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INTERNATIONAL EVIDENCE ON BUSINESS CYCLE DURATION DEPENDENCE

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ABSTRACT

We provide an investigation of duration dependence in prewar business expansions, contractions, and whole cycles for France, Germany, and Great Britain. Our results, obtained using both nonparametric and parametric procedures, generally indicate the presence of positive duration dependence in expansions and whole cycles but not in contractions. Our results corroborate those of our earlier studies of the United States.

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1. Introduction

Do business cycles exhibit duration dependence? That is, do expansions, contractions, or whole cycles become more likely to end or less likely to end as they grow older? In recent work, Diebold and Rudebusch (1990a) and Sichel (1989) argue that understanding business cycle duration dependence is of importance for understanding business cycles more generally, provide a framework for answering the questions posed above, and provide some preliminary answers.

Previous research, however, has focused almost exclusively on durations derived from the National Bureau of Economic Research (NBER) chronology of business cycles in the United States. There have been roughly 30 complete cycles since 1854, so that only a limited number of duration observations are available. An obvious strategy for obtaining more information about business cycle duration dependence is to expand the information set by using the NBER chronologies of business cycles in other countries.[1] Such chronologies are available for France, Germany, and Great Britain during the pre-World War II period, which is the focus of this paper.

We thus seek to confront the existing conclusions for prewar U.S. business cycles with prewar data for three additional countries. There are two such major conclusions. First, prewar U.S. expansions display significant positive duration dependence, so that the probability of an expansion ending increases with its age. Second, prewar U.S. contractions display no significant duration dependence, so that the probability of a contraction ending is not significantly dependent on its age. These conclusions are reached regardless of whether nonparametric procedures are used, as in Diebold and Rudebusch (1990a), or parametric procedures are used, as in Sichel (1990). Here we shall use <u>both</u> nonparametric and parametric tests in our extension of the analysis to prewar France, Germany, and Britain.

1. Similarly, international data have been used in attempts to refine estimates of macroeconomic persistence (e.g., Campbell and Mankiw (1989), Kormendi and Meguire (1990)).

The paper proceeds as follows. In the next section, we describe various nonparametric and parametric tests of duration dependence; the discussion is brief because these test procedures are detailed elsewhere. In section 3, we present empirical results for French, German, and British expansions, contractions, and whole cycles. Section 4 contains concluding remarks.

2. Tests for Duration Dependence

A hazard function, $h(\tau)$, is defined as the conditional probability that a process ends at duration τ, given that it has not ended earlier. If this hazard function is increasing (decreasing) in τ, then the process is said to exhibit positive (negative) duration dependence. Our null hypotheses are that the processes that generate the durations of business expansions, contractions, and whole cycles exhibit no duration dependence, so their associated hazard functions do not depend on τ. However, we do allow for specification of a minimum duration, denoted t_0, which all durations must exceed. Thus, our null hypothesis is

$$H_0\colon h(\tau) = \begin{cases} 0, & \text{if } t_0 > \tau \geq 0 \\ \lambda, & \text{if } \tau \geq t_0 \end{cases} \tag{1}$$

where λ is an unknown constant. The constant hazard, λ, and the minimum duration, t_0, will of course be different for expansions, contractions, and whole cycles.

As noted by Kiefer (1988), specifying the form of the hazard function is equivalent to specifying the unconditional density of durations, $f(\tau)$. The constant-hazard null corresponds to an exponential density of durations:

$$H_0'\colon f(\tau) = \begin{cases} 0, & \text{if } t_0 > \tau \geq 0 \\ \lambda \exp[-\lambda(\tau - t_0)], & \text{if } \tau \geq t_0. \end{cases} \tag{2}$$

Essentially, our nonparametric and parametric tests of the null hypothesis determine how well this density describes the sample distribution of observed durations.

The parametric procedure considers the hazard,

$$h_w(\tau) = \begin{cases} 0, & \text{if } t_0 > \tau \geq 0 \\ \lambda\, \alpha\tau^{\alpha-1}, & \text{if } \tau \geq t_0 \end{cases}, \tag{3}$$

where α parameterizes the amount of duration dependence.[2] This hazard function nests the null hypothesis; when $\alpha = 1$, $h_w(\tau) = \lambda$. If α is greater than one, the conditional probability of termination of a business cycle phase increases with its duration (i.e, there exists positive duration dependence). This hazard function implies a Weibull density of durations (with truncation), $f_w(\tau)$, which yields the log likelihood,

$$L(\alpha, \lambda; \tau_1, \ldots, \tau_N) = \sum_{i=1}^{N} \{\log(\alpha\lambda) + (\alpha-1)\log(\tau_i) - \lambda(\tau_i^{\alpha} - t_0^{\alpha})\}, \tag{4}$$

for a given sample of observed durations, $\tau_1, \tau_2, \tau_3, \ldots, \tau_N$. Our parametric test for duration dependence entails estimating the parameters of this likelihood and testing whether α is significantly different from unity.

We also employ three nonparametric tests of the null hypothesis.[3] First, renumber the sample of durations in ascending order, and add to the sample the assumed minimum possible duration, so that $\tau_1 \leq \tau_2 \leq \ldots \leq \tau_{N+1}$, with $\tau_1 = t_0$. Then form the test statistic

2. See Sichel (1989) for further details.
3. See Diebold and Rudebusch (1990a) for further details.

$$W = (\bar{\tau}-\tau_1)^2 / (N\hat{\sigma}^2), \tag{5}$$

where $\bar{\tau} = \sum_{i=1}^{N+1} \tau_i/(N+1)$ and $\hat{\sigma}^2 = \sum_{i=1}^{N+1} (\tau_i-\bar{\tau})^2/(N+1)$. As noted by Stephens (1978), the distribution of W is invariant to the true value of λ, and its exact finite-sample critical values under the exponential null hypothesis have been tabulated by Shapiro and Wilk (1972) for N ranging from 3 to 100.

For a second nonparametric test of the null hypothesis, define the normalized spacings between the ordered durations (including the minimum possible duration) as

$$Y_i = (N-i+1)(\tau_i-\tau_{i-1}), \quad i = 2, \ldots, N+1. \tag{6}$$

A plot of Y_i versus i provides resembles a plot of the mirror image of the hazard function; that is, increasing spacings imply a decreasing hazard function. Brain and Shapiro (1983) exploit this fact to obtain an asymptotic test of the exponential null hypothesis. Let $\tilde{I}$ and $\tilde{Y}_i$ denote the de-meaned variables $(i-(N+1)/2)$ and $(Y_i-\bar{Y})$. Then form the test statistic

$$Z = \frac{\sum_{i=1}^{N} \tilde{I}\, \tilde{Y}_{i+1}}{\sum_{i=1}^{N} Y_{i+1} \left[\sum_{i=1}^{N} \tilde{I}^2 / N(N+1)\right]^{1/2}} . \tag{7}$$

Under the null hypothesis, the distribution of Z is asymptotically N(0, 1), which it quickly approaches even in quite small samples.

The Z statistic is closely related to the t statistic for significance of order in a linear regression of normalized spacings on order. As such, the Z test can be expected to have power against linear departures from the null (flat) hazard. Brain and Shapiro also provide an alternative statistic, denoted Z^*, that is intended to be more sensitive to alternative duration distributions associated with nonlinear hazard functions. The Z^* statistic, which is closely related to the F statistic for significance of order in a quadratic regression of normalized spacings on order, has an asymptotic chi-squared distribution with two degrees of freedom. The simulation study in Brain and Shapiro indicates that the chi-squared provides a reliable guide to finite-sample behavior even in quite small samples.

3. Empirical Results

We take as given the NBER chronologies of business cycle peaks and troughs for prewar France, Germany, Great Britain, and the United States, which are shown in Tables 1 to 4.[4] For each country, these tables also show the durations of expansions, contractions, and whole cycles measured both peak to peak and trough to trough. We are limited to prewar samples with international data because of the scarcity of true recessions, involving actual declines in output, in Europe during the 1950s and 1960s. After the devastation of Europe during World War II, there was a reconstruction of extraordinary pace; thus, it is impossible to identify the classic business cycles in the postwar period in the European countries.[5]

Summary statistics, including the minimum observed duration, for each of the four samples from each country are displayed in Table 5. We also include summary statistics from pooled samples of all expansions, contractions, and whole cycles; however, we will not conduct our tests below on these pooled samples, and only present results for each country

4. These dates are taken from Moore and Zarnowitz (1986), which are the same as those in Burns and Mitchell (1946, pp. 78-79) with minor revisions for some of the U.S. dates.
5. In the postwar period, growth cycles, which refer to periods of rising and falling activity relative to trend growth, have been identified for the European countries (see, Moore and Zarnowitz (1986)). However, the timing, and hence duration dependence, of these cycles is not comparable with the prewar business cycles.

separately. Although it might be appealing to pool durations across countries to expand the sample, the conformity of business cycle timing across countries suggests that the observations across countries are not independent.[6] Hence, simple pooling would be inappropriate. Test procedures that control for the degree of interdependence are likely to be complicated, particularly since so little is known about the transmission of business cycles from one country to another; thus, we do not consider the pooled samples in tests below.[7]

There is one area in which we do pool information from the four countries; namely, in the specification of minimum possible duration, t_0. This minimum duration criterion is necessary because, by definition, the NBER does not recognize an expansion or contraction unless it has achieved a certain maturity. The exact required maturity is not spelled out by the NBER, but Moore and Zarnowitz (1986), in describing the guidelines enforced since Burns and Mitchell (1946), indicate that full cycles of less than 1 year in duration and contractions of less than 6 months in duration would be very unlikely to qualify for selection.[8] Because this is an NBER definitional criterion of business cycles, the choice of t_0 should not be country specific, but uniform across countries. In particular, we set t_0 for expansions, contractions, or whole cycles equal to the minimum duration actually observed in any of the four countries.[9] Our test results are not sensitive to reasonable variation in t_0.

6. See Moore and Zarnowitz (1986) and Morgenstern (1959) for qualitative descriptions of the conformity of international business cycles.
7. Additional complications arise from the fact that different countries have experienced different numbers of business cycles over identical historical periods. (Compare, for example, the chronologies for the U.S. and for Great Britain.)
8. Note that Geoffrey Moore and Victor Zarnowitz are two of the eight members on the NBER's Business Cycle Dating Committee.
9. We also specify a uniform t_0 for peak-to-peak and trough-to-trough cycles, given evidence that the NBER makes no distinction between these two types of whole cycles. See Diebold and Rudebusch (1990a). Also note that Sichel (1989) specified t_0 as one less than the minimum observed duration.

To summarize the evidence from the variety of tests that we consider, table 6 provides the associated p-values, which are the probabilities of obtaining the sample test statistic under the null of no duration dependence.[10] Small p-values therefore indicate significant departures from the null. These are two-sided tests, so the relevant alternatives include both positive and negative duration dependence. In fact, for all of the samples, departures from the null, whether significant or not, were in the direction of positive duration dependence (i.e., sample values of α were greater than unity and the sample Z statistics were negative).

For a given sample, the results are broadly consistent across testing methodologies. For expansions, the U.S. finding of significant positive duration dependence (sample US1) is mimicked in the three European countries, although the European p-values are slightly higher.[11] For Great Britain and Germany, the null is rejected at approximately the 10 percent level, while the significance level is somewhat higher for France. Note, however, that the French p-values for W and α, which we might expect to be more accurate than those for Z and Z^* in small samples, are reasonably small.

For contractions, the U.S. finding of no significant duration dependence (sample US2) is mimicked again in the European countries: no evidence whatsoever is found for France, Germany or Great Britain.

Evidence for duration dependence in whole cycles, which is fairly strong in the U.S. samples (US3 and US4), is more muted (but nevertheless

10. The p-values of the W statistic are obtained by linearly interpolating the tables in Shapiro and Wilk (1972). The p-values of the Z and Z^* statistics are obtained using their asymptotic distributions. The p-values for the Weibull parameter α are calculated with standard errors for α computed from 500 bootstrap simulations of duration data.

11. It is interesting to compare our results to those of McCulloch (1975) and Savin (1977), who fail to find evidence of duration dependence in prewar business cycles. The divergence may be traced to the poor small-sample power of chi-square goodness-of-fit tests (Sichel, 1989), as well as to the sensitivity of such tests to t_0 and to the number of histogram bins used (Diebold and Rudebusch, 1990b).

present) in the European countries. This is true for both the peak-to-peak and trough-to-trough samples. Again, note that for both the peak-to-peak and trough-to-trough samples, the finite-sample p-values (corresponding to W and α) are quite small. In fact, the W and α tests reject the null of no duration dependence at the 10% level 13 of 16 times. It would appear, however, that the significant whole-cycle duration dependence is a manifestation of the earlier-discussed significant half-cycle (expansion) duration dependence.

We stress that we have reported <u>two-sided</u> p-values, in order to maintain conservatism. The p-values for each country and each test against the <u>one-sided</u> alternative of positive duration dependence, which may be reasonable on a priori grounds, are half those shown in table 6 for the two-sided tests. Use of such p-values would enhance substantially our finding of significant duration dependence in expansions and whole cycles, while leaving intact our finding of no duration dependence in contractions.

While our tests indicate the <u>statistical</u> significance of duration dependence in prewar expansions and whole cycles, they convey little information as to its <u>economic</u> significance. That is, do the expansion and whole-cycle hazards rise quickly enough to merit attention? Table 7, which shows estimates of the hazard functions that underlie the results in the last column of table 6, provides some insight.[12]

Consider first the expansion samples. The estimated hazard for German expansions, for example, shows the probability of a peak occurring during a month rising from close to zero after 12 months to about 12 percent after only 48 months. The other countries also show substantial slope in their expansion hazard functions. Even France and Britain, whose expansion hazards rise the most slowly, have hazard probabilities in the 9% - 13%

12. The hazard (3) is estimated by maximizing the likelihood (4), using the minimum durations shown in table 6.

range after 72 months, a very large increase relative to their earlier values near zero.

For contractions, all of the estimated hazards nearly flat. In contrast to the expansion hazard probabilities, which start near zero and grow relatively quickly (and at increasing rates), the contraction hazard probabilities start near 5% and grow less quickly (and at decreasing rates). The contrast between the expansion and contraction hazards is readily apparent in figures 1 and 2, in which the hazard functions for expansions and contractions are graphed.

The estimated full-cycle hazards show some positive slope, but not nearly as much as the expansion samples. This is in line with our earlier assertion that the full-cycle duration dependence is driven by the duration dependence in expansions.

4. Concluding Remarks

We began this paper by asking whether expansions, contractions, or whole cycles are more or less likely to end as they grow older, a question whose answer is of importance both methodologically and substantively. Methodologically, for example, the answer has implications for the proper specification of empirical macroeconomic models, such as the Markov-switching models proposed recently by Hamilton (1989). Substantively, for example, the answer has implications for turning point prediction and business-cycle dating, as pointed out by Diebold and Rudebusch (1989, 1990b).

Here we have investigated the pattern of duration dependence in France, Germany, and Great Britain before World War II, and compared the evidence to our previous results for the United States. We find that, for expansions, all four countries exhibit evidence of positive duration dependence. For contractions, none of the countries do. The results paint a similar picture for each country: statistically significant and economically important positive duration dependence is consistently associated with expansions, and never associated with contractions. The similarities in the prewar pattern of duration dependence across countries suggest conformity in the characteristics of business cycles in these countries.

The empirical results in this paper and in our earlier papers pose substantial challenges for the construction of macroeconomic models; we hope that our measurement stimulates fresh theory. Obvious questions abound: What types of economic propagation mechanisms induce duration dependence in aggregate output, and what types do not? What are the theoretical hazard functions associated with the equilibria of various business-cycle models, and how do they compare with those estimated from real data? What types of models are capable of generating equilibria with differing expansion and contraction hazard functions, and how do they relate to existing linear and nonlinear models? How can we explain and model secular variation in the degree of duration dependence in expansions and contractions? Some recent work has begun to address various of these questions (e.g., Murphy, Shleifer and Vishny (1989) develop a model in which cyclical duration is influenced by the stock of durables), but much remains to be done.

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Table 1
Business Cycle Chronology and Durations
United States, 1854-1938

Trough	Peak	Contractions	Expansions	Trough To Trough	Peak To Peak
December 1854	June 1857	--	30	--	--
December 1858	October 1860	18	22	48	40
June 1861	April 1865	8	46	30	54
December 1867	June 1869	32	18	78	50
December 1870	October 1873	18	34	36	52
March 1879	March 1882	65	36	99	101
May 1885	March 1887	38	22	74	60
April 1888	July 1890	13	27	35	40
May 1891	January 1893	10	20	37	30
June 1894	December 1895	17	18	37	35
June 1897	June 1899	18	24	36	42
December 1900	September 1902	18	21	42	39
August 1904	May 1907	23	33	44	56
June 1908	January 1910	13	19	46	32
January 1912	January 1913	24	12	43	36
December 1914	August 1918	23	44	35	67
March 1919	January 1920	7	10	51	17
July 1921	May 1923	18	22	28	40
July 1924	October 1926	14	27	36	41
November 1927	August 1929	13	21	40	34
March 1933	May 1937	43	50	64	93
June 1938	--	13	--	63	--

Table 2
Business Cycle Chronology and Durations
Germany, 1879-1932

Trough	Peak	Contractions	Expansions	Trough To Trough	Peak To Peak
February 1879	January 1882	--	35	--	--
August 1886	January 1890	55	41	90	96
February 1895	March 1990	61	61	102	122
March 1902	August 1903	24	17	85	41
February 1905	July 1907	18	29	35	47
December 1908	April 1913	17	52	46	69
August 1914	June 1918	16	46	68	62
June 1919	May 1922	12	35	58	47
November 1923	March 1925	18	16	53	34
March 1926	April 1929	12	37	28	49
August 1932	--	40	--	--	77

Table 3
Business Cycle Chronology and Durations
France, 1865-1938

Trough	Peak	Contractions	Expansions	Trough To Trough	Peak To Peak
December 1865	November 1867	--	23	--	--
October 1868	August 1870	11	22	34	33
February 1872	September 1873	18	19	40	37
August 1876	April 1878	35	20	54	55
September 1879	December 1881	17	27	37	44
August 1887	January 1891	68	41	95	109
January 1895	March 1900	48	62	89	110
September 1902	May 1903	30	8	92	38
October 1904	July 1907	17	33	25	50
February 1909	June 1913	19	52	52	71
August 1914	June 1918	14	46	66	60
April 1919	September 1920	10	17	56	27
July 1921	October 1924	10	39	27	49
June 1925	October 1926	8	16	47	24
June 1927	March 1930	8	33	24	41
July 1932	July 1933	28	12	61	40
April 1935	June 1937	21	26	33	47
August 1938	--	14	--	40	--

Table 4
Business Cycle Chronology and Durations
Great Britain, 1854-1938

Trough	Peak	Contractions	Expansions	Trough To Trough	Peak To Peak
December 1854	September 1857	--	33	--	--
March 1858	September 1860	6	30	39	36
December 1862	March 1866	27	39	57	66
March 1868	September 1872	24	54	63	78
June 1879	December 1882	81	42	135	123
June 1886	September 1890	42	51	84	93
February 1895	June 1900	53	64	104	117
September 1901	June 1903	15	21	79	36
November 1904	June 1907	17	31	38	48
November 1908	December 1912	17	49	48	66
September 1914	October 1918	21	49	70	70
April 1919	March 1920	6	11	55	17
June 1921	November 1924	15	41	26	56
July 1926	March 1927	20	8	61	28
September 1928	July 1929	18	10	26	28
August 1932	September 1937	37	61	47	98
September 1938	--	12	--	73	--

Table 5
Pre-War Business Cycle Sample Summary Statistics

Sample	Sample Size (N)	Minimum Duration	Mean Duration	Standard Error
Great Britain, 1854-1938				
GB1: Expansions	16	8	37.1	17.8
GB2: Contractions	16	6	25.7	19.4
GB3: Peak-to-Peak	15	17	64.0	32.9
GB4: Trough-to-Trough	16	26	62.8	28.6
France, 1865-1938				
F1: Expansions	17	8	29.2	14.8
F2: Contractions	17	8	22.1	15.9
F3: Peak-to-Peak	16	24	52.2	25.3
F4: Trough-to-Trough	17	24	51.3	23.0
Germany, 1879-1932				
G1: Expansions	10	16	36.9	14.2
G2: Contractions	10	12	27.3	18.1
G3: Peak-to-Peak	10	34	64.4	27.5
G4: Trough-to-Trough	9	28	62.8	25.5
United States, 1854-1938				
US1: Expansions	21	10	26.5	10.7
US2: Contractions	21	7	21.2	13.6
US3: Peak-to-Peak	20	17	47.9	20.3
US4: Trough-to-Trough	21	28	47.7	18.1
All Countries				
Expansions	64	8	31.5	14.8
Contractions	64	6	23.5	16.3
Peak-to-Peak	61	17	55.7	26.7
Trough-to-Trough	63	24	54.7	23.9

Table 6
Tests for Exponentiality
(p-values under the null of no duration dependence)

Sample	W	Z	Z^*	α
Expansions				
GB1 (t_0=8)	.047	.091	.123	.108
F1 (t_0=8)	.158	.357	.623	.088
G1 (t_0=8)	.026	.067	.132	<.01
US1 (t_0=8)	<.01	.021	.008	.064
Contractions				
GB2 (t_0=6)	.769	.413	.389	.885
F2 (t_0=6)	.775	.421	.292	.816
G2 (t_0=6)	.888	.952	.559	.440
US2 (t_0=6)	.858	.956	.102	.507
Peak to Peak				
GB3 (t_0=17)	.193	.409	.591	.109
F3 (t_0=17)	.233	.265	.064	.074
G3 (t_0=17)	.094	.214	.095	<.01
US3 (t_0=17)	.057	.080	.010	.021
Trough to Trough				
GB4 (t_0=17)	.060	.143	.123	.010
F4 (t_0=17)	.103	.196	.317	<.01
G4 (t_0=17)	.080	.194	.414	<.01
US4 (t_0=17)	.010	.018	<.01	<.01

Notes to table 6: The samples are identified in table 5. The p-values are two-sided probabilities under the null.

Table 7
Estimated Hazard Functions

Sample	$\hat{\alpha}$	$\hat{\lambda}$	12	18	24	36	48	72	96
			Duration in months						
Expansions									
GB1	2.09	.0004	.01	.02	.03	.04	.05	.09	.12
F1	1.85	.0018	.03	.04	.05	.06	.07	.13	.16
G1	2.98	.00002	.01	.02	.03	.07	.12	.28	.48
US1	2.47	.0003	.03	.05	.08	.14	.21	.39	.59
Contractions									
GB2	1.07	.0383	.05	.05	.05	.05	.05	.06	.06
F2	1.11	.0412	.06	.06	.06	.07	.07	.07	.07
G2	1.43	.0090	.04	.04	.05	.06	.07	.08	.09
US2	1.35	.0183	.06	.07	.07	.08	.09	.11	.12
Peak to Peak									
GB3	1.82	.0005	--	.01	.01	.02	.02	.03	.04
F3	1.89	.0005	--	.01	.02	.02	.03	.04	.06
G3	2.44	.00003	--	.00	.01	.01	.02	.03	.05
US3	2.15	.0002	--	.01	.02	.03	.04	.06	.08
Trough to Trough									
GB4	2.18	.0001	--	.01	.01	.02	.02	.03	.05
F4	2.10	.0002	--	.01	.01	.02	.03	.05	.06
G4	2.67	.00001	--	.00	.01	.01	.02	.03	.06
US4	2.47	.00006	--	.01	.02	.03	.04	.08	.12

FIGURE 1

ESTIMATED HAZARD FUNCTIONS, EXPANSIONS

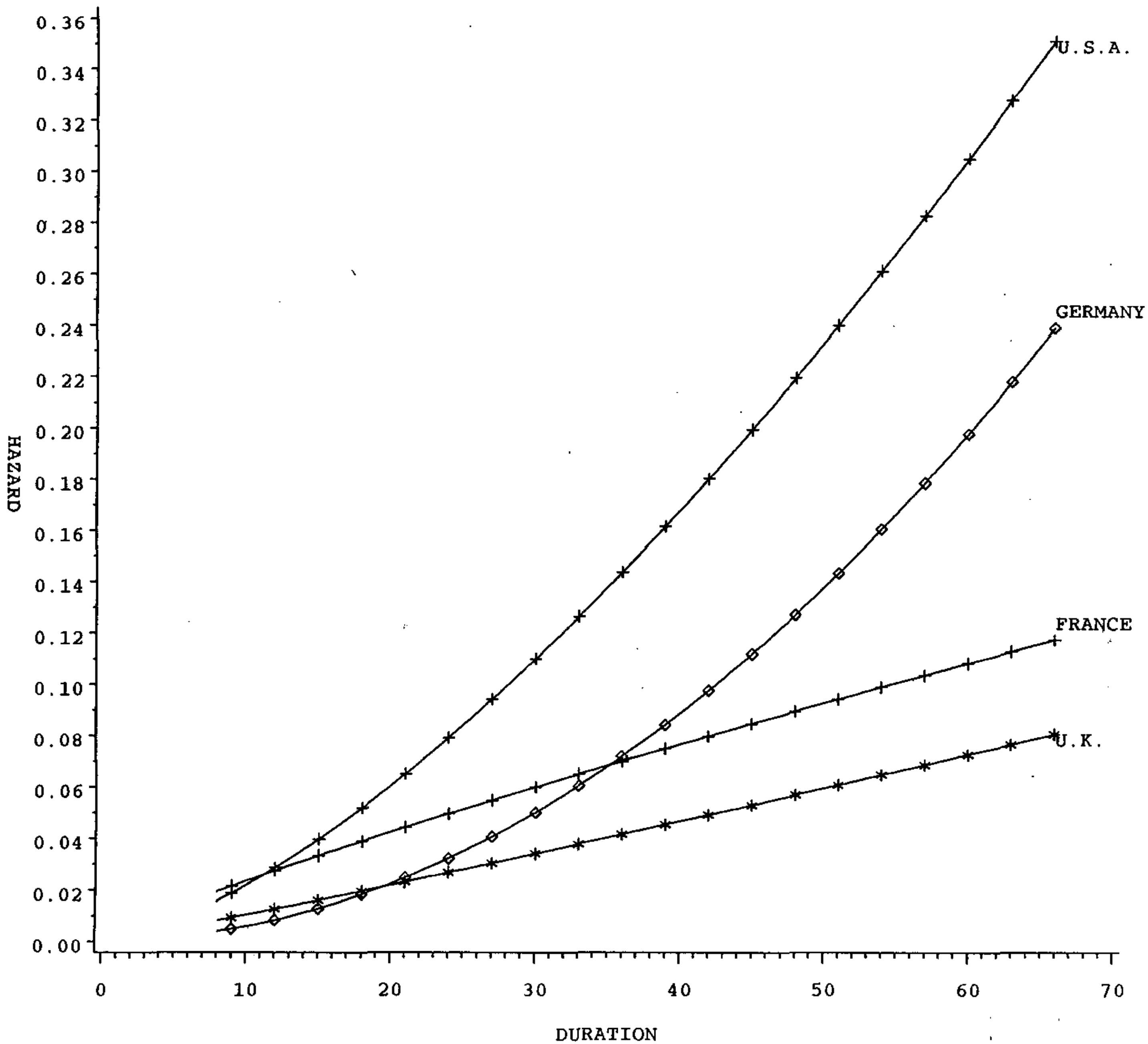

FIGURE 2

ESTIMATED HAZARD FUNCTIONS, CONTRACTIONS