the Germans were supposed to follow an "organic-biological" methodology for research and forecasting—collecting and reporting as many economic time series as possible and combining them into "barometers" of economic activity.

[3]German securities laws required that all shares of stock have a par value of 100 marks. Averages of stock prices

(1934), their indices made no attempt to correct for new issues of stock, or for the entry of new firms into the sample. Donner (1934) assembles period-to-period price changes for his index by taking the weighted average of price changes for firms that are quoted in both periods and do not issue any new shares.[4]

Donner's index covers only twelve companies from 1870 to 1875. The number of companies covered rises over time, reaching twenty-one by 1876 and nearly sixty by 1890. This rise in the number of companies proceeds alongside a shift mix of industries represented. The original twelve companies covered in 1870 include four banks, four railroads, and four mining companies.[5] Railroads disappear from the index with their nationalization in 1890. Companies in other industries are added as the industrialization of Germany proceeds.[6] Especially in the years from 1890 on, the Donner index is a cross section of Germany's largest companies, weighted toward the heavy industries in which Germany's companies were largest and its international comparative advantage greatest.

Alongside his stock price index Donner reports a yield index for his sample. His yield index is available only on an annual basis: Donner believed that examining dividends at any frequency finer than an annual one ran the unacceptable risk of conflating real shifts in payout rates with shifts induced by changes in the timing of payments.

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are thus averages of nominal prices relative to par values as well.

[4]Such a procedure is potentially subject to a different bias because firms that go bankrupt and exit the sample will be omitted. But the only firms that exit Donner's sample are the German railroads. Donner makes a special correction for these railroads, which exit the sample not because of bankruptcy but because of nationalization.

[5]Two of the mining companies—the Bochumer Verein für Bergbau and Gußstahlfabrik and the Hoerder Bergwerks- und Hüttenverein—also had metal fabrication or railway divisions.

[6]On the eve of World War I, the index covers eight banks, two shipping companies, fourteen mining and steel producers, four electrical machinery manufacturers, four utilities, nine metalworking manufacturers, six in chemicals, seven in textiles, two in paper and wood products, three makers of building materials, two construction companies, three glass and porcelein manufacturers, and four breweries.

Figure A.1
Pre-World War I German Stock Price Indices Available

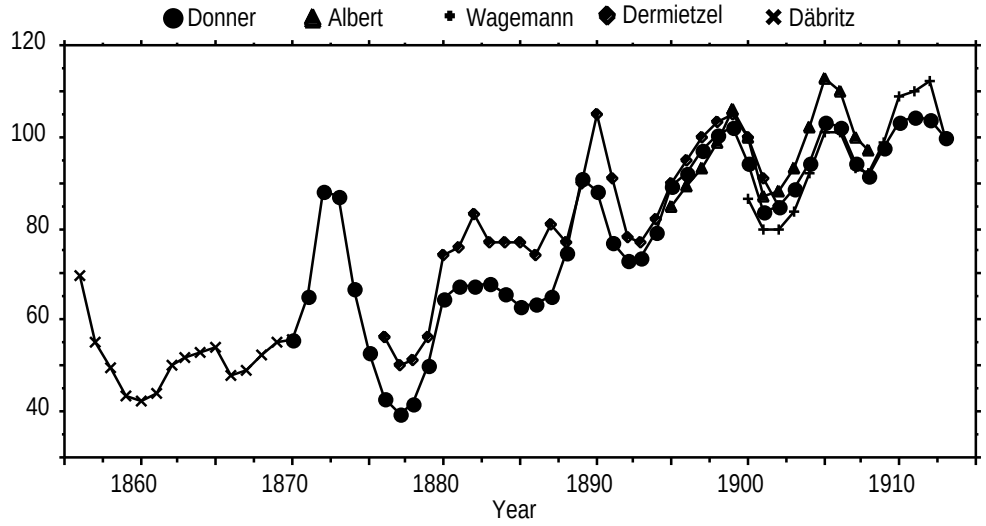


Figure A.2
Donner Dividend Yield Series

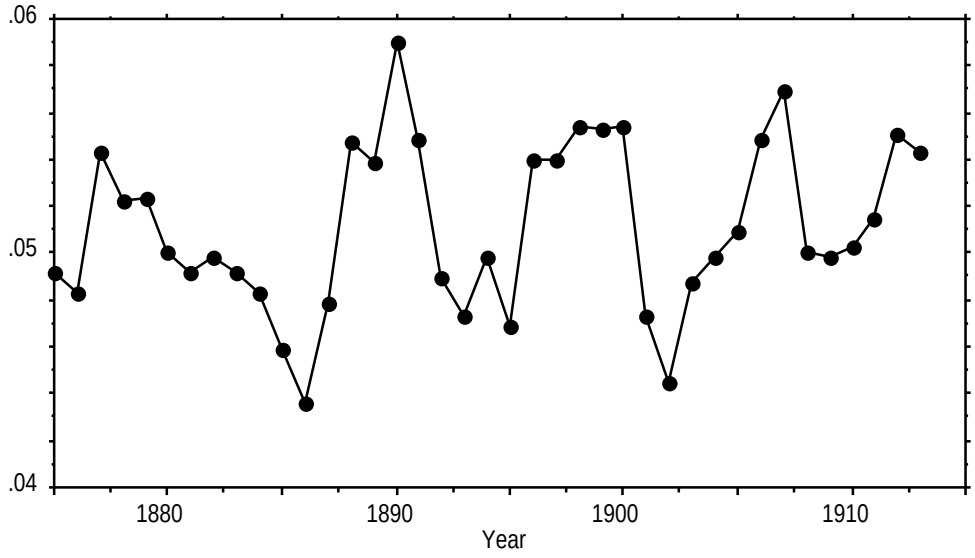


Figure A.1 graphs the nominal values of the five stock price indices available for the pre-World War I era. As can be readily seen, they track each other relatively closely. Especially after 1876—when Donner's index consists of more than twenty and Dermietzel's index of more than forty companies—it is possible to be confident that the indices do capture fluctuations in the German market. Before 1876 it is not so clear that this

is the case, and dividend indices are not available before 1870. Thus the empirical work in the body of the paper begins in 1876.

Figure A.2 plots Donner's annual dividend yield series for the pre-World War I period. As noted above, dividend yield fluctuations are contained within a relatively narrow band—between 4.3 and 5.9 percent.

Interwar Series

Donner's index ends on the eve of World War I. During the interwar period the *Statistisches Reichsamt* (National Bureau of Statistics), the official statistical bureau of first the democratic Weimar Republic and then the Third Reich, constructed a portfolio-based index covering the period from 1914 up to the 1923–24 hyperinflation. Its construction is outlined in the official *Wirtschaft und Statistik* (see Statistisches Reichsamt, 1922a, 1922b). This is the first, official stock market index for Germany.

The Reichsamt sought an indicator that would allow "first, to measure stock market trends in terms of some average, second, to show the effect of inflation on stock market prices" (1922a:168). A three-page article describes the index, constructed by averaging the prices of 300 companies, with weights corresponding to December 1913.

This first *Reichsamt* index is of the Laspeyres type. Its weights are derived from the registered capital of all German corporations, including those not traded on the stock exchange. The companies are divided into 33 industrial groups, the industry average is then calculated as an arithmetic average of share prices, and the market average is then calculated as a weighted average of the industry averages. This index

takes account of *Bezugsrechte*—the preferential right of existing shareholders to purchase new share issues on favorable terms.[7]

In 1928, the previous stock market index was revised: the distortions of the hyperinflation, the related change from Mark to Reichsmark, shifts in the industry composition of the corporate sector, and the desire by the official statisticians to slightly change their methodology (Statistisches Reichsamt 1928, 1929) all served as reasons to replace the first interwar index.

The replacement index—the second *Reichsamt* index—covers 329 share titles, and takes the average price between 1924 and 1926 as its basis. Once again the weighting across industries uses the registered capital of all corporations as of the end of December 1926, including those companies not traded on the exchange. Companies are classified into 24 industrial groups.

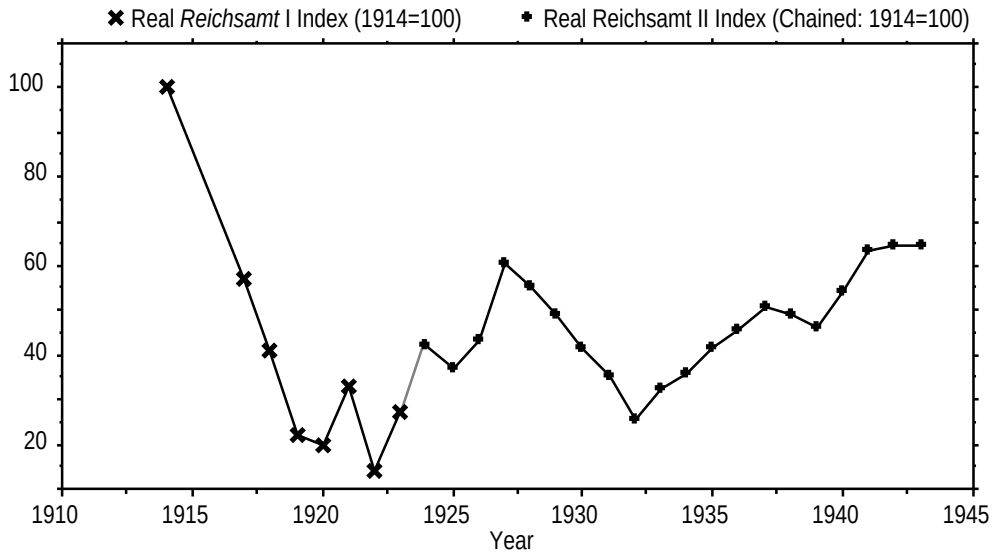
The 24 industry averages were grouped into three intermediate indices and the final index. The index excludes price movements induced by new share issues—thus the *Reichsamt* II index is also a portfolio index, using the same procedure as Donner (1934) to take account of new share issues, and changes in the sample. Bundesbank (1976) and the *Wochenberichte's* statistical supplements published by the *Institut für Konjunkturforschung* conveniently summarize the time series of values reported for this index.

The two interwar series can be linked, and in the body of the paper we do link them, to provide an estimate of real capital gains across the hyperinflation era, but we do not have great confidence in the reliability of the link. Real values of the indices across the interwar period are

[7]The *Reichsamt* made an arithmetic mistake in the initial calculation of its index, which it repaired in a subsequent issue (Statistisches Reichsamt 1922b).

presented in figure A.3. Because of the hyperinflation, it makes no sense to plot nominal stock prices for the interwar period.

Figure A.3
Real Interwar Stock Price Series



Alternative indices of the ratios of book to par value are also available for the interwar period. They behave very differently from the portfolio indices calculated by the *Reichsamt*. The market-wide ratio of market to par values rises steeply in the early years of the Depression, reaching a peak in 1931: companies fail, and their subsequent omission from the index leaves only companies with high ratios of market to par value in the sample.

For the post-hyperinflation portion of the interwar period, the available yield series is the yield on all traded stocks, plotted in figure A.4.[8] This yield series is reported in the *Aktiengesellschaftsstatistik*—the statistics of corporations, computed to track corporation profits and performance, which contains other measures of profitability as well—as

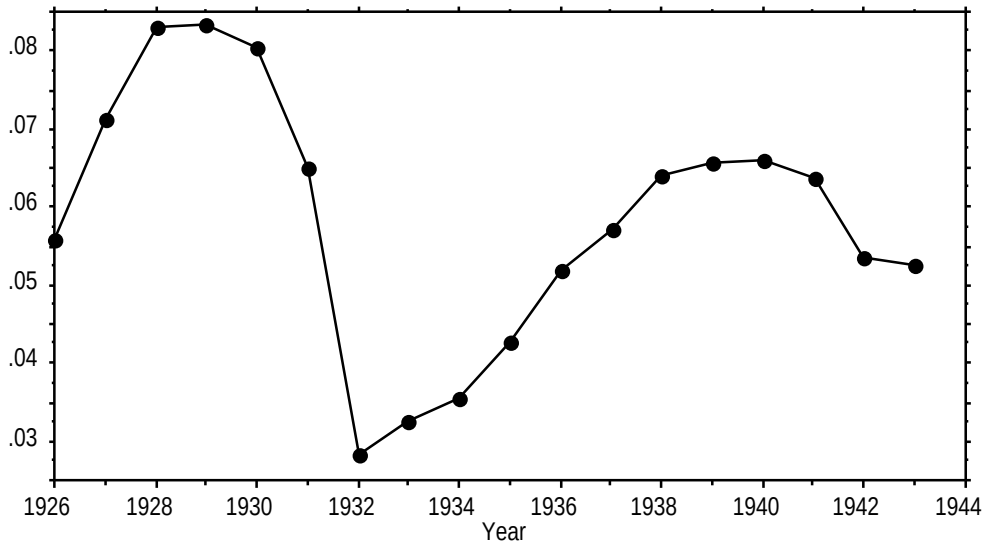
[8]Another dividend series is also reported: the yield of all corporations, publicly traded or not.

well as in the *Börsenstatistik*—the statistics of financial markets, computed to track relative asset values, which contains the price indices. The diverging orientation of these two bodies of statistics means that the different series are not built on consistent bases: while the *Reichsamt* took pains to make sure that its stock price index did represent the value of a broad-based portfolio, it thought it more important that its dividend index have comprehensive coverage than that it correspond to the stock price index. Thus the yield statistics are calculated from a different sample of corporations than are the price indices.

In the interwar period, this is extremely hazardous. Since the ratio of market to par value for all traded corporations does not track movements in the market portfolio, why should the dividend yield for all traded corporations track movements in the yield on the market portfolio?

The interwar yield index should therefore be used with caution. Nevertheless, it is reassuring to note that it is procyclical. If it were countercyclical—if yields rose during economic recessions and fell during economic booms—this would raise the possibility that low-yield companies were going bankrupt with high probability in the recession. If such low-yield companies in the market as a whole went bankrupt and disappeared from the stock market either more or less frequently than did companies in the index, then considerable inaccuracies would be sure to result.

Figure A.4
Interwar Dividend Yields



Note that there is no dividend series available for the time spanned by the first *Reichsamt* index.

Post-World War II Series

For the post-World War II period, the stock price series is constructed by linking official portfolio index series constructed by the *Statistisches Bundesamt* (Federal Bureau of Statistics), the official statistical bureau of the post-World War II West German *Bundesrepublik*. Three different portfolio indices are chained together, shifting from each one to the next in the first year in which the following sequence becomes available (see Herrmann, 1956; Spellerberg and Schneider, 1967; Silbermann, 1974; Lützel and Jung, 1984; Statistisches Bundesamt, 1985).

The *Bundesamt für Statistik* began to publish its first new index of stock values for the Federal Republic of Germany in 1956 (see Herrmann, 1956)—but note that this index is not used in the construction of our data, as its replacement covers its complete sample period as well. The

index begins in 1953, and uses 430 share titles with a registered capital of 9516.4 million DM. Prices are recorded four times a month.

The 1953 index weights the share prices of corporations in a given industry traded on the exchange by the registered capital of *all* corporations. Herrmann (1956) claims that the alternative procedure—weighting by market capitalization—would have discriminated against some industrial sectors, like the energy industry, underrepresented on the exchange.

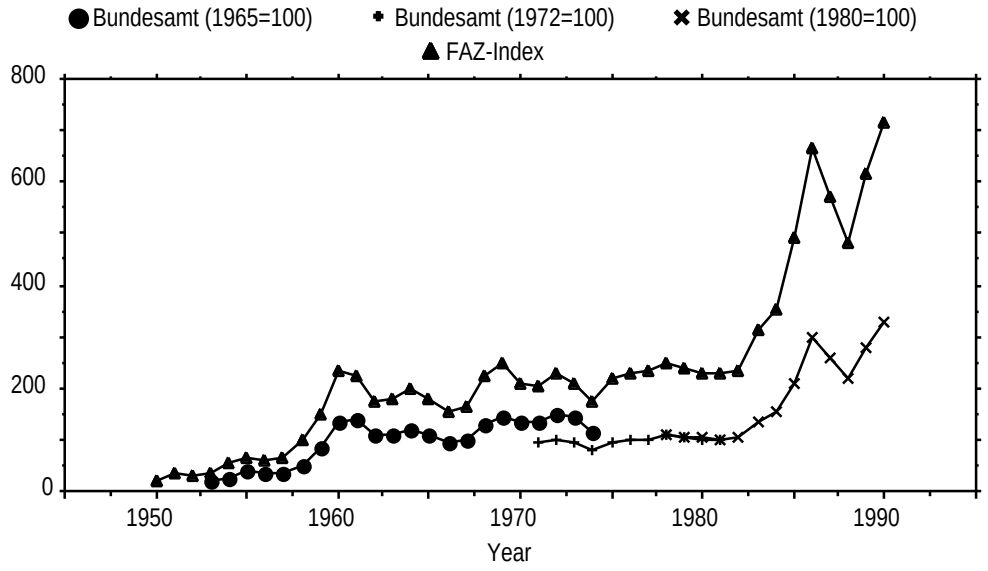
The index is also adjusted for the lower share prices associated with new share issues in the same way as Donner (1934) and the interwar indices.

This index was replaced in 1967 (Spellerberg, Schneider 1967) by a new portfolio index using the end of 1965 as a base. This second post-World War II portfolio index covers 545 ordinary share titles, with a registered capital of 23.05 billion DM. As before, the index is adjusted for new share issues.

The 1953 "portfolio" was considered out of date for several reasons. First, in the twelve years from 1954 to 1965 the registered capital on the stock exchange had risen by 12.7 billion DM. Thus the previous index covered only some forty percent of the registered capital. Different industry groups had raised capital at different rates.

In addition, the new index introduced three important computational changes. First, the classification of industrial groups was revised according to the 1961 "Systematik der Wirtschaftszweige." Second, companies registered in West Berlin were included. Third, industry groups were once again weighted by the capital of corporations traded on the stock exchange—not by the capital of all corporations in the industry.

Figure A.5
Post-World War II Nominal Stock Prices



In 1965, a total of 627 titles with a capital of 23.88 billion DM were registered on the German exchanges. The share price index represents 94.6% of the total registered capital. Once again, the index was adjusted for new share issues and changes in coverage.

This index was in its turn replaced by a new revised index in 1972. The 1972 revision was straightforward. The third portfolio index has the base date 29 December 1972, comprises 285 titles with a registered capital of 27.88 billion DM, and represents 96.4% of the total registered capital. In addition to correcting for *Bezugsrechte* (preference rights), it also adjusts for *Ausgabe von Berichtigungsaktien* (issues of correction shares) and for mergers.

Silbermann (1972) gives a detailed account of the computational procedures which, presumably, also apply to the 1953 and 1965 indices. The index is constructed in three stages. The first is the construction of unweighted industry group price averages. The second stage is the computation of sub-indices for "main industry groups"

(*Hauptwirtschaftsgruppe*), weighting individual industry indices by the registered capital of all share titles traded on the exchange, *including those not contained in the share price index.* The third stage is the construction of the general index from the *Hauptgruppenindex.* using the same procedure used to construct the *Hauptgruppenindex* from the industry averages.

The most recent portfolio index was introduced by Lützel and Jung (1984). It is based on 295 shares with a registered capital of 37595 billion DM. It represents 95.2% of the registered capital that year, 39501 billion DM. Note, however, that this index is not a Laspeyres index but a chain index. The portfolio to which it implicitly corresponds is thus rebalanced every year.

The *Frankfurter Allgemeine Zeitung* (FAZ) index (graciously provided by the *Frankfurter Allgemeine Zeitung*) can also be used to track the rapid Korean-War era rise in German stock values. Even though the FAZ index is available for the entire post-World War II period, we prefer the sequence of overlapping *Bundesamt* portfolio indices because the FAZ index is a Paasche index. It is difficult to interpret its movements as the movements of a broad-based portfolio.

The nominal values of the post-World War II German stock market indices are plotted alongside each other in figure A.5. Once again, the series move together strongly.

For the post-World War II as well as for the interwar period, the available yield series used is the yield on all traded stocks—not the yield on all stocks covered in the index.[9] This yield series is reported in the *Aktiengesellschaftsstatistik*—the statistics of corporations, computed to track corporation profits and performance, which contains other

[9]Another dividend series is also reported: the yield of all corporations, publicly traded or not.

measures of profitability as well. The diverging orientation of the *Aktiengesellschaftsstatistik* has the unfortunate consequence that the yield statistics are calculated from a different sample of corporations than are the price indices.

Nevertheless, the post-World War II dividend series—calculated by multiplying price times yield—is a good approximation to the true dividend series that would correspond to the price index series we use. The post-World War II price index series covers close to ninety-five percent of the par value of stocks traded on the German exchanges. The approximation error could become significant only if the uncovered five percent of stocks had truly extraordinary dividend payout patterns. This is especially unlikely because the index sample was chosen to provide a good approximation to the size and industry distribution of the German corporate sector.

Figure A.6
Post-World War II Yield Series

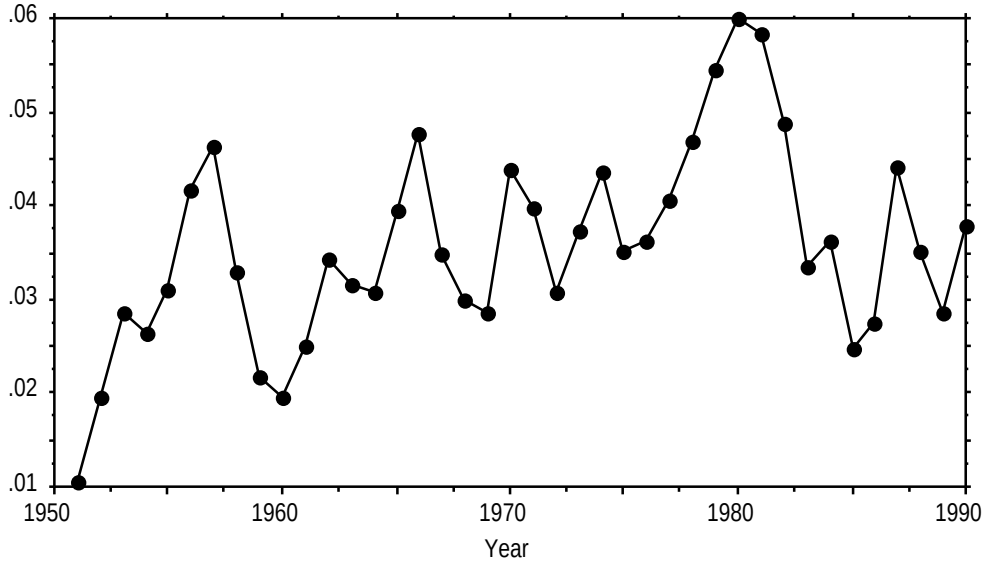


Figure A.6 plots the post-World War II yield series. Its variability is far, far greater than the variability of the pre-World War I yield series

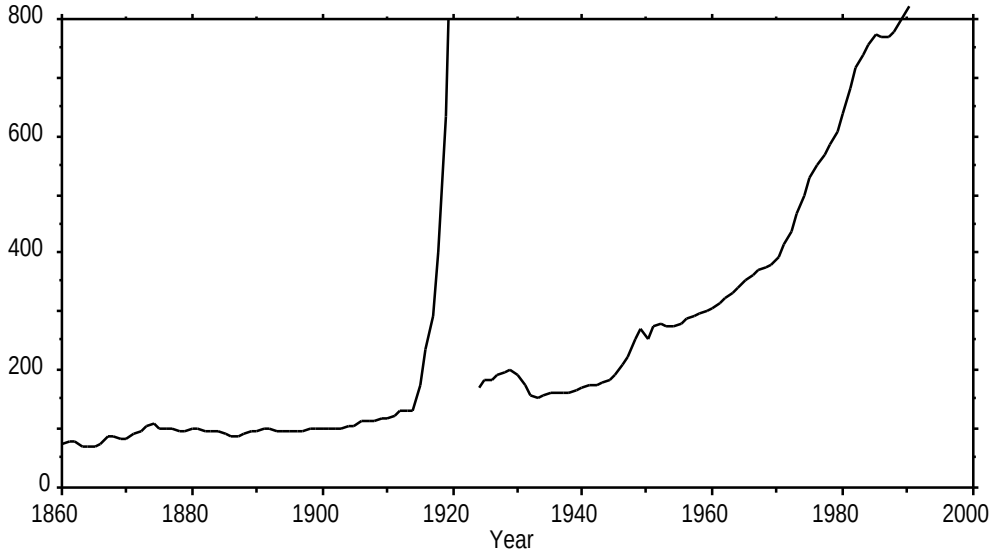
plotted in figure A.2. While pre-World War I market average dividend yields varied between four and six percent, post-World War II yields vary between one and six percent—and even post-*Wirtschaftswunder* yields vary between two and six percent.

Price Deflator Indices

Figure A.7 plots the consumer price index used to deflate the series in this paper. The series used is endorsed by the Deutsche Bundesbank (1976), and runs continuously with the exception of one gap covering World War II and the post-war reconstruction period to the present day.

The index was assembled from four different sources. Up until 1914 the cost of living figures come from Kuczynski (1947), who investigated the standard of living of German workers since 1800. Kuczynski's cost of living index consists of estimates of food prices and housing costs. From 1915 to 1919 the index is derived from calculations by the *Statistisches Bundesamt,* the Federal Statistical Bureau of post-World War II West Germany, made after World War II in order to close the gap between Kuczynski's and the subsequent indices. From 1920 to 1940 the cost of living index is that compiled for a five-person working-class household by the *Statistisches Reichsamt,* the National Statistical Bureau of first the Weimar Republic and then the Third Reich. For the post-World War II years from 1949 to the present, the cost of living index used is that calculated for a four-person middle-class household by the *Statistisches Bundesamt.*

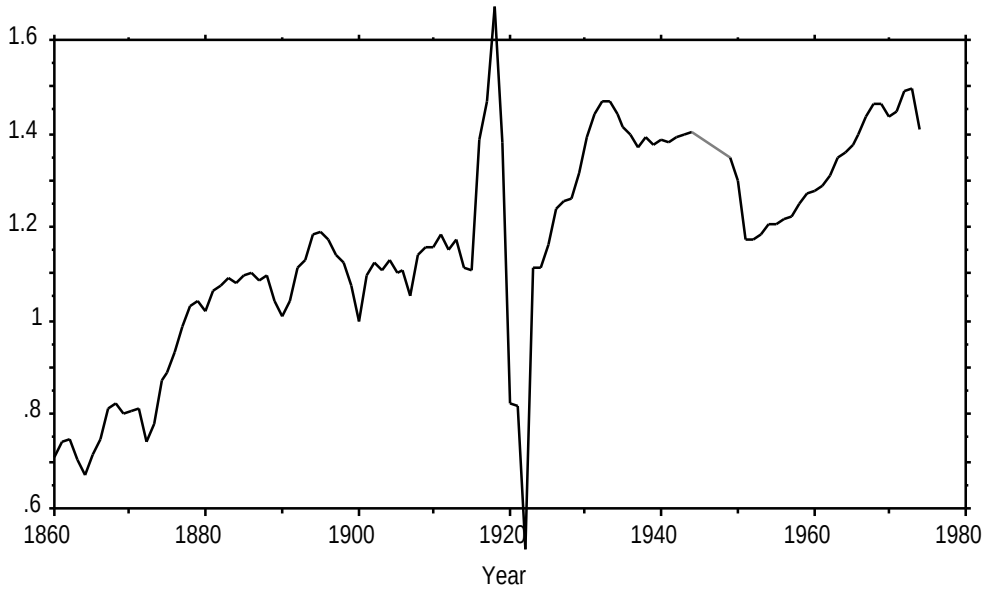
Figure A.7
German Consumer Price Index



The different consumer price series have different base years. They chart the changes in the price level for different consumption bundles, and are not completely consistent. Nevertheless, the indices have a relatively broad coverage of commodities even in the mid-nineteenth century years.

The Deutsche Bundesbank (1976) reports similar indices for wholesale prices. Figure A.8 plots the ratio of the consumer price index to the wholesale price index. The ratio of the indices exhibits a sharp jump in the 1870's, extraordinarily erratic behavior during World War I and the post-World War I decade, and a substantial upward drift in the post-World War II era. The periods of greatest variation in the ratio of consumer to wholesale prices are, however, periods during which dividend data are absent.

Figure A.8
Ratio of German Consumer to Wholesale Price Index



Final Series

Finally, table A.1 reports the final real stock prices and dividend series that we constructed, and that make up the data used in the body of this paper.

Table A.1
Underlying Data for the German Stock Market

Year	Dividend Yield	Log Real Stock Price	Log Real Dividend	Log Perfect-Foresight Fundamental
1876	0.048	-0.567	-3.598	-0.540
1877	0.054	-0.665	-3.578	-0.504
1878	0.052	-0.560	-3.513	-0.468
1879	0.052	-0.363	-3.312	-0.434
1880	0.050	-0.164	-3.160	-0.408
1881	0.049	-0.130	-3.142	-0.391
1882	0.050	-0.104	-3.104	-0.373
1883	0.049	-0.097	-3.109	-0.358
1884	0.048	-0.095	-3.124	-0.340
1885	0.046	-0.102	-3.184	-0.321
1886	0.044	-0.064	-3.197	-0.296
1887	0.048	-0.039	-3.079	-0.269
1888	0.055	0.066	-2.839	-0.248
1889	0.054	0.220	-2.700	-0.242
1890	0.059	0.164	-2.666	-0.249
1891	0.055	-0.004	-2.908	-0.259
1892	0.049	-0.038	-3.054	-0.249
1893	0.047	-0.019	-3.069	-0.228
1894	0.050	0.067	-2.933	-0.204
1895	0.047	0.200	-2.860	-0.188
1896	0.054	0.243	-2.675	-0.177
1897	0.054	0.272	-2.648	-0.179
1898	0.055	0.276	-2.618	-0.184
1899	0.055	0.297	-2.599	-0.193
1900	0.055	0.202	-2.691	-0.204
1901	0.047	0.069	-2.981	-0.207
1902	0.045	0.085	-3.028	-0.188
1903	0.049	0.126	-2.896	-0.165
1904	0.050	0.179	-2.821	-0.149
1905	0.051	0.233	-2.744	-0.138
1906	0.055	0.162	-2.740	-0.131
1907	0.057	0.070	-2.796	-0.124
1908	0.050	0.041	-2.953	-0.112
1909	0.050	0.079	-2.920	-0.089
1910	0.050	0.117	-2.874	-0.067
1911	0.052	0.092	-2.874	-0.045
1912	0.055	0.039	-2.861	-0.023
1913	0.054	0.000	-2.914	0.000
1914	•	-0.020	•	•

1915	•	•	•	•
1916	•	•	•	•
1917	•	-0.580	•	•
1918	•	-0.908	•	•
1919	•	-1.540	•	•
1920	•	-1.628	•	•
1921	•	-1.130	•	•
1922	•	-1.988	•	•
1923	•	-1.442	•	•
1924	•	-0.951	•	•
1925	•	-1.084	•	•
1926	0.056	-0.927	-3.813	-0.935
1927	0.071	-0.596	-3.237	-0.910
1928	0.083	-0.687	-3.177	-0.929
1929	0.084	-0.801	-3.285	-0.957
1930	0.081	-0.969	-3.488	-0.977
1931	0.065	-1.133	-3.866	-0.978
1932	0.028	-1.465	-5.031	-0.952
1933	0.033	-1.228	-4.651	-0.885
1934	0.035	-1.115	-4.458	-0.825
1935	0.043	-0.974	-4.130	-0.769
1936	0.052	-0.881	-3.843	-0.721
1937	0.057	-0.773	-3.638	-0.683
1938	0.064	-0.804	-3.553	-0.653
1939	0.066	-0.865	-3.590	-0.626
1940	0.066	-0.702	-3.421	-0.595
1941	0.064	-0.550	-3.301	-0.573
1942	0.054	-0.536	-3.464	-0.557
1943	0.052	-0.530	-3.479	-0.530
1944	•	•	•	•
1945	•	•	•	•
1946	•	•	•	•
1947	•	•	•	•
1948	•	•	•	•
1949	•	•	•	•
1950	•	•	•	•
1951	0.011	-1.567	-6.111	-1.316
1952	0.020	-1.800	-5.730	-1.241
1953	0.029	-1.717	-5.271	-1.169
1954	0.027	-1.445	-5.077	-1.102
1955	0.031	-1.017	-4.489	-1.038
1956	0.042	-1.094	-4.275	-0.986
1957	0.046	-1.115	-4.186	-0.941
1958	0.033	-0.876	-4.291	-0.898
1959	0.022	-0.324	-4.147	-0.848
1960	0.020	0.128	-3.805	-0.803
1961	0.025	0.132	-3.561	-0.770
1962	0.034	-0.149	-3.520	-0.750

1963	0.032	-0.179	-3.634	-0.732
1964	0.031	-0.088	-3.568	-0.705
1965	0.039	-0.217	-3.452	-0.680
1966	0.048	-0.400	-3.446	-0.661
1967	0.035	-0.373	-3.732	-0.642
1968	0.030	-0.103	-3.609	-0.605
1969	0.029	-0.021	-3.572	-0.572
1970	0.044	-0.140	-3.267	-0.540
1971	0.040	-0.182	-3.407	-0.524
1972	0.031	-0.145	-3.627	-0.499
1973	0.037	-0.271	-3.562	-0.460
1974	0.044	-0.496	-3.629	-0.423
1975	0.035	-0.415	-3.764	-0.381
1976	0.036	-0.380	-3.698	-0.332
1977	0.041	-0.414	-3.617	-0.283
1978	0.047	-0.368	-3.428	-0.236
1979	0.054	-0.447	-3.359	-0.195
1980	0.060	-0.545	-3.358	-0.155
1981	0.058	-0.608	-3.451	-0.113
1982	0.049	-0.650	-3.668	-0.066
1983	0.033	-0.408	-3.806	-0.010
1984	0.036	-0.303	-3.624	0.051
1985	0.025	-0.015	-3.717	0.108
1986	0.027	0.334	-3.264	0.170
1987	0.044	0.194	-2.926	0.220
1988	0.035	0.016	-3.336	0.260
1989	0.029	0.233	-3.326	0.315
1990	0.038	0.372	-2.905	0.372

Appendix 2: Monte Carlo Estimates of the Significance of Volatility Ratios

The post-World War II German stock market does show volatility ratios greater than one, and thus might provide some evidence of excess volatility. Table A.2 below reports Monte Carlo distributions of volatility ratios, computed to evaluate the statistical significance of the volatility ratios, calculated under the assumptions that the log level of dividends follows an error-correction model or that it follows an ARIMA process

The error correction model assumes that dividend policy is irrelevant to the firm's value—that all money not paid out as dividends but reinvested in the firms that make up the market yields an expected increase in firm value of r, so that:

(A.1) $$E_t P_{t+1} = (1+r)[P_t - D_t]$$

Define the "permanent" level of dividends D^*_t as that level that allows real expected dividend payouts and prices to grow at an annual rate of g:

(A.2) $$D^*_t = (r-g)P_t$$

Suppose the representative firm desires to maintain a constant dividend yield of r-g and thus keep the dividend near to its "permanent" sustainable level, but also is averse to rapid upward or downward changes in dividends. Take a given year's dividend is a weighted average of last year's actual dividend (scaled up by the growth factor g) and this year's "permanent" dividend:

(A.3) $$D_t = \theta(1+g)D_{t-1} + (1-\theta)D^*_t$$

where θ is a weight between zero and one. The closer θ is to zero, the less inertia there is in the dividend process and the more closely to dividends approximate a random walk. The closer θ is to one, the slower are

dividends to adjust and the larger are persistent shifts in the realized dividend growth rate.

Table A.2
Monte Carlo Distributions of the Volatility Ratio in Line 6 of Table 1 for Various Generating Processes

Probability	θ=0.1	θ=0.5	θ=0.8	Pre-WWI IMA(1, 6)	Post-WWII IMA(1, 6)
0.01	0.992	0.948	0.974	0.863	0.973
0.05	0.998	0.992	1.065	0.934	0.991
0.10	1.001	1.017	1.130	0.955	1.003
0.50	1.011	1.112	1.519	1.076	1.041
0.90	1.039	1.393	2.846	1.341	1.167
0.95	1.057	1.494	3.346	1.432	1.242
0.99	1.080	1.763	5.167	1.641	1.420

Table A.2 reports the Monte Carlo distributions of the volatility ratio in line six of table 1, if the dividend process is the error-correction model given by equations (A.1), (A.2), and (A.3) for various values of the parameter θ if the process is observed for a forty year period. The values of θ chosen are intended to more than span the range of reasonable error-correction models. In addition, table A.2 reports the Monte Carlo distributions of the volatility ratios if the dividend process is—and investors know it to be—the IMA(1, 6) in levels estimated for dividends in the pre-World War I and post-World War II periods.

As noted above, the pre-World War I German market does not show any signs of excess volatility. If anything, the volatility of the price-dividend ratio in the pre-World War I period is deficient: in only one of the Monte Carlo simulations—that for dividends following and known to follow the IMA(1, 6) estimated for the pre-World War I era—is there

even a one percent chance of a value of the summed volatility ratios in line 6 of table 1 as *low* as the actual value observed.

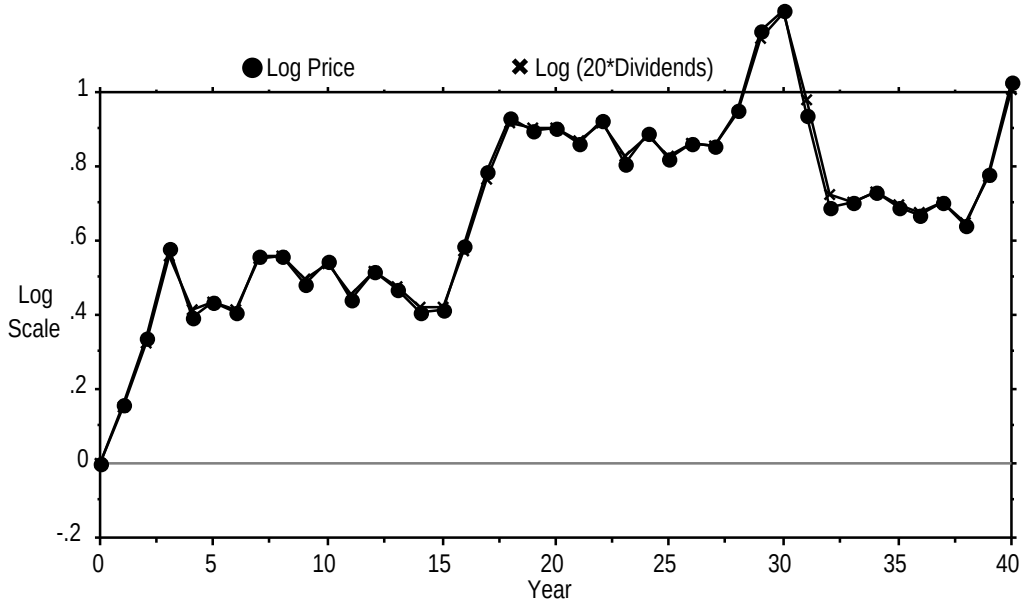
The post-World War II period considered as a whole generates volatility ratios that are significant rejections of the null hypothesis on the high side for all generating processes considered save those with high values of θ. When θ is near one year-to-year dividend level changes are small and shifts in dividend growth rates are persistent. Accordingly, the variability of the price-dividend ratio is large. A value of θ=0.8 implies that each year dividends adjust only one-fifth of the way to the "permanent" sustainable dividend level. This is a greater degree of relative smoothness in real dividends vis-a-vis prices than is in fact found in the sample. A value of θ=0.1 implies that each year dividends adjust ninety percent of the way to the "permanent" dividend level: this makes the price-dividend ratio too close to a constant to be consistent with the data.

Figures A.9 through A.11 plot sample paths of simulated log prices and dividends for values of θ equal to 0.1, to 0.5, and 0.8 in the Monte Carlo simulations underlying table A.2. These values of θ are intended to more than span the range of reasonable error-correction models. The low θ case has the current dividend move in a single year ninety percent of the way to the "permanent" expected annuity value of the stock market's future payouts. As a result, in figure A.9 dividends are nearly proportional to prices and the stochastic process followed by both is very close to a random walk.

Since dividends are nearly proportional to prices, the distribution of the sum of volatility ratios reported in table 2 is very tightly clustered around one: the variability of prices relative to dividends is small, and the variability of both prices and dividends relative to perfect-foresight

fundamentals are approximately equal. If the Monte Carlo distribution calculated for θ=0.1 is the correct distribution of volatility ratios under the efficient-markets and constant real interest rate null, then the pre-World War I German stock market exhibits statistically significant deficient volatility, and the post-*Wirtschaftswunder* market exhibits statistically significant excess volatility.

Figure A.9
Sample Monte Carlo Price and Dividend Realization for θ=0.1

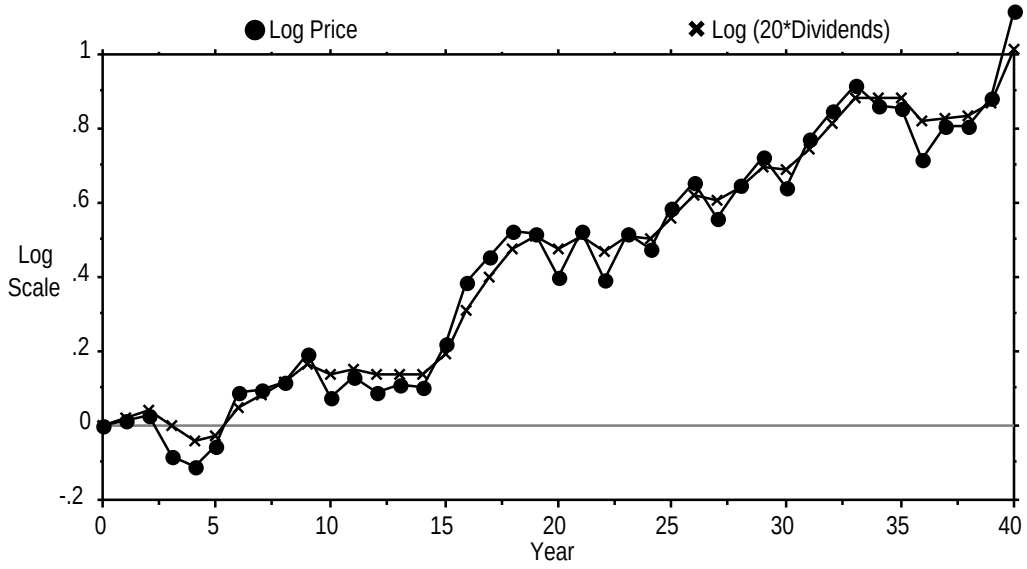


The intermediate θ case has the current dividend move in a single year halfway to the "permanent" expected annuity value of the stock market's future payouts. In figure A.10 the year to year variability of relative changes in prices and dividends is closest to that observed in actual data. Dividends are not proportional to prices. Moreover, the sample average growth rate of prices and dividends is not known to investors *ex ante:* it depends on the average reinvestment rate, and the slow responsiveness of dividends to shifts in fundamentals makes the

average reinvestment rate depend on shocks over the sample. Thus for θ=0.5 the sum of the volatility ratios reported in table A.2 does contain an upward bias—the median is 1.1 and not 1.0.

If the Monte Carlo distribution for θ=0.5 is a correct representation of the distribution of volatility ratios under the efficient-markets and constant real interest rate null, then the post-*Wirtschaftswunder* market exhibits statistically significant excess volatility, although less strongly so than was the case for θ=0.1; the post-World War II period considered as a whole, however, does not. Moreover, the upward bias in the distribution of the sum of the volatility ratios makes the gap between the actual volatility ratios of the pre-World War I German market and their expected values even greater.

Figure A.10
Sample Monte Carlo Price and Dividend Realization for θ=0.5

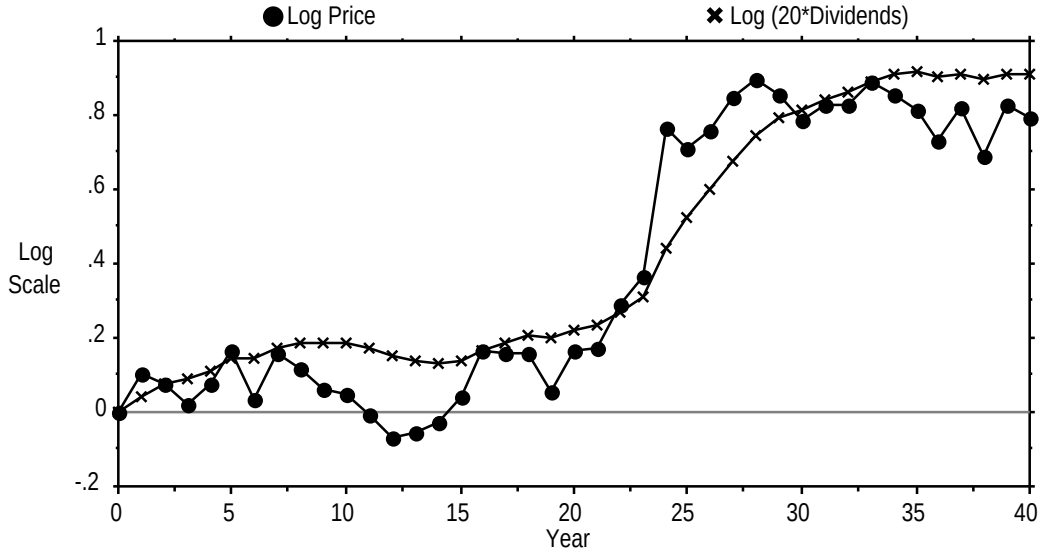


The high θ case has the current dividend move in a single year only twenty percent of way to the "permanent" expected annuity value of the stock market's future payouts. As a result, in figure A.11 the sample path of dividends is very smooth, and far smoother than is observed in

actual data. The sample average growth rate of prices and dividends is once more not known to investors *ex ante:* it depends on the average reinvestment rate, and the very slow responsiveness of dividends to shifts in fundamentals makes the average reinvestment rate depend heavily on shocks over the sample. Thus for θ=0.8 the sum of the volatility ratios reported in table A.2 contains a substantial upward bias—the median is 1.5, and not 1.0.

If the Monte Carlo distribution for the error-correction model with θ=0.8 is the correct distribution of volatility ratios under the efficient-markets and constant real discount rate null, then even the post-*Wirtschaftswunder* market fails to exhibit statistically significant excess volatility. The upward bias in the distribution of the sum of the volatility ratios makes the behavior of the pre-World War I German market even more anomalous: if θ=0.8, then there is only a five percent chance of observing a value for the sum of the volatility ratios of less than 1.06—and yet the pre-World War I German stock market exhibits a value of 0.86.

Figure A.11
Sample Monte Carlo Price and Dividend Realization for θ=0.8



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Monte Carlo simulations to calculate confidence intervals

Pre-World War I autocorrelations of dividend growth:

1.00
0.497
-0.099
-0.487
-0.481
-0.351
0.103

Post-World War II autocorrelations of dividend growth:

1.00
0.38
0.188
0.022
-0.012
0.152
0.132

Post-1960 autocorrelations of dividend growth

1.00
0.132
-0.070
-0.199
-0.249
-0.050
0.015

In Excel File “Monte Carlo September/Becht”...

Pre-World War I autocorrelations of dividend growth:	Post-World War II autocorrelations of dividend growth:	Post-1960 autocorrelations of dividend growth:

	1	1	1
	0.497	0.38	0.132
	-0.099	0.188	-0.07
	-0.487	0.022	-0.199
	-0.481	-0.012	-0.249
	-0.351	0.152	-0.05
	0.103	0.132	0.015
sum sq AC's	1.85915	1.2209	1.1266
Actual Change Variance=	0.013	0.05	0.043

United States Autocorrelations of Dividend Changes

Post-WWII
1.00
.556
.142
-.013
.024
.014
-.077

Pre-WWI
1.00
.023
-.095
-.128
-.362
-.072
-.070

Entire Century
1.00
.152
-.150
-.097
-.121
.013
-.043

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For example, suppose log dividends follow an IMA (1,1) process:

(1) $d_t = d_{t-1} + \varepsilon_t - \theta\varepsilon_{t-1} + g$

Where $0 \leq \theta \leq 1$ is a parameter, g is the long-run upward rate of drift of dividends, and ε_t is an innovation, unforecastable before period t. With a constant discount rate r, under the efficient markets hypothesis the log real stock price will to first order be:

(2) $p_t = -\ln(r-g) + d_t - \rho\theta(\varepsilon_t)$

where $\rho = \exp(-(r-g))$ is a one-year logarithmic discount factor. Now suppose an *ex post* time trend π is fitted to the first and last observations, t=0 and t=T:

(3) $\pi_t = p_0 + \frac{t}{T}\left(p_T - p_0\right)$

Calculate the covariance between the one-year realized return:

(4) $r^{*1}_t = r + (1-\rho\theta)\varepsilon_{t+1}$

and the price relative to the *ex post* time trend, conditional on knowledge of the current price p_t and of the current value π_t of the *ex post* time trend:

(5) $E\left(r^{*1}_t(p_t - \pi_t) \mid p_t, \pi_t\right) = -\left(\frac{t}{T}\right)(1-\rho\theta)(1-\theta)\varepsilon^2_{t+1}$

Equation (5) shows that there are excess returns from buying when the price is low relative to the simple *ex post* time trend, and selling when it is high. By contrast, the return is uncorrelated with the price relative to an *ex ante* time trend π'_t:

(6) $\pi'_t = p_0 + tg$

(7) $E\{r^{*1}_t(p_t - \pi'_t) \mid p_t, \pi'_t\} = 0$

Why don't the rational investors in this example take advantage of the in-sample correlation between $(p_t - \pi_t)$ and future returns? Because at the time they would have to trade they do not yet know what the end-of-sample value π_T will be, and so cannot calculate the current value of the *ex post* time trend π_t. Investors would love to know π_T—such knowledge would allow them to calculate the value of the sum of the ε innovations yet to come. But they do not. A regression of returns on prices and a time trend is indeed likely to find significant return predictability and excess volatility, but in this example such a finding is spurious: it arises from the use of a test that implicitly assumes that rational investors had a particular form of knowledge of future shocks.

Statistical Significance

The post-World War II German stock market does show volatility ratios greater than one, and thus might provide some evidence of excess volatility. Table 2 reports Monte Carlo distributions of volatility ratios, computed to evaluate the statistical significance of the volatility ratios, calculated under the assumption that the level of dividends follows an error-correction model.

Assume that dividend policy is irrelevant to the firm's value—that money not paid out but reinvested yields an expected increase in firm value of r, so that:

(8) $$E_t P_{t+1} = (1+r)[P_t - D_t]$$

Define the "permanent" level of dividends D^*_t as that level that allows real expected dividend payouts and prices to grow at an annual rate of g:

(9) $$D^*_t = (r-g)P_t$$

Suppose the representative firm desires to maintain a constant dividend yield of r-g and thus keep the dividend near to its "permanent" sustainable level, but also is averse to rapid upward or downward changes in dividends. Take a given year's dividend is a weighted average of last year's actual dividend (scaled up by the growth factor g) and this year's "permanent" dividend:

(10) $$D_t = \theta(1+g)D_{t-1} + (1-\theta)D^*_t$$

where θ is a weight between zero and one. The closer θ is to zero, the less inertia there is in the dividend process and the more closely to dividends approximate a random walk. The closer θ is to one, the slower are dividends to adjust and the larger are persistent shifts in the realized dividend growth rate.[10]

Table 2
Monte Carlo Distributions of the Volatility Ratio in Line 6 of Table 1 for Various Generating Processes

Probability	θ=0.1	θ=0.5	θ=0.8	Pre-WWI IMA(1, 6)	Post-WWII IMA(1, 6)
0.01	0.992	0.948	0.974	0.863	0.973
0.05	0.998	0.992	1.065	0.934	0.991
0.10	1.001	1.017	1.130	0.955	1.003
0.50	1.011	1.112	1.519	1.076	1.041
0.90	1.039	1.393	2.846	1.341	1.167
0.95	1.057	1.494	3.346	1.432	1.242
0.99	1.080	1.763	5.167	1.641	1.420

Table 2 reports the Monte Carlo distributions of the volatility ratio in line six of table 1, if the dividend process is the error-correction model given by equations (8), (9), and (10) for various values of the parameter

[10]Barsky and De Long (1989, 1990) argue that the long swings in the U.S. stock market over the past century can be interpreted as due to investors'—perhaps irrational—expectations of such permanent or persistent shifts in dividend growth rates.

θ if the process is observed for a forty year period. The values of θ chosen are intended to more than span the range of reasonable error-correction models. In addition, table 2 reports the Monte Carlo distributions of the volatility ratios if the dividend process is—and investors know it to be—the IMA(1, 6) in levels estimated for dividends in the pre-World War I and post-World War II periods.[11]

As noted above, the pre-World War I German market does not show any signs of excess volatility at all. If anything, the volatility of the price-dividend ratio in the pre-World War I period is deficient: in only one of the Monte Carlo simulations—that for dividends following and known to follow the IMA(1, 6) estimated for the pre-World War I era—is there even a one percent chance of a value of the summed volatility ratios in line 6 of table 1 as *low* as the actual value observed.

The post-World War II period considered as a whole generates volatility ratios that are significant rejections of the null hypothesis on the high side for all generating processes considered save those with high values of θ. When θ is near one year-to-year dividend level changes are small and shifts in dividend growth rates are persistent. Accordingly, the variability of the price-dividend ratio is large.[12]

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[11]The IMA process estimated was chosen to be integrated to allow shocks to the level of dividends to have permanent effects; the process was chosen to have a relatively large number of coefficients to allow it flexibility. Experiments with processes with AR components lead to similar significance levels.

[12]A value of θ=0.8 implies that each year dividends adjust only one-fifth of the way to the "permanent" sustainable dividend level. This is a greater degree of relative smoothness in real dividends vis-a-vis prices than is in fact found in the sample. A value of θ=0.1 implies that each year dividends adjust ninety percent of the way to the "permanent" dividend level: this makes the price-dividend ratio too close to a constant to be consistent with the data. Appendix II plots sample price and dividend series for various values of θ from the Monte Carlo simulations underlying table 2.