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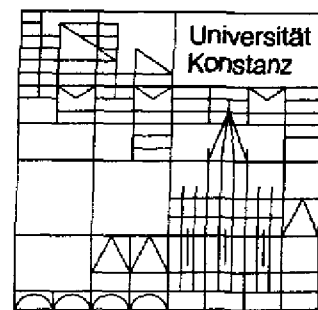
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Sonderforschungsbereich 178
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Diskussionsbeiträge



Juristische
Fakultät

Fakultät für Wirtschafts-
wissenschaften und Statistik

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**Consumption Smoothing
across Seven Countries**

A Time Series Analysis

CONSUMPTION SMOOTHING ACROSS SEVEN COUNTRIES
- A TIME SERIES ANALYSIS -

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Consumption Smoothing Across Seven Countries

- A Time Series Analysis -

Abstract: With representative agents maximizing their expected life time utility, it can be shown under certain functional form assumptions that consumption follows a random walk and should be cointegrated across countries, because in an optimal risk pooling arrangement agents smooth consumptions with respect to erratic income movements. These implications are analyzed for the G-7-countries using spectral based and cointegration techniques. Also the contemporaneous and causal feedback and a factor analytical model are estimated for the first differences of the consumption series. The results indicate little comovement of consumption across countries for annual data from 1950 to 1985.

1 Introduction

The life cycle theory of consumption concludes that risk averse agents tend to smooth their intertemporal consumption patterns with respect to erratic income movements. This result is consistent with the stylized fact that aggregate consumption exhibits a smoother time path than aggregate income. The stochastic implications of the life cycle theory of consumption have been explored extensively since the work of Hall (1978). Within the representative agent framework, he showed that as an implication of optimizing behavior marginal utility of consumption follows a random walk. Assuming a constant relative risk aversion utility function, this implies that the logarithms of the agent's consumption exhibits random walk behavior. When the life cycle model is extended to the heterogeneous agent case, it can be shown that agents maximizing their expected utility also have an incentive to smooth out intratemporally erratic income movements between each other.

In analogy to Backus/Kehoe (1989a), who set up a multi agent framework in their analysis of the time series properties of a number of world and country specific macro variables, implications of a multi agent life cycle model are derived in section 2 of this paper. The model is applied to the case of the G-7-countries, where each country is modelled as a representative consumer. Assuming complete international financial markets and constant relative risk aversion utility functions the random walk results follows as well.

In a recent study, Durlauf (1989b) explored the time series properties of log real per capita output in six of the G-7-countries.² He found, that there was little comovement in these series across countries. Within the framework developed in section 2 it can be shown that the logarithms of real per capita consumption in two countries should be cointegrated in an optimal risk sharing arrangement across countries given that the income processes follow stochastic trends.

In the empirical part, section 3, these implications and some modifications in light of the empirical results will be tested using spectral-based-tests, tests for cointegration, Geweke's (1982) feedback analysis, and the method of factor analysis. The first three methods were advocated in recent papers of Durlauf (1990a) and (1990b). The spectrum of a time series is an appealing object of study as it encompasses all second moment properties of a time series.

²Italy was not part of Durlauf's study.

Durlauf describes several ways of using the sample periodogram in testing certain hypothesis about a time series. The analysis in the sequel tries to scrutinize the relations between the consumption series across the different countries.

Section 4 concludes the paper. The strong implications for consumption smoothing across countries derived in section 2 are generally refuted. There is, however, evidence for a weak relation between the innovations in the consumption processes.

2 A representative agent model for aggregate consumption in different countries

In the first part of this section the consumption decisions of a country will be derived within a representative consumer framework. The random walk behavior for the logarithms of per capita consumption follows obviously under the constant relative risk aversion utility specification. In the second part, the consumption smoothing property is more easily derived for the competitive equilibrium within a social planner's problem using the welfare properties of the specified economy. The result assumes complete international financial markets.

It is assumed that aggregate consumption decisions in each of the seven countries can be generated by a representative consumer j , who maximizes her expected lifetime utility as a function of the time path of per capita consumption, $\{c_{j,t}\}$,

$$V_j(y_{j,0}, A_{j,0}) = \max E_0 \sum_{t=0}^T \beta_j^t U_j(c_{j,t}) \quad (1)$$

with $j \in \{J, US, C, UK, G, F, I\}$ ³, $U_j(\cdot)$ denoting instantaneous utility, β_j the discount factor, and $V_j(\cdot, \cdot)$ the value function representing the life time utility of country j given income, $y_{j,0}$, and assets, $A_{j,0}$, in period 0.

Assuming that the representative consumer faces an interest rate $r_{j,t}$ ⁴,

³These abbreviations stand for the respective country name, J stands for Japan, US for the United States, C for Canada, UK for the United Kingdom, G for West Germany, F for France and I for Italy. These are the G-7-countries.

⁴The interest rates will be shown to depend on the specific random events, which have occurred. Confer the social planner's problem in the sequel.

the first order condition of her maximisation problem is given by the standard Euler-equation:

$$U'_j(c_{j,t}) - \beta_j E_t(1 + r_{j,t})U'_j(c_{j,t+1}) = 0. \quad (2)$$

In an autarky equilibrium, interest rates adjust such that aggregate consumption equals aggregate real income in each period⁵. In addition, I assume a competitive equilibrium in each country. The real income process is driving aggregate consumption in each country and interest rates move in each country accordingly without any international link.

Following evidence by Durlauf (1989a), (1989b), and (1990a) it is postulated as a simplifying assumption that the logarithms of per capita real income follow random walks with drifts.

$$y_{j,t} = d_j + y_{j,t-1} + \eta_{j,t} \quad (3)$$

Once free trade and a complete international financial market are introduced, the situation changes; now each consumer faces the same interest rate, i.e. $r_{j,t} = r_t$ for all j . Unless particular functional forms for the utility functions U_j are specified, the Euler-equation is empirically vacuous. To derive a linear cointegration relation, I assume constant-relative-risk-aversion momentary utility functions:

$$U_j(c_{j,t}) = \frac{c_{j,t}^{1-\gamma_j}}{1-\gamma_j} \text{ with } \gamma_j \in (0, \infty) \quad (4)$$

Thus the Euler equation for agent j becomes

$$E_t \beta_j (1 + r_t) \left(\frac{c_{j,t}}{c_{j,t+1}} \right)^{\gamma_j} = 1 \quad (5)$$

⁵For simplicity I ignore capital accumulation - see Backus/Kehoe(1989a) -, and output is assumed to be perishable. Then the autarky equilibrium is equivalent to the equilibrium in the economy described by Lucas(1978); see also Sargent(1987) chapter 3. These assumptions simplify the derivation of the link of aggregate consumption across countries, as it will be shown with the social planner's problem. Alternatively one could assume under certain separability assumptions, that $y_{j,t}$ is the amount of income in country j allotted to consumption in period t .

One can derive a linear relation between $\ln(c_{j,t+1})$ and $\ln(c_{j,t})$,

$$\ln(c_{j,t+1}) - \ln(c_{j,t}) = \alpha_j + \frac{1}{\gamma_j} \ln(1 + r_t) + \epsilon_{j,t+1}.^6 \quad (6)$$

When the right hand side is a stationary process, a first result one can obtain from this equation is, that the processes of the logarithm of real consumption have a unit root. When the right hand side is even i.i.d. then the consumption process follows a random walk with drift⁷.

In the given setting the first welfare theorem holds, such that all competitive equilibria are Pareto-optimal. This property can be used to derive the result that consumption is smoothed across countries in an optimal risk sharing arrangement. The social planner's problem gives the optimal risk pooling arrangement in a date-0 competitive equilibrium. Complete financial markets, modelled in this section by assuming a common real interest rate, can replicate this result. The date-0 equilibrium is then equivalent to a sequence of spot market equilibria. With a complete international financial market all countries face the same safe interest rate r_t and under risk aversion - $\gamma_j > 0$ - they have an incentive to hedge against the entire income risk $\eta_t = \sum_j \eta_{j,t}$ one period ahead. By deriving the associated social planner's problem, which gives an equivalent representation of the competitive equilibrium, one obtains again the individual optimality condition in equation 6 and one can show that equation 6 for the different countries would have the same common shock up to a factor of proportionality for each of the agents. This property is a sufficient condition for a linear cointegration relation between the logarithms of per capita consumption in two countries.⁸

⁶For the processes, $\eta_{j,t}$, $j = 1, \dots, 7$, being white noise, and having only a finite number of possible values, α_j is a constant, determined by the distribution of the $\eta_{j,t}$'s, $j=1, \dots, 7$.

⁷First observed in Hall(1978).

⁸If the error terms in equation 6 for two countries at a point of time were not the same up to a time independent factor of proportionality, then substituting in for r_t to combine the equations for the two countries would result into a linear equation for the first differences of the logarithms of per capita consumption in the two countries generally still containing a stationary error term. Transforming back the result into levels therefore would not give a linear cointegration relation because the error term of the latter equation would be nonstationary.

The social planner is assumed to maximize expected social welfare

$$\begin{aligned} \max \sum_j \lambda_j V_j &= \sum_j \sum_{t=0}^T \beta_j^t E_0 U_j(c_{j,t}) = \\ &= \sum_j \lambda_j \sum_{t=0}^T \beta_j^t \sum_{s^t \in S^t} P(s^t) U_j(c_{j,t}(s^t)) \end{aligned} \quad (7)$$

for all agents j , with respect to the consumption paths $\{c_{j,t}\}$ ⁹, $t=0,\dots,T$, where λ_j are the date-0 weights of the different agents, i.e. the inverses of their marginal utilities of wealth at date 0. The maximization is subject to the constraint

$$\sum_j c_{j,t}(s^t) = \sum_j y_{j,t}(s^t) \quad (8)$$

for all states $s^t \in S^t$ and $t=0,\dots,T$.

The social planner's problem in equation 7 can be modified to

$$\max \sum_{t=0}^T \sum_{s^t \in S^t} P(s^t) \sum_j \lambda_j \beta_j^t U_j(c_{j,t}(s^t)). \quad (9)$$

Because it is assumed that expected social welfare is maximized, output is perishable, and the agents' life-time utility function is strongly time separable the social planner's problem is equivalent to

$$\max \sum_j \lambda_j \beta_j^t U_j(c_{j,t}(s^t)) \quad (10)$$

for each $t=0,\dots,T$ and $s^t \in S^t$ subject to equation 8. The first order conditions of this maximization problem yield the following relations for the utility functions assumed under equation 4

$$\ln(c_{j,t}) - \gamma_{ij} \ln(c_{i,t}) = \frac{1}{\gamma_j} \{ \ln(\beta_j^t \lambda_j) - \ln(\beta_i^t \lambda_i) \} \quad (11)$$

⁹ $s^t = \{s_0, \dots, s_t\}$ is the history of the stochastic shocks, which have occurred until time t in this economy, and S^t is the finite set of all possible histories, because the shocks η_t are supposed to have only finitely many outcomes. $P(s^t)$ is the probability of a particular history s^t to occur. The approach, to represent a competitive equilibrium as an outcome of a social planner's problem is a standard procedure in the literature for an Arrow-Debreu-economy, where the first Welfare Theorem holds. See e.g. Backus/Kehoe(1989a), Breeden/Litzenberger(1978), Scheinkman(1984), and Townsend(1986).

where $\gamma_{ij} = \gamma_i/\gamma_j$. Allowing for stationary measurement error in the levels of the logarithms of per capita consumption, this implies a cointegration relation for a country pair (i,j), which could have been derived directly from equation 6 under the assumption of a common shock term - perfect risk sharing - such that $\epsilon_{j,t} = \frac{1}{\gamma_j}\epsilon_t$ for all j, as follows

$$\Delta \ln(c_{j,t}) - \gamma_{ij} \Delta \ln(c_{i,t}) = \alpha_j - \gamma_{ij} \alpha_i, \quad (12)$$

When one changes from an equation in first differences to an equation in levels, this implies:

$$\ln(c_{j,t}) - \gamma_{ij} \ln(c_{i,t}) = (\alpha_j - \gamma_{ij} \alpha_i)t + b_{ij}^{10}, \quad (13)$$

Once measurement error, $\nu_{i,j,t}$, is allowed for in the levels, one obtains the following cointegration relation

$$\ln(c_{j,t}) - \gamma_{ij} \ln(c_{i,t}) - (\alpha_j - \gamma_{ij} \alpha_i)t - b_{ij} = \nu_{i,j,t}. \quad (14)$$

We define

$$a_{ij} = \alpha_j - \gamma_{ij} \alpha_i.$$

If two countries have the same discount rates, $\beta_i = \beta_j$, the standard result follows, that $a_{ij} = 0$, i.e. the cointegration relation between log real consumption in the two countries does not involve a trend component¹¹ In this case the logarithms of real consumption in the two countries alone are cointegrated.

$$\ln(c_{j,t}) - \gamma_{ij} \ln(c_{i,t}) - b_{ij} = \nu_{i,j,t}. \quad (15)$$

If the two consumption variables and time are cointegrated, then at most there could be two independent cointegration relations, i.e. two integrating vectors, $(1, \gamma_{ij}(1), a_{ij}(1))$ and $(1, \gamma_{ij}(2), a_{ij}(2))$, not taking account of the constant. Each linear combination of the two is then also a cointegration relation, because each linear combination of two stationary variables is stationary again. If one finds two cointegrating coefficient vectors by estimating the last two equations 14 and 15, the second one is constrained, such that the

¹⁰ b_{ij} is analogous to an integration constant in the solution of a differential equation.

¹¹This can be seen most easily from the first order conditions in the associated social planner's problem.

time coefficient is zero. Therefore, without loss of generality¹², the above is a test for two independent cointegrating vectors, according to Granger(1986)¹³.

Section 3 analyzes the data in terms of the framework set up in this section. In section 3.1, I will test whether log real consumption follows a random walk in each country, as equation 3 under the assumption of white noise interest rates suggests. In 3.2, I test for cointegration between log real consumption in two countries with and without time as a third variable. In 3.3 Geweke's (1982) general framework for examining the feedback between the first differences in log real consumption will be applied. Finally in section 3.4, I will use the method of factor analysis to test whether the first differences in log real consumption in the seven countries are likely to be driven by one common factor, i.e. the innovation in world aggregate income, η_t , as the preceding simple model suggests.

3 Data analysis

The following section analyzes the time series behavior of the logarithms of per capita real aggregate consumption in the G-7-countries, Japan, US, Canada, UK, West Germany, France and Italy. The data are taken from a recent study by Summers/Heston, which provides annual data from 1950 to 1985, i.e. 36 observations. These data are widely used, because they are regarded as the best available series for cross-country comparisons of real activity due to the care with which exchange rate and price information are incorporated into the construction of the aggregated real series from nominal observations¹⁴.

¹²I.e. except for the special case that the estimate for γ_{ij} are the same - what we would like, however, from an economic point of view.

¹³Page 220 ff in Granger.

¹⁴See the articles by Summers/Heston(1988), Durlauf(1989a) and (1989b). The estimations and calculations for section 3.1. were mostly done using Math-Lab. With the help of Andrew Bernard I was able to use the available software from Steve Durlauf. Some calculations for 3.1., all estimations and calculations for 3.2. and 3.3. were done using TSP. TSP was also used for fitting low order ARMA models in 3.4., while the factor analysis was done with SAS.

3.1 Spectral analysis of aggregate consumption

The spectrum of a time series gives a picture of the second moment properties of a time series. To analyze whether log real consumption has a unit root according to equation 3, the spectrum of the first differences of log real consumption in the seven countries is examined. Figure 1 - 7 in the appendix give the normalized estimated spectral distribution function of the seven time series,

$$F_j = F_{\Delta \ln(c_j)}(\lambda) = \frac{2 \int_0^\lambda f_{\Delta \ln(c_j)}(\omega) d\omega}{\sigma_{\Delta \ln(c_j)}(0)} \quad (16)$$

which provides a scale free way to analyze the time series¹⁵. According to the Cramér Representation Theorem, the expression

$$F_j(\lambda_2) - F_j(\lambda_1)$$

gives the contribution of frequencies in the interval $[\lambda_1, \lambda_2]$ to the whole variance of $\Delta \ln(c_{j,t})$ ¹⁶. One can use the estimated spectral distributions in figure 1-7 to describe the time series behavior of the first differences in log real consumption in the seven countries by analysing the importance of different frequency ranges for the overall variance. If log real consumption in a country contains a unit root, then the spectral density at frequency zero should be nonzero, the only testable implication of a unit root. Often, however, a test of this implication gives ambiguous results, because the standard errors are too high for the small sample sizes one has with annual macrodata. The power of these tests is extremely low for the alternative of long run mean reversion¹⁷.

For the more narrowly defined null, that log real per capita consumption has a unit root with independent but not necessarily homoscedastic innovations, one can specify the exact shape of the normalized spectral distribution

¹⁵The spectral distribution function is defined for the frequencies $\lambda \in [0, \pi]$. The integral is multiplied by a factor 2, because by symmetry one can ignore negative frequencies. $f_{\Delta \ln(c_j)}(\omega)$ is the spectral density for frequency ω , which is estimated by the periodogram, $I_T(\lambda)$, for $T=35$ observations. $\sigma_{\ln(c_j)}(k)$ is the k th-order autocovariance, which is estimated by the sample autocovariance. See Durlauf (1990a) for the methodology.

¹⁶With $\Delta \ln(c_{j,t})$ being heteroscedastic this refers to the mean variance.

¹⁷See Introduction in Durlauf(1990a).

function of the first differences under the null:

$$H_0 : F_j(\lambda) = \frac{1}{\pi} \lambda \quad (17)$$

As discussed in Durlauf(1990b), different goodness of fit tests can be empirically implemented. In order to metrize the deviations of the empirical spectral distribution function from its theoretical shape under H_0 , define the random function

$$B_{j,T}(t) = \sqrt{2T} \int_0^{\pi t} \left(\frac{I_T(\omega)}{\sigma_{\Delta \ln(c_{j,t})}(0)} - \frac{1}{2\pi} \right) d\omega \text{ for } t \in [0, 1], \quad (18)$$

where $I_T(\omega)$ ¹⁸ is the periodogram estimate of the spectral density at frequency ω . This formulation computes the deviations of the normalized periodogram-based spectral distribution from a diagonal. It has been shown, that despite of the inconsistency of $I_T(\omega)$ as an estimator, $B_{j,T}$ converges under H_0 to a Brownian Bridge¹⁹ under fairly general conditions. One can now test for H_0 , using either of two methods. In the first method, test statistics are developed for the entire frequency range to measure the deviation of the estimated spectral distribution function from the diagonal under the null. In the second method, one may examine for specific ranges of frequencies $[\lambda_1, \lambda_2]$ whether the variance contribution is consistent with the null²⁰.

To implement the first test of whether the entire shape of the estimated spectral distribution is consistent with the null, I will use the following three test statistics²¹:

$$CVM_{j,T} = \int_0^1 B_{j,T}(t)^2 dt$$

Cramér – von – Mises statistic

¹⁸The periodogram is calculated for 257 equidistant points in the intervall $[0, \pi]$.

¹⁹A Brownian bridge $B(t)$ for $t \in [0, 1]$ is defined as $B(t) = BM(t) - tBM(1)$, where $BM(t)$ is a standard Brownian Motion.

²⁰We will use the facts that for a Brownian Bridge $B(t)$, for $t \in [0, 1]$, $B(t)$ is normally distributed, $N[0, t - t^2]$, and the difference $B(t_2) - B(t_1)$ is normally distributed, $N[0, (t_2 - t_1) - (t_2 - t_1)^2]$.

²¹The CVM-, KS-, and K-statistic are standard measures of dispersion of an empirical probability distribution function from a specified null. Bernard(1990) shows in a Monte-Carlo-study, that the CVM-statistic has excellent small sample properties for sample size $T=40$. The KS-statistic and the K-statistic are asymptotically valid.

$$KS_{j,T} = \sup |B_{j,T}(t)| \text{ with respect to } t \in [0, 1]$$

Kolmogorov – Smirnov statistic

$$K_{j,T} = \sup |B_{j,T}(t) - B_{j,T}(s)| \text{ with respect to } t, s \in [0, 1]$$

Kuiper statistic

These test statistics each give a general goodness of fit measure without specifying a range of frequencies to explore. They are calculated for the seven countries in table 1 including the critical values for the distributions under the null. Durlauf (1990b) shows that under general conditions these statistics diverge, if H_0 is not true.

To implement the second test, I analyze whether the variance contribution of certain frequency ranges is consistent with the null. I am looking at the intervals $[0, k\frac{\pi}{8}]$, for $k = 1, \dots, 7$, in table 2-3 and the intervals $[(k-1)\frac{\pi}{8}, k\frac{\pi}{8}]$, for $k = 1, \dots, 8$, in table 3-4. Under H_0 the first set of intervals should contribute $k/8$ of the entire variance, while in the later case the share is $1/8$ for each of the eight intervals. The test statistics are derived from the estimated $B_{j,T}(t)$ functions using their asymptotic distribution with $t = \frac{\lambda}{\pi}$. The critical values can therefore be easily drawn from a normal table. This procedure seems reasonable if one has a specific prior one wants to test for as the alternative to H_0 . The ranges of frequencies chosen here are arbitrary. If one is interested in long run mean reversion, it seems appropriate to test for the interval starting at the zero frequency.

Following the first approach, one finds very distinct estimates of the spectral distribution functions in figure 1-7 in the appendix. The patterns of the spectral distribution functions can be classified into three groups of countries: Four countries, Japan, West Germany, France, and Italy, exhibit spectral distribution functions, which are concentrated above the diagonal and have high contributions to small frequencies. All four reach more than 50% of the entire variance at the frequency $\frac{\pi}{4}$, as shown in table 2 and 3. In addition Canada's spectral distribution function lies mostly above the diagonal, but this effect is less pronounced than for the four countries referred to before. The graph for the US, however, fluctuates very closely around the diagonal representing H_0 . Finally the UK indicates a very low weight on frequencies below $\frac{\pi}{5}$ and has then most weight in the interval $[\frac{\pi}{5}, \frac{\pi}{2}]$. Formally the difference becomes evident by comparing the variance contributions up to the frequency $\frac{\pi}{4}$, i.e.

the relative importance of cycles with a period of greater or equal to eight years:

$$Japan = 60.25\%$$

$$US = 18.36\%$$

$$Canada = 42.95\%$$

$$WestGermany = 61.53\%$$

$$UnitedKingdom = 11.82\%$$

$$France = 50.53\%$$

$$Italy = 55.47\%$$

Under the null the value should be 25%.

The visual evidence for Japan, West Germany, France, and Italy, and, to a certain extent Canada, indicates that a temporary shock in log per capita consumption has permanent effects, which even accumulate over time. This result is the opposite effect to mean reversion. The US series seems very close to a random walk, whereas the British series is dominated by cycles with periods between four and ten years. In addition there is a strong indication for long run mean reversion for this series.

The formal test results are reported in table 1-5. They are consistent with the visual evidence. In the global goodness-of-fit tests in table 1 H_0 cannot be rejected for Canada, the US and the UK. The statistics for Japan, West Germany, France, and Italy, however, indicate strong rejection.

The picture changes if one examines the accumulated variance contributions in table 2-3 and the incremental variance contributions in table 4-5. The implications of H_0 once again can be rejected almost uniformly for Japan, West Germany, France, and Italy. Here also, Canada and the UK show nearly uniform rejection patterns, because of the uneven distribution of the variance contributions. There appears to be almost no deviation from H_0 only for the US.

The interpretation of the result in this section is quite evident in light of the model in section 2. The seven countries exhibit quite different time series behavior in log real per capita consumption and only the US seems to be in accordance to the simple process derived in equation 3. It seems, however, that there is at least a potential for strong statistical cross country relations along the lines of equation 14 and 15 for the group Japan, West Germany,

Table 1: Spectral Distribution Function Tests
(General Goodness-of-Fit)

Country	CVM	KS	K
Japan	1.12***	1.50**	1.52
United States	0.05	0.46	0.73
Canada	0.28	0.82	0.94
West Germany	1.37***	1.73***	1.76**
United Kingdom	0.22	0.81	1.49
France	0.80***	1.43**	1.47
Italy	0.81***	1.37**	1.40

Asymptotic significance levels:

Statistic	10%	5%	1%
CVM	0.35	0.46	0.74
KS	1.22	1.36	1.63
K	1.62	1.75	2.00

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

Table 2: Spectral Distribution Function Tests
(Accumulated Variance Contributions)

$H_0 : F(\lambda) = \frac{\lambda}{\pi}$	Japan	United States	Canada
$F(\frac{\pi}{8}) = 0.125$	0.480 (1.49***)	0.105 (-0.08)	0.241 (0.51)
$F(\frac{\pi}{4}) = 0.25$	0.603 (1.48***)	0.184 (-0.27)	0.430 (0.76*)
$F(\frac{3\pi}{8}) = 0.375$	0.651 (1.16**)	0.427 (0.22)	0.546 (0.72)
$F(\frac{\pi}{2}) = 0.5$	0.765 (1.12**)	0.573 (0.31)	0.648 (0.63)
$F(\frac{5\pi}{8}) = 0.625$	0.882 (1.08**)	0.720 (0.41)	0.743 (0.52)
$F(\frac{3\pi}{4}) = 0.75$	0.946 (0.82*)	0.798 (0.21)	0.837 (0.37)
$F(\frac{7\pi}{8}) = 0.875$	0.952 (0.32***)	0.892 (0.07)	0.987 (0.47)

($B_{j,T}(t)$ in parentheses, $t = \frac{\lambda}{\pi}$.)

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

Table 3: Spectral Distribution Function Tests
(Accumulated Variance Contributions)

$H_0 : F(\lambda) = \frac{\lambda}{\pi}$	West Germany	United Kingdom	France	Italy
$F(\frac{\pi}{8}) = 0.125$	0.447 (1.38***)	0.010 (-0.47)	0.352 (0.98***)	0.247 (0.53)
$F(\frac{\pi}{4}) = 0.25$	0.615 (1.56***)	0.118 (-0.55)	0.505 (1.10**)	0.555 (1.31***)
$F(\frac{3\pi}{8}) = 0.375$	0.742 (1.57***)	0.434 (0.26)	0.665 (1.24**)	0.700 (1.39***)
$F(\frac{\pi}{2}) = 0.5$	0.847 (1.49***)	0.675 (0.75)	0.798 (1.27**)	0.747 (1.06**)
$F(\frac{5\pi}{8}) = 0.625$	0.922 (1.27**)	0.772 (0.63)	0.830 (0.88*)	0.905 (1.20**)
$F(\frac{3\pi}{4}) = 0.75$	0.947 (0.84*)	0.844 (0.40)	0.901 (0.65)	0.938 (0.80*)
$F(\frac{7\pi}{8}) = 0.875$	0.974 (0.42)	0.931 (0.24)	0.930 (0.23)	0.974 (0.42)

($B_{j,T}(t)$ in parentheses, $t = \frac{\lambda}{\pi}$.)

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

Table 4: Spectral Distribution Function Tests
(Incremental Variance Contributions)

$H_0 : F(\lambda_2) - F(\lambda_1) = 0.125$	Japan	United States	Canada
$F(\frac{\pi}{8}) - F(0)$	0.478 (1.52***)	0.105 (-0.07)	0.241 (0.51)
$F(\frac{\pi}{4}) - F(\frac{\pi}{8})$	0.123 (-0.01)	0.079 (-0.20)	0.189 (0.27)
$F(\frac{3\pi}{8}) - F(\frac{\pi}{4})$	0.048 (-0.33)	0.244 (0.50)	0.117 (-0.04)
$F(\frac{\pi}{2}) - F(\frac{3\pi}{8})$	0.115 (-0.05)	0.146 (0.09)	0.102 (-0.10)
$F(\frac{5\pi}{8}) - F(\frac{\pi}{2})$	0.116 (-0.04)	0.147 (0.09)	0.095 (-0.13)
$F(\frac{3\pi}{4}) - F(\frac{5\pi}{8})$	0.064 (-0.26)	0.079 (-0.20)	0.094 (-0.13)
$F(\frac{7\pi}{8}) - F(\frac{3\pi}{4})$	0.006 (-0.51)	0.094 (-0.14)	0.150 (0.10)
$F(\pi) - F(\frac{7\pi}{8})$	0.048 (-0.33)	0.108 (-0.07)	0.013 (-0.48)

($B_{j,T}(t) - B_{j,T}(t - \frac{1}{8})$ in parentheses, $t = \frac{\lambda}{\pi}$.)
 ***: denotes significance at asymptotic 1% level
 **: denotes significance at asymptotic 5% level
 *: denotes significance at asymptotic 10% level

Table 5: Spectral Distribution Function Tests
(Incremental Variance Contributions)

$H_0 : F(\lambda_2) - F(\lambda_1) = 0.125$	West Germany	United Kingdom	France	Italy
$F(\frac{\pi}{8}) - F(0)$	0.447 (1.38***)	0.010 (-0.47)	0.352 (0.98***)	0.247 (0.53)
$F(\frac{\pi}{4}) - F(\frac{\pi}{8})$	0.169 (0.18)	0.108 (-0.08)	0.154 (0.12)	0.308 (0.77**)
$F(\frac{3\pi}{8}) - F(\frac{\pi}{4})$	0.127 (0.01)	0.316 (0.81**)	0.160 (0.14)	0.145 (0.08)
$F(\frac{\pi}{2}) - F(\frac{3\pi}{8})$	0.105 (-0.09)	0.240 (0.49)	0.134 (0.03)	0.047 (-0.33)
$F(\frac{5\pi}{8}) - F(\frac{\pi}{2})$	0.075 (-0.22)	0.097 (-0.12)	0.031 (-0.40)	0.158 (0.14)
$F(\frac{3\pi}{4}) - F(\frac{5\pi}{8})$	0.025 (-0.43)	0.073 (-0.23)	0.071 (-0.23)	0.033 (-0.40)
$F(\frac{7\pi}{8}) - F(\frac{3\pi}{4})$	0.027 (-0.42)	0.086 (-0.17)	0.029 (-0.41)	0.037 (-0.38)
$F(\pi) - F(\frac{7\pi}{8})$	0.026 (-0.42)	0.070 (-0.24)	0.070 (-0.23)	0.026 (-0.42)

($B_{j,T}(t) - B_{j,T}(t - \frac{1}{8})$ in parentheses, $t = \frac{\lambda}{\pi}$.)

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

France, and Italy and, to a lesser extent for the US and Canada. Note, however, that there is a striking similarity between the spectral distribution functions of consumption in Japan, US, Canada, West Germany, UK, and France in this paper and the spectral distribution functions for log real per capita income for those six countries estimated in Durlauf(1989b). This point raises some doubt about the argument, that consumption tends to be smoothed across countries in a risk sharing arrangement to cope with erratic income behavior.

Finally, all consumption series, except for that of the UK, seem to contain a unit root.

3.2 Cointegration relations

In section 2 the following two possible cointegration relations for a country pair (i,j) were derived:

$$\ln(c_{j,t}) - \gamma_{ij}\ln(c_{i,t}) - a_{ij} t - b_{ij} = \nu_{i,j,t}$$

and for $a_{ij} = 0$

$$\ln(c_{j,t}) - \gamma_{ij}\ln(c_{i,t}) - b_{ij} = \nu_{i,j,t}$$

In testing for cointegration, one has to run a second stage regression involving the estimated residuals from the two above equations in order to test the null if the residuals still contain a unit root²². Under the null the coefficient ρ_1 in the following regression equation is equal to zero

$$\Delta\nu_{i,j,t} = \rho_1\nu_{i,j,t-1} + \rho_2\Delta\nu_{i,j,t-1} + \dots + \rho_k\Delta\nu_{i,j,t+1-k} + u_{i,j,t} \quad (19)$$

Table 6 reports the t-statistics for ρ_1 for $k=2$ and $k=3$ for the cointegration relation including time, and table 7 for the relation without time. The t-statistics are taken from a conventional least-squares estimation, their distribution under the null, however, is different²³. Table 6 and 7 include, if a t-statistic is significant at levels 10%, 5%, and 1%. The qualitative results within both tables are quite similar, i.e. adding a further lag does not have an important effect on the results. The evidence indicates between only one and

²²See Engle/Granger(1987) for the methodology

²³Confer Dicker/Fuller(1981) or Engle/Granger(1987).

Table 6: Cross-Country Cointegration Tests
(Log real consumption in two countries with time)

Countries	US	C	G	UK	F	I
Japan	1.04	1.02	0.70	1.02	-0.10	1.28
	1.61	1.45	0.99	1.53	0.50	1.83
United States		2.17	2.14	1.77	2.97*	2.28
		2.78	2.62	2.10	3.65**	2.89*
Canada			0.88	1.18	2.40	0.85
			0.79	1.03	2.46	0.84
West Germany				0.35	-0.75	-0.26
				1.25	0.29	0.23
United Kingdom					4.11***	4.10***
					6.43***	6.27***
France						1.03
						1.41

t-statistics for the coefficient ρ_1 reported in the table

Cointegration relation: $\ln(c_{j,t}) = C + a \ln(c_{i,t}) + b TIME + \nu_{i,j,t}$

Second stage regression:

First value: $\Delta \nu_{i,j,t} = \rho_1 \nu_{i,j,t-1} + \rho_2 \Delta \nu_{i,j,t-1} + u_{ij,t}$

Second value: $\Delta \nu_{i,j,t} = \rho_1 \nu_{i,j,t-1} + \rho_2 \Delta \nu_{i,j,t-1} + \rho_3 \Delta \nu_{i,j,t-2} + u_{ij,t}$

(Significance levels based on Engle/Granger(1987))

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

Table 7: Cross-Country Cointegration Tests
(Log real consumption in two countries without time)

Countries	US	C	G	UK	F	I
Japan	1.27	0.56	0.50	1.52	0.06	0.84
	1.87	0.76	0.87	2.33	0.66	1.28
United States		0.87	0.71	1.76	3.72**	2.70
		0.94	1.03	2.15	4.62***	3.64**
Canada			0.39	1.62	1.64	0.92
			0.44	1.76	1.76	0.99
West Germany				1.50	-0.78	-0.20
				2.78	0.26	0.26
United Kingdom					2.90*	2.91*
					4.37***	4.19***
France						1.13
						1.62

t-statistics for the coefficient ρ_1 reported in the table

Cointegration relation: $\ln(c_{j,t}) = C + a \ln(c_{i,t}) + \nu_{i,j,t}$

Second stage regression:

First value: $\Delta \nu_{i,j,t} = \rho_1 \nu_{i,j,t-1} + \rho_2 \Delta \nu_{i,j,t-1} + u_{i,j,t}$

Second value: $\Delta \nu_{i,j,t} = \rho_1 \nu_{i,j,t-1} + \rho_2 \Delta \nu_{i,j,t-1} + \rho_3 \Delta \nu_{i,j,t-2} + u_{i,j,t}$

(Significance levels based on Engle/Granger(1987))

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

four country pairs are cointegrated in the data for different significance levels and lag lengths. This potential candidates for cointegration are the four country pairs, (US,France), (US,Italy), (UK,France), and (UK,Italy), which do not consistently form a "risk-sharing subgroup". The results do not differ if time is included as a third variable. Two of the four country pairs which show some evidence of cointegration include the UK; this provides some evidence against a unit root. Even though the number of rejections for $k=3$ is slightly above what one could on average attribute to sampling error, there is almost no indication of cointegration for log real per capita consumption across the seven countries. In general, the results are again quite similar to Durlauf's (1989a) and (1989b) analysis for log real per capita output, which showed that there is almost no evidence for cointegration across countries. Consumption and income seem to follow very similar patterns, i.e. the national development seems to dominate consumption movements.

3.3 Linear feedback analysis

Thus far I have tried to test the explicit reduced form relations derived from the restricted model in section 2. In a broader perspective one could interpret the results in section 2 as indicating that the innovations in the log real per capita consumption processes in different countries should be driven by the innovation in joint income, which is spread in a optimal risk sharing way. Therefore this section explores the linear feedback relations between the first differences in log real per capita consumption.

The statistical relationship between first differences in log real per capita consumption can be analyzed in the general framework developed by Geweke(1982). In this framework one successively estimates the linear temporal interactions of two time series, here the first differences of log real per capita consumption in two countries. For a country pair (i, j) one estimates the following sequence of relations,

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \epsilon_{i,t} \quad (20)$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \eta_{i,t} \quad (21)$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \gamma_1 \Delta \ln(c_{j,t}) + \xi_{i,t} \quad (22)$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \quad (23)$$

$$\gamma_1 \Delta \ln(c_{j,t}) + \gamma_2 (L^{-1}) \Delta \ln(c_{j,t+1}) + \nu_{i,t}$$

The first equation, 20, is the univariate autoregression of the first difference of country i 's log real per capita consumption on its lagged values. The interaction with country j is revealed by relating equation 20 to 23, i.e. by testing, if $\Delta \ln(c_{j,t})$, its future, or its past values significantly help to predict $\Delta \ln(c_{i,t})$. This total feedback is measured more formally by using the Likelihood-Ratio test statistic²⁴

$$F_T(i, j) = T_1 \log(\sigma_\epsilon^2 / \sigma_\nu^2)$$

F_T may be decomposed into measures of causal feedback and a measure of contemporaneous feedback. The causal feedback measures coincide with the notion of Granger-Sims-causality. The measure of causal feedback from country j to i , $F_{CA}(i, j)$, indicates the extent to which a distributed lag of past first differences in country j helps to predict $\Delta \ln(c_{i,t})$. It relates equation 21 to 20 and is therefore defined as

$$F_{CA}(i, j) = T_1 \log(\sigma_\epsilon^2 / \sigma_\eta^2)$$

The contemporaneous feedback measure finally relates equation 22 and 21; thus it is defined as

$$F_{CO}(i, j) = T_1 \log(\sigma_\eta^2 / \sigma_\xi^2)$$

These feedback measures are asymptotically χ^2 distributed, where the degrees of freedom are given by the number of the implied respective restrictions on γ_0 , γ_1 , and γ_2 .

Table 8 provides the results of the estimations in terms of the calculated feedback measures. Even though it makes numerically a difference in which order (i, j) a country pair is analyzed, the qualitative results are almost the same²⁵. The equations have been estimated alternatively for lag-operator polynomials of order 0 or 1. It should be noted that the results are quite sensitive to this difference.

In table 8 one can find some country pairs which exhibit significant total feedback. This finding, however, almost always relies on significant contemporaneous feedback measures. In fact more than half of the country pairs

²⁴ T_1 is the number of available data points.

²⁵The results of the symmetric estimations are available on request.

Table 8: Geweke Feedback Statistics
(Cross-Country Fluctuations in Log Real Per Capita Consumption)

Measures of feedback between countries					
Country i	Country j	Total feedback	Causal feedback		Contemporaneous feedback
			j to i	i to j	
Japan	United States	5.12	0.39	0.28	4.58**
	Canada	10.05	2.06	0.04	7.43***
		0.64	0.08	0.46	0.56
		8.78	5.12*	1.71	2.80*
	West	4.38	0.48	0.43	3.74*
	Germany	7.92	0.22	1.75	4.72**
	United Kingdom	6.80*	3.37*	0.20	3.42*
	France	8.59	3.52	0.21	4.38**
		5.60	1.25	0.17	4.30**
		8.16	0.08	0.77	7.83***
	Italy	11.14**	0.25	3.35*	7.37***
		9.21	0.30	3.11	6.74***
United States	Canada	14.61***	0.50	0.11	14.06***
		15.56***	0.36	0.54	14.78***
	West	10.28**	1.03	0.61	8.57***
	Germany	9.42*	0.58	1.08	8.33***
	United Kingdom	7.38*	0.79	0.02	6.13**
	France	10.46*	2.14	2.07	5.82**
		5.48	0.35	1.93	4.44**
		6.61	0.64	1.52	4.35**
	Italy	7.40*	3.82*	2.47	0.71
		8.73	3.88	3.07	1.49
Canada	West	4.82	0.11	0.39	4.56**
	Germany	6.00	1.23	0.11	4.31**
	United Kingdom	1.70	0.98	0.19	0.70
		4.80	0.67	1.98	3.95**

Country i	Country j	Total feedback	Causal feedback		Contemporaneous feedback
			j to i	i to j	
Canada	France	6.69*	0.40	2.50	5.55**
		19.55***	7.18**	1.13	10.59***
	Italy	3.12	0.64	0.79	1.16
		7.30	2.59	3.11	3.26*
West	United	1.12	0.59	0.19	0.17
Germany	Kingdom	3.71	0.56	4.12	2.00
		3.33	0.12	2.62	1.03
	France	5.95	0.38	3.14	2.53
		5.66	2.52	5.60**	0.09
United Kingdom	Italy	8.44	2.70	4.19	0.13
		1.64	0.08	0.11	1.56
	France	7.26	1.20	0.41	0.32
		0.66	0.00	0.00	0.47
France	Italy	5.05	1.53	0.16	1.79
		7.18*	0.20	1.56	6.15**
	France	12.74**	1.53	0.68	10.31***

Feedback-statistics use results from the following system of regressions:

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \epsilon_{i,t}$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \eta_{i,t}$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \gamma_1 \Delta \ln(c_{j,t}) + \xi_{i,t}$$

$$\Delta \ln(c_{i,t}) = \beta_1 + \pi(L)\Delta \ln(c_{i,t}) + \gamma_0(L)\Delta \ln(c_{j,t-1}) + \gamma_1 \Delta \ln(c_{j,t}) + \gamma_2(L^{-1})\Delta \ln(c_{j,t+1}) + \nu_{i,t}$$

First (Second) value: All lag polynomials have order 0 (1) and $T_1 = 33$ ($T_1 = 31$)

Total feedback equals $T_1 \log(\sigma_\epsilon^2/\sigma_\nu^2)$. The null hypothesis is that γ_0 , γ_1 , and γ_2 equal zero. Causal feedback j to i equals $T_1 \log(\sigma_\epsilon^2/\sigma_\eta^2)$. The null hypothesis is that γ_0 equals zero. Contemporaneous feedback j to i equals $T_1 \log(\sigma_\eta^2/\sigma_\xi^2)$. The null hypothesis is that γ_1 equals zero.

(Significance levels based on χ^2 -table)

***: denotes significance at asymptotic 1% level

** : denotes significance at asymptotic 5% level

* : denotes significance at asymptotic 10% level

show significant contemporaneous feedback. These results reveal some degree of contemporaneous correlatedness among the first differences in the consumption processes across countries. This, however, is not enough to generate a fixed long run relation between consumption across countries, as shown by the rejection of cointegration relations in section 3.2. . Within the framework of section 2., it could be interpreted as evidence for partial risk sharing across countries. This interpretation is consistent with the results in Durlauf(1989a)²⁶, that there is almost no significant contemporaneous feedback in the first differences of log real per capita output across countries. According to this interpretation innovations in consumption have a significant purely domestic component. The following section 3.4. uses factor analysis to explore if there is one significant common factor, which the contemporaneous correlation of the first differences of the consumption series can be attributed to. In the framework of section 2., this factor would presumably be the innovation in joint income.

3.4 Factor analysis of innovations in log real consumption

This section tests, how many significant common factors one can identify in the innovations of the log real per capita consumption processes for the seven countries. To perform this test, factor analysis is employed. is used²⁷.

Let X be the observable vector of p components²⁸ and let it be written as

$$X = \Lambda f + U + \mu \quad (24)$$

where X , U , and μ are vectors of p components, f is a column vector of m ($\leq p$) independent components, and Λ is a $p \times m$ -matrix. It is assumed, that U is distributed independently of f with mean $E(U)=0$ and that the components of U are mutually independent. The components of f are called the common factors and U , μ , and f are unobserved.

Although not all parameters and variables of this model can be identified without restrictions, it is possible to estimate the variance contributions of

²⁶See page 94.

²⁷Confer Anderson(1984), Chapter 14, as a general reference.

²⁸ $p=7$ in our case

different factors. It may also be tested whether a model with $p+1$ common factors fits the data significantly better than one with just p factors²⁹.

It is not clear what the innovations of the consumption processes are. Therefore I fitted at first low order ARMA models for the first differences using conventional Box Jenkins procedures. This approach resulted in the following processes for the first difference of log real per capita consumption in the seven countries:

Japan : $ARMA(1,1)$

US : $ARMA(0,0)$ {White noise}

Canada : $AR(1)$

West Germany : $ARMA(1,1)$

UK : $ARMA(2,1)$

France : $AR(1)$

Italy : $MA(1)$

Note that for the US series there is no significant ARMA model to fit.

In the sequel the factor analysis was done for three sets of data:

- 1) First differences in log real per capita consumption
- 2) First differences in log real per capita consumption for those countries - US, Canada, and UK - , for which the null in section 3.1. could not be rejected, and the estimated residuals for the remaining four other four other countries from the above estimation of low order ARMA models - Japan, West Germany, France, and Italy -
- 3) The estimated residuals from the above ARMA models, except for the US

The results are the following. For the first data set two significant common factors can be identified, whereas for the second and the third one there is only one significant common factor³⁰. Thus one can find evidence for at least one common factor in the innovations of the processes of log real

²⁹I have used the Maximum Likelihood procedure for factor analysis in SAS, which automatically gives these test statistics for a chosen number of common factors.

³⁰The estimation results are available on request

per capita consumption. Note, however, that this is not a statement about its importance per se. Its contribution to the over all variance of the first differences cannot be too high, as the preceding analysis in section 3.2. and 3.3. suggests. There is not enough comovement in the data to generate the strong results derived within the framework of section 2.

4 Conclusions

This paper tried to explore if evidence could be found for consumption smoothing across the G-7-countries. A framework to study this phenomenon was built on the stochastic version of the life cycle model of consumption. Under certain functional form assumptions, it could be derived that consumption smoothing takes place in an optimal risk pooling arrangement given complete international financial markets. With the income processes exhibiting stochastic trends, the consumption processes should follow random walks and should be cointegrated across countries.

In the empirical part the consumption series were only consistent with a pure random walk specification for the US and Canada. The rejection of the random walk specification for the other countries was, however, generally not in the direction of a stationary alternative, i.e. it was concluded that the consumption processes most likely have a unit root.

The cointegration implication was almost uniformly rejected in the data. In the sequel two weaker forms for comovement of the consumption series were analyzed. Whereas there was also almost no evidence for the first differences of the consumption processes to exhibit causal or contemporaneous feedback relations, at least one significant common factor could be identified in a factor analytical framework. This is weak evidence for some partial smoothing of consumption across countries, and the overall comparison of the results for consumption here and for income in Durlauf (1989b) reveals slightly stronger comovements between international consumption series than between income series.³¹

There are various possible criticisms of the methodology and explanations for the estimation results. One might legitimately argue that a sample size of 36 observations is quite short to draw strong conclusions. It seems, it

³¹A discussant indicated, that this contradicted conventional wisdom about international business cycle comovements.

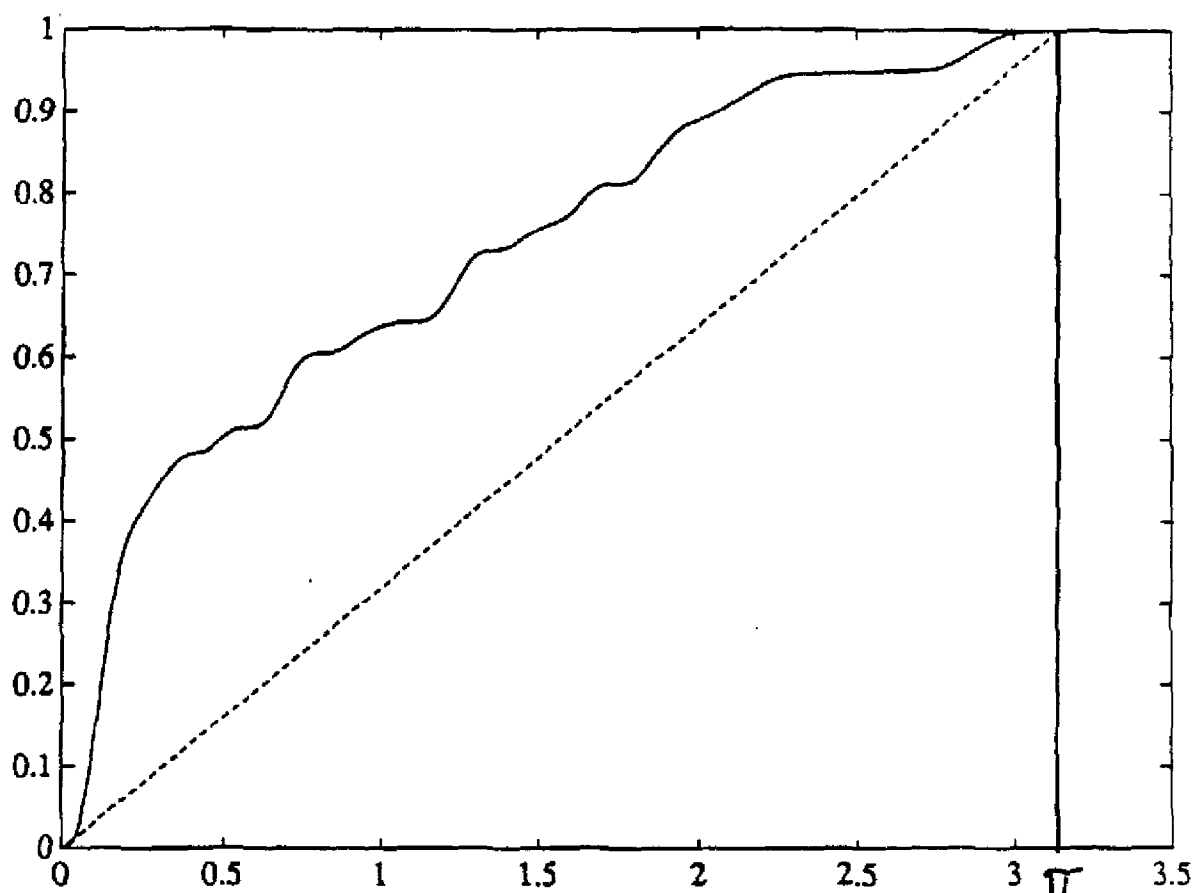
would be a fruitful exercise to repeat the study for quarterly postwar data, which meets the Summers/Heston(1988) standards, but I am not aware of an equivalent data source. It should be noted, however, that for the examination of long run movements and comovements it is rather a longer physical time range, what is needed. A second obvious criticism also applies. The predictions in section 2. were derived under specific functional form assumptions. Thus the empirical tests are joint tests including these assumptions, i.e. it is unclear which part of the null is rejected. The model set up in section 2. is quite restrictive, but it could be extended allowing for capital formations, the distinction between tradable and non-tradable goods, trade barriers or some types of rigidities, like capital market imperfections. It could be worthwhile, as well, to extend the analysis to a multivariate statistical framework.

In the given type of analysis, the time series behavior of consumption is quite similar to the domestic output behavior. Both do not show constant long run linear relations across countries. Durlauf(1989a), in the second part of his paper, sketches a coordination failure model with path dependence and multiple pareto-rankable equilibria, which is consistent with these empirical findings.

5 Appendix

Figure 1 - 7: Estimated spectral distribution functions

Figure 1: JAPAN



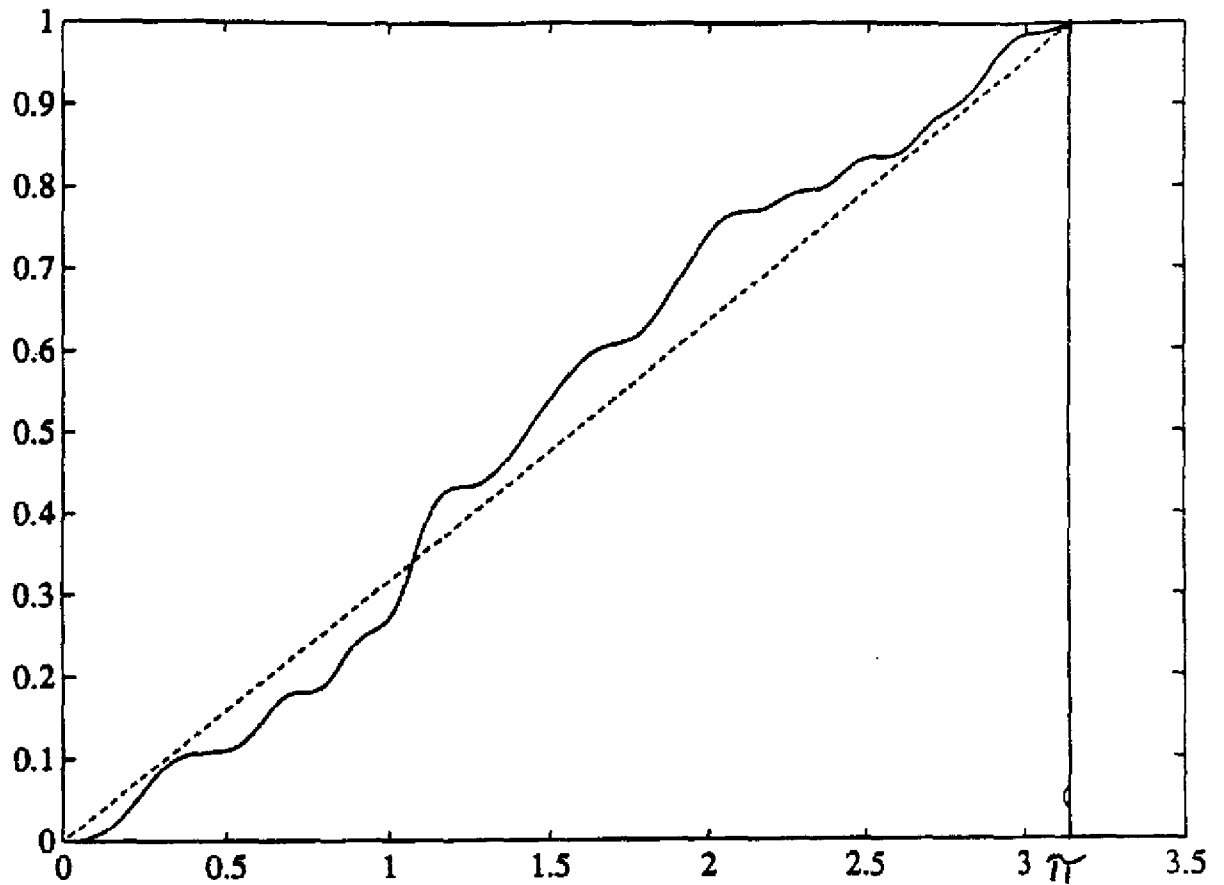
Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for Japan

(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 2: United States

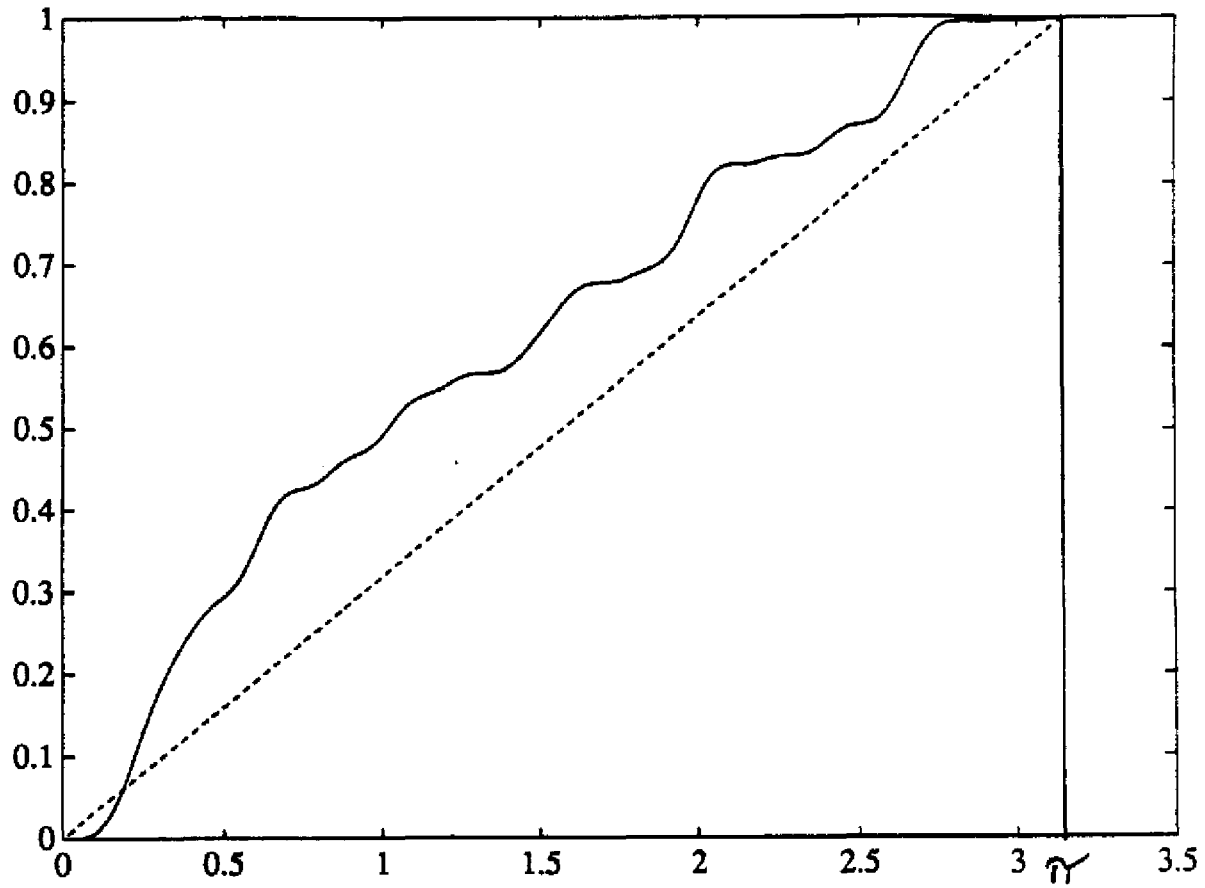


Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for United States
(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 3: CANADA



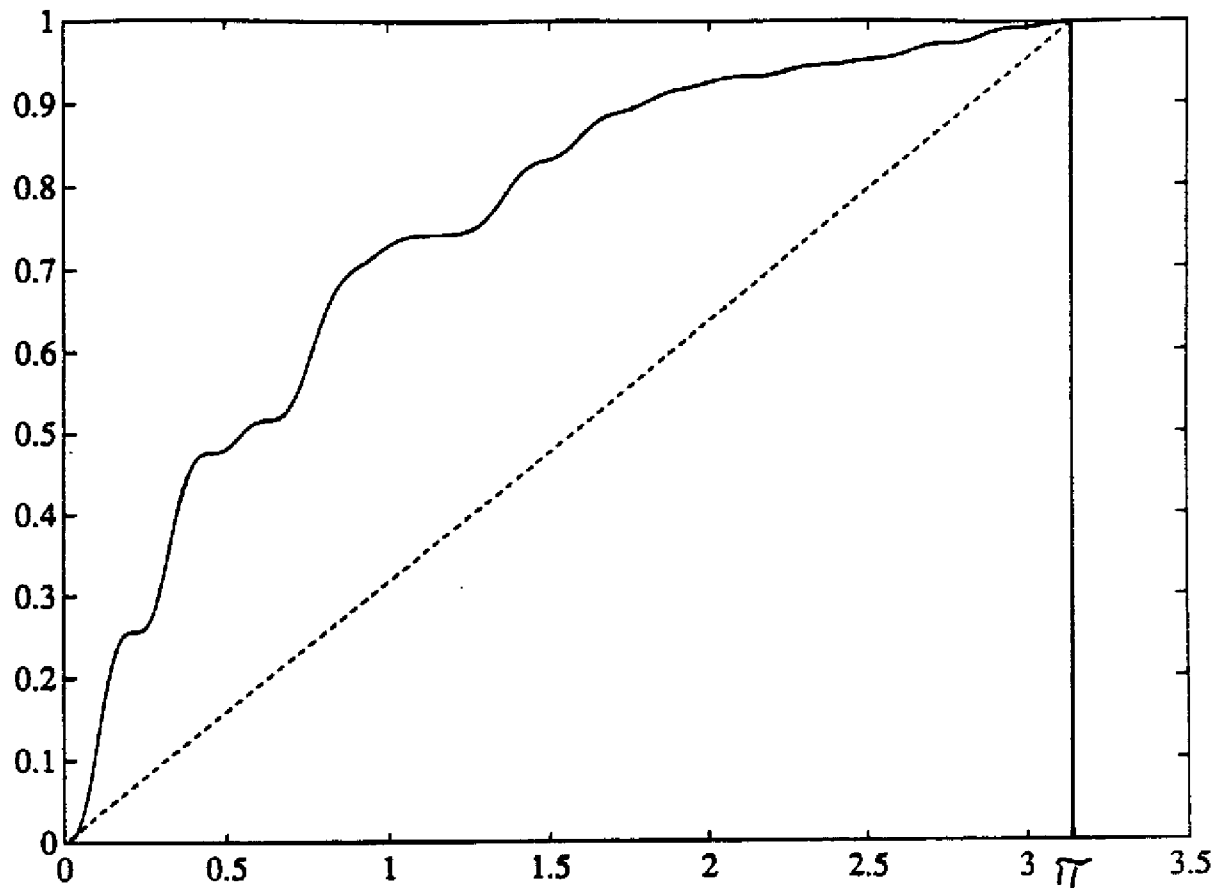
Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for CANADA

(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 4: West Germany

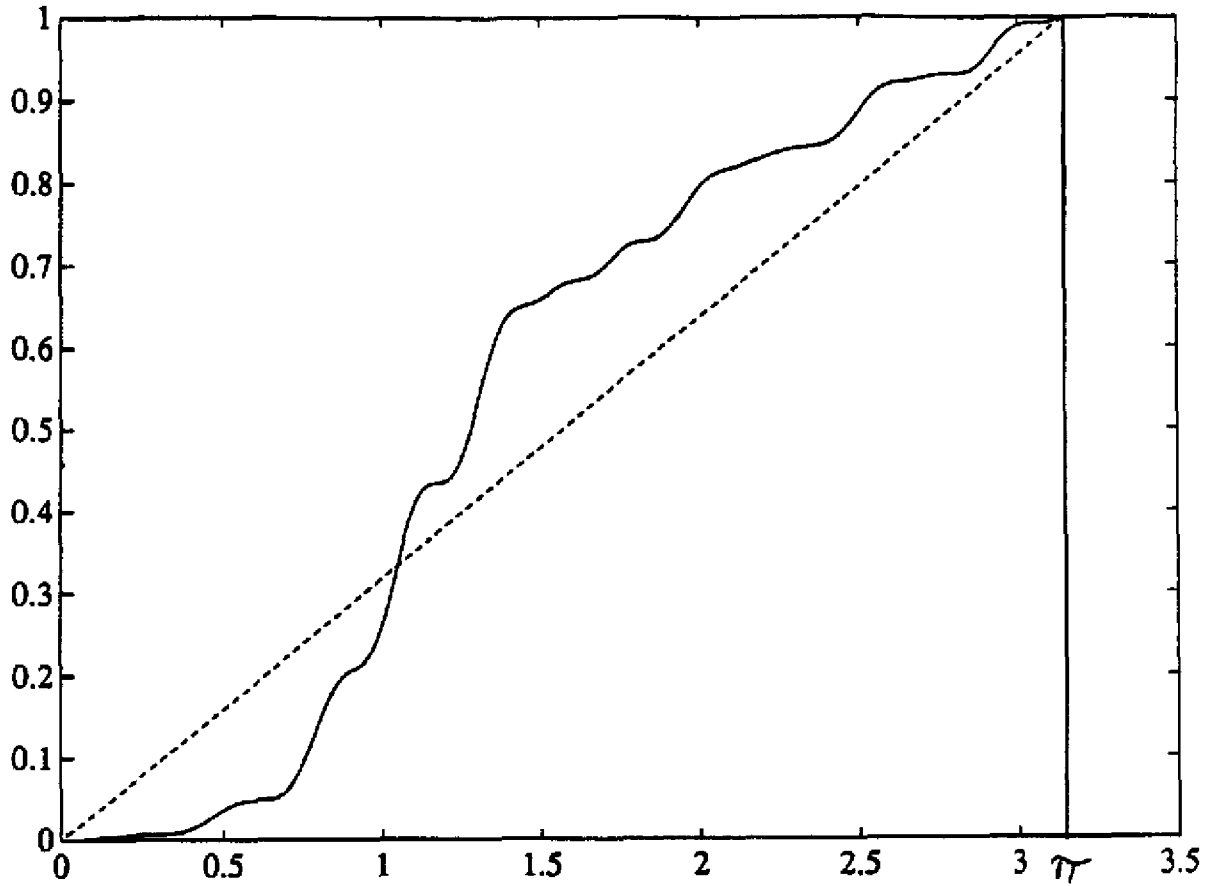


Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for West Germany
(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 5: United Kingdom

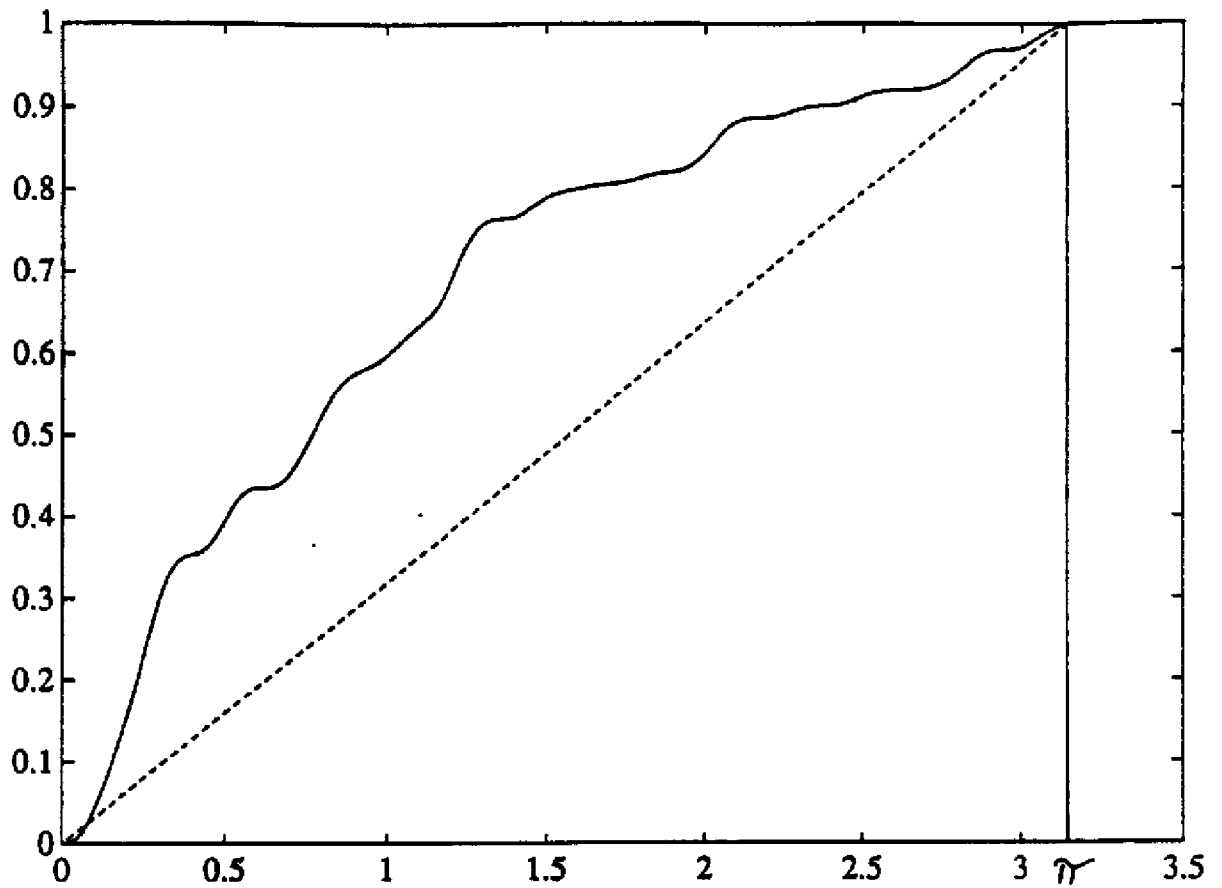


Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for United Kingdom
(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 6: FRANCE



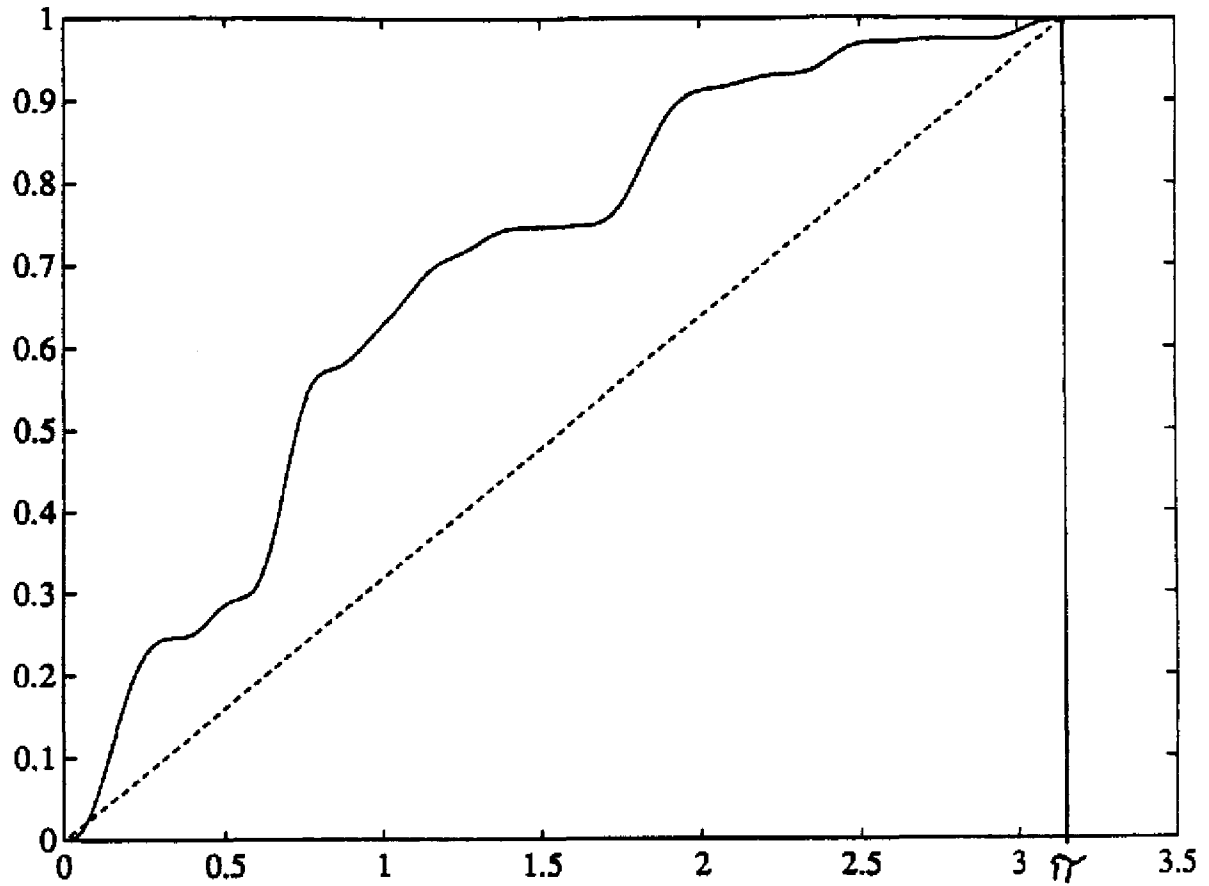
Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for FRANCE

(Accumulated Periodogram Estimates for Annual Data 1951-85)

Horizontal Axis : frequency $\lambda \in [0, \pi]$

Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

Figure 7: ITALY



Estimated Normalized Spectral Distribution Function of the first
Differences in Log Real Consumption for Italy
(Accumulated Periodogram Estimates for Annual Data 1951-85)
Horizontal Axis : frequency $\lambda \in [0, \pi]$
Vertical Axis : fraction of variance attributable to
fluctuations of frequency λ or lower

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