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MACROECONOMIC FLUCTUATIONS AND THE FIRMS’ RATE OF GROWTH DISTRIBUTION: EVIDENCE FROM UK AND US QUOTED COMPANIES

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Macroeconomic Fluctuations and the Firms' Rate of Growth Distribution: Evidence from UK and US Quoted Companies.

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Abstract

We fit the asymmetric Subbotin distribution introduced by Bottazzi and Secchi (2003) on UK and US data on quoted companies, in order to detect sources of asymmetries in the transmission of aggregate shocks, and cyclical patterns of higher moments of the firms' rate of growth distribution over the business cycle. We support the evidence provided by Higson et al. (2002, 2004) of a negative correlation between the rate of growth of GDP and the standard deviation and skewness of the distribution. Kurtosis exhibits a procyclical pattern. Furthermore, we provide an explanation of the emergence of these stylised facts based on the evidence that the left tail of the distribution is more responsive to macroeconomic fluctuations than its right counterpart. The evidence points to financial factors as one of the main drivers of the observed pattern.

JEL: C16, E32, G30

Keywords: Subbotin Distribution, Corporate Growth, Business Cycle, Financial Fragility

Introduction

The "industrial organization" literature on the demography of firms[1] has focused for a long time on the "static" cross-sectional features of variables such as firm-specific rate of growth and size, without considering properties such as stationarity and stability of the distributions describing these variables. Most of the theoretical and empirical efforts in this field were devoted to the assessment of the theoretical proposition known as Gibrat's law (1931). Gibrat's law states that growth rate of firms does not depend on firms' size (Gibrat's law in weak form). Gibrat's original aim was to explain the skewed distributions arising in several contexts, such as income, wealth and firms' size in manufacturing industries. Gibrat started from the observation that his data fit well with a lognormal distribution. To generate such a form, he assumed that a firm's absolute growth were a normally distributed random variable, whose mean was proportional to its size. This means that the firms specific rate of growth is a gaussian random variable with mean independent of the firm's current size (the so called Law of Proportionate Effect). The Law of Proportionate Effect suggests that the process of firm growth produces levels of market concentration that increase over time, as the variance in the lognormal distribution becomes asymptotically infinite.

Gibrat's law has been subjected to a wide empirical scrutiny during the 1950s and 1960s, leading to controversial results and interpretations. We briefly trace the most significant contributions to the description of the statistical properties of the firms' rate of growth distribution. Simon (1955) extended the intuition behind the Law of Proportionate Effect to a broader class of skewed distributions, including Pareto, Yule and Lognormal, and generated a literature on stochastic models whose main advantage consisted in relaxing Gibrat's Law. The introduction non negligible rates of entry and exit and the hypothesis of constant returns to scale allowed to overcome the occurrence of infinite variance in firms' size, generating skewed distributions in steady state. The empirical literature has found some support for Simons's approach[2]. It must be pointed out however that this class of theoretical models has a purely stochastic nature, not relying on any economic explanatory variables. Following Sutton (1997), two main statistical regularities can be identified in the size-growth relationship. The first one is based on the link between Size and Growth and points out that the probability to survive increases with firm size and the proportional rate of growth of a firm (or plant) conditional on survival is decreasing in size. The second statistical regularity, which is in opposition to the Law of Proportionate Effect, is widely recognised as the Life Cycle[3]: for any given size, the older the firm (or plant), the smaller the proportional rate of growth and the

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[1] See Steindl (1968), Geroski (1995), Sutton (1997) and Caves (1998) for comprehensive reviews of the literature.

[2] Hart and Prais (1956), Simon and Bonini, (1958), Mansfield (1962), Ijiri and Simon (1964, 1977) can be considered the most significative contributions in this strand of literature.

[3] The Life Cycle approach finds in Jovanovic (1982) one of its main advocates.

greater its probability of survival. Over time, profits convey new information about the level of efficiency of a firm relative to its competitors: consiquently, firms can decide to exit the market if they learn of their relative inefficiency. Put together, the two mechanisms imply that large firms are likely to have a lower rate of growth but a greater probability to survive.

Several empirical studies have found evidence of a negative relationship between growth rates and firm's size[4]. Consistent with the assumption of decreasing returns to scale, these studies have shown that small firms tend to grow faster than large firms. This implies a mean reversion effect on firm size, which introduces an overall limit on the variance of the size distribution, as firm size converges in the long run towards an optimal level. In interpreting this evidence, however, Geroski (2000) argues that the negative correlation between growth and firm size is negligible and that it could be due to methodological and data limitations. Geroski points out that most studies that test Gibrat's Law do so through cross-section analyses, and do not allow for heterogeneity in the firm specific growth. More recent empirical studies adopting heterogeneous panel techniques have delivered mixed results[5]. In opposition to the empirical evidence produced by these early studies, we aim at identifying a characteristic pattern in the evolution of the firms' rate of growth distribution, by considering the asymmetric impact of aggregate shocks.

Only a few empirical studies have analysed the dynamic properties of the distribution of the rates of growth, with particular attention to its stability. Remarkably fruitful contributions have been provided by Bottazi and Secchi (2003), who have programmed the routine that will be adopted for our empirical exercises. Marsili et al. (2004) focus on the most basic assumptions of Gibrat's Law, without testing the derived propositions, and investigating whether the distribution of the rates of growth can be fitted by a Gaussian, and if the distribution may be considered invariant over time and across sectors. The authors examine the static and dynamic properties of the distribution of the rates of growth, using sales data on dutch firms from 1978 to 1997. They claim that their analysis contributes to the existing research along three main directions. First, they fit a general form of the Subbotin distribution, allowing for asymmetric shapes at the tails, to establish whether there is structure in the distribution of the rates of growth. Second, they look at the evolution of the distribution of the rates of growth over time by carrying out a time series analysis of the Subbotin parameters. Third, they examine whether these previous patterns hold at different levels of aggregation, by looking at total manufacturing, and at four different manufacturing industries. The authors claim that each of these industries may be at different stages of the Industry

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[4] See Evans (1987a, b), Hall (1987), Dunne and Hughes (1994), Hart and Oulton (1996).

[5] Goddard et al. (2002) find that the evidence against the Law of Proportionate Effect is stronger when applying heterogeneous panel estimation techniques than when applying cross sectional analysis.Geroski et al. (2003), working with a panel of UK firms over 30 years, observe no significant tendency for firm size to converge to some optimum level and found no persistent differences across firms. Geroski et al. (2003) conclude that if any mean reversion effect is to be found, it is at best weak.

Life Cycle and that it is important to take into consideration the possibility that each of them experiences different processes of growth. In the present analysis we adopt a similar perspective in order to establish a link between the literature on industrial demography and the study of the business cycle from the cross sectional point of view, which has been recently enriched with the evidence provided by Higson et al. (2002, 2004) and Battacharjee et al. (2004). Furthermore, a significative difference with previous studies catalogued in the industrial demography literature, will consists in the fact that our analysis will provide empirical evidence arising from large datasets of quoted companies.

A different perspective is assumed in the study of the dynamic pattern of the firms' rate of growth distribution pursued by Higson et al. (2002 , 2004), who focus their analysis on the determinants of shifts and changes of the shape. The evidence provided by Higson et al. (2002, 2004) suggests that the distribution is highly sensitive to macroeconomic shocks. These studies have identified a number of interesting stylised facts regarding the cross sectional dynamics of the business cycle, using both UK and US data on quoted firms[6]. In particular, macroeconomic fluctuations provide a better predictor of the dynamics of the cross sectional distribution of growth rates than firms' intrinsic characteristics such as age, size or industry, while the residual, idiosyncratic component accounts almost for all the variance and the skewness of the distribution. Higher moments of the cross sectional distribution fluctuate at business cycle frequencies, displaying countercyclical skewness and standard deviation and a pro-cyclical kurtosis. The analysis of the percentiles of the cross section shows that aggregate shocks are propagated with varying intensity to firms growing at different rates. The choice of the percentile time-series analysis is due to the fact that the authors deal with unbalanced panels. However, even with a complete dataset it would be difficult to characterize each firm in terms of invariant position in the range of growth. Relying on these considerations, for each period the cross sectional sample is classified in percentiles, thus obtaining hundred time series of percentiles. For each of these time series the following regression is run:

$$(1 - \alpha_{1k}L - \alpha_{2k}L^2)g_{kt} = \alpha_{0k} + (\lambda_{1k} + \lambda_{2k}L)\rho_t$$

where k denotes the k^{th} percentile, L is the lag operator, g_{kt} is the rate of growth of the k^{th} percentile at time t and ρ_t is the continuous rate of growth of the aggregate GDP. The estimated coefficients λ_{1k} and λ_{2k} capture the marginal response of the percentile rate of growth to aggregate growth. The estimated coefficients for the hundred percentiles are then plotted on the same graph. This empirical exercise shows that the marginal response increases monotonically up to the 25^{th} percentile, declining monotonically thereafter. The evidence that the peak of $\lambda_{(i)}$ is reached at a lower than mean growth rate can explain, from a statistical point of view, why countercyclical skewness is observed. Both rapidly

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[6] Studies focusing on the tent-shaped distribution generally observe a stable distribution (Bottazzi et al. (2002)), although analysis has been limited to a relatively short time period. Over a long time period, there is empirical evidence of a change in the distribution.

growing and declining firms are substantially insulated from the macroeconomic variation, being less responsive to business fluctuations than firms lying in the middle range of the rate of growth. During contractionary phases the central mass of the distribution shifts closer to the negative end, generating a positive tail and hence a counter-cyclical skewness. Opposite evidence holds during phases of expansion.

Furthermore, Battacharjee et al. (2004) draw similar conclusions from the analysis of the impact of the interest rate spread on the cross sectional distribution of rates of growth: the monetary transmission mechanism (MPTM hereafter) mainly affects firms in the middle range of the rate of growth. The authors argue that the credit view of the MPTM could provide an explanation of the facts highlighted, arguing that firms growing in the middle range are likely to rely more on external finance and hence are more affected in terms of production and investment decisions by marginal changes in the cost of external finance. This new evidence is somehow in contrast with the traditional credit view of the MPTM, which predicts that the impact of monetary decisions propagated through the credit market (both for the lending and the balance sheet channel) should have a greater effect on smaller firms, which are likely to rely more on external finance.

1 Recent Evidence on the Static Properties of the Firms' Rate of Growth Distribution

The Law of Proportionate Effect implies that if the rates of growth are identically and independently distributed, the distribution of the firms' size tends asymptotically to a lognormal.Given the premises characterizing Gibrat's law it follows that the distribution of firms' rates of growth is Gaussian. More recent empirical studies in industrial demography have detected two empirical regularities which are so widespread across countries and persistent over time to be characterized as universal laws:

- the distribution of firms size is right skew and can be fitted by a Power Law (or Zipf) probability density function[7];
- the growth rates of firms output and countries' GDP follow a Laplace distribution.

The Zipf's law is the discrete counterpart of the Pareto continuous distribution (power law). It links the probability to observe the dimension of a social or natural phenomenon with rank greater than, say, z_i, to the cumulative frequency. Roughly speaking, a discrete random variable Z is said to follow a Power Law (also known as Rank-Size, or Pareto-Levy) distribution, if its cumulative distribution function takes the form

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[7] See for instance Axtell (2001) and Gaffeo et al. (2003).

$$\Pr(Z \geq z_i) = \left(\frac{z_i}{z_0}\right)^{\alpha}$$

with $z_i \geq z_0$, $\alpha > 0$, where z_0 is the minimum efficient size and α is the scaling exponent or shape parameter.

Stanley et al. (1996), Amaral et al. (1997) and Bottazzi and Secchi (2003) have found that the growth rate of firms output y_i follows, instead of a normal distribution, a Laplace distribution:

$$L(y_i, b) = \frac{b}{2}\exp(-by_i)$$

where $b > 0$ is the scale parameter.

To explain this evidence, the literature has followed two lines of research. The first one focuses only on the statistical properties of the link between the distribution of the state variable (represented by firms' size) and that of the rates of growth. For instance, Reed (2001) shows that independent rates of change do not generate a lognormal distribution of firms' size if the time of observation of firms variables is not deterministic but is itself a random variable following approximately an exponential distribution. In this case, even if Gibrat's law holds true at the individual level, firms' variables will converge to a double Pareto distribution.

The second line of research stresses the importance of non-price interactions among firms hit by multiplicative shocks, hence building on the framework put forward by Herbert Simon and his co-authors during the 1950s and 60s. As a matter of example, Bottazzi and Secchi (2003) obtain a Laplace distribution of firms' growth rates within Simon's model, just relaxing the assumption of independence of firms' growth rates. In the present analysis, following Marsili et al. (2004), we will test the stability of the firms' rate of growth distribution, by fitting an asymmetric Subbotin density, whose symmetric counterpart encompasses the Laplace and the Gaussian densities as particular cases.

1.1 The Asymmetric Subbotin Distribution

Empirical analyses aimed at assessing the Law of Proportionate Effect have shown that the postulated Normal distribution of the rates of growth barely describes the fatness of the tails. For this reason researchers have turned their attention to a class of fat-tailed distributions, such as the Subbotin or Exponential Power Distribution, introduced by Subbotin (1923). The fuctional form of the symmetric[8] Subbotin distribution is characterised by three parameters, a position parameter m (which is at the same time the mean, the median and the mode of the density), a scale parameter a (describing the spread or width of

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[8] This distribution was introduced by Subbotin (1923) and popularized by Box and Tiao (1962, 1964, 1973), who used it in robustness studies (see also Tiao and Lund (1970), Swamy and Mehta (1977), West (1984), and more recently Osiewalski and Steel (1993)).

the density) and a shape parameter b (which is inversely related to the fatness of the tails) and is described by

$$f(x;a,b,m) = \frac{\exp(-\frac{1}{b}\left|\frac{x-m}{a}\right|^{b})}{2ab^{1/b}\Gamma(1+1/b)} \tag{1}$$

The symmetric Subbotin distribution enconpasses the Gaussian and the Laplace (or double exponential) distributions as special cases: for $b = 2$ it boils down to the Gaussian and for $b = 1$ to a Laplace, while for $b \longrightarrow \infty$ the distribution tends to a Uniform. The lower b, the fatter the tails: hence the distribution is platikurtic for $b > 2$ while it is leptokurtic for $b < 2$: this property will turn out to be central in our analysis. This symmetric version of the Subbotin density has all central moments of odd order equal to zero. Following Bottazzi and Secchi (2003), the central moment of order $2l$ reads as

$$M_{2l} = \left[ab^{1/b}\right]^{2l} \frac{\Gamma((2l+1)/b)}{\Gamma(1/b)} \tag{2}$$

Particular interest will be attached in the subsequent analysis to the excess Kurtosis exhibited by the fitted distribution: in the symmetric case the index reads as follows

$$\gamma_k = \frac{\Gamma(1/b)\Gamma(5/b)}{[\Gamma(3/b)]^2} \tag{3}$$

It is relatively straightforward to check that $\partial\gamma_k/\partial b < 0$ for $b > 0$: this aspect will turn out to be particularly important for our analysis on the dynamic pattern of higher moments of the distribution.

The asymmetric Subbotin density extends the family described above by considering different values for the parameters a and b in the two halves of the density. Its functional form depends on five parameters: a positioning parameter m, two scale parameters a_l and a_r respectively for the values below or above m, and two shape parameters b_l and b_r characterizing, respectively, the lower and upper tail of the density. The following factorisation has been introduced by Bottazzi and Secchi (2003)

$$P(X) = \begin{cases} \frac{\exp(-(x-m)/a)^{b_l}\,\frac{1}{b_l}}{A} & x < m \\ \frac{\exp(-(x-m)/a)^{b_r}\,\frac{1}{br}}{A} & x > m \end{cases}$$

where

$$A = a_l b_l^{\frac{1}{b_l}} \Gamma\left(1 + \frac{1}{b_l}\right) + a_r b_r^{\frac{1}{br}} \Gamma\left(1 + \frac{1}{br}\right)$$

This parameterisation is particularly attractive due to the fact that parameters describing the main features of either side of the distribution will turn out to be useful to capture the relative responsiveness of declining and of growing firms to macroeconomic shocks.

1.2 Data

As already pointed out, the present analysis will focus on two datasets on UK and US, the same adopted in Higson et al. (2002, 2004).

As regards UK, four sources have been considered to build the necessary panel: the Cambridge/DTI databank, the London Share Price Database (LSPD), EXSTAT and DATASTREAM. The Cambridge/DTI databank is a data-set on firms' balance sheeet that dates from 1948. Companies were included only if: they were admitted to the official list of the stock exchange; they were independent companies or company groups; they operated mainly in the UK; and their principal activity was manufacturing, distribution, construction, or transport and certain services. EXSTAT and DATASTREAM, dating from 1970, are datasets that collect published company accounts data for UK quoted companies, as well as members of the Times 1000 list of large UK companies. These databases were expanded to include smaller quoted firms in 1975–76. The combination of databases was used to construct the underlying UK quoted population. This yielded 43,612 company years of data over the period 1967–97. The number of reporting companies averaged 1400 a year, ranging from a maximum of 1844 in 1969 to a minimum of 1284 in 1992.

The unique source for the US data is instead represented by the COMPUSTAT database of quoted companies accounts, over the 1951-1999 period.

1.3 Descriptive Statistics

Tables 1 and 2 report the descriptive statistics of the rates of growth for UK and US and the relative number of firms for each year. Annual rates of growth have been obtained by considering total sales as a proxy for the size of the firm[9]. The number of firms in the sample is approximately constant for UK, ranging from a minimum of 1453 in 1968 to a maximum of 1800 in 1998, while for the US we observe a minimum of 1032 in 1951 and a maximum of 7000 in 1995 and 1996.

Insert Table 1 *and* 2 about *here*

Insert Figure 1 *and* 2 about *here*

In line with Higson et al. (2002, 2004), the moments of the empirical distribution display characteristic correlations with business cycle fluctuations: Figure

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[9] To exclude outliers, the sample is truncated and the results reported are based on growth rates lying between the range ±40%.

1 and 2 plot each of the higher moments of the distributions against the rate of growth of GDP for UK and US respectively: mean and kurtosis display a cyclical pattern, while standard deviation and skewness are counter-cyclical. Furthermore, it is possible to observe that the samples we are considering for both UK and US allow to consider a large part of the relative GDP's, since the empirical mean of the rates of growth closely tracks the rate of growth of aggregate GDP in both cases.

Furthermore, the tables report the Cramer-von Mises test[10], which compares the empirical distribution and the specified theoretical distribution function, the Normal in the specific case: statistics reported in bold are those associated to a p-value below 0.1. A substantial instability of the parameters is evident from this preliminary analysis.

The distribution for both UK and US appears to be rather unstable over time: the result is at odds with previous studies, where a substantial stability has been highlighted[11]: however we claim that no studies so far have adopted a dataset spanned on a temporal dimension suitable for analysing the dynamic behaviour of higher moments of the distribution. Higson et al. (2002, 2004) have applied a mixture of parametric and non-parametric methods for the study of the cross sectional dynamics of the business cycle, but never imposing any structure on the data under scrutiny. Marsili et al. (2004) have followed a different route, by fitting the asymmetric[12] Subbotin density on data on Netherlands over a rather long time period (1968-1997): however the analysis has not focused on the links between the dynamics of the distribution of the rates of growth and macroeconomic fluctuations, being mainly oriented to the analysis of the dynamics within different industries, in consideration of the possible occurrence of asynchronous Industry Life Cycles. In the present work we try to establish a link for the two approaches, relying on the availability of large datasets in both the dynamic and the cross sectional dimensions and exploiting the possibility to estimate an asymmetric distribution that enconpasses as special cases the two main benchmarks considered by the theoretical literature on industrial demography, namely the Gaussian and the Laplace densities.

2 Results

In this section we report the results of the estimation of the five parameters asymmetric Subbotin function and of the subsequent dynamic analysis aimed

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[10] This test is similar to a Kolmogorov-Smirnov test, but instead of using the maximum difference between two cdf's, it uses the integrated difference between them, weighted by the pdf of the null hypothesis distribution.

[11] See Marsili et al. (2004).

[12] It must be pointed out that Marsili et al. (2004) have fitted the four paraeters assymmetric Subbotin density, which allows for asymmetry just in the tails parameters (b). In the present work we will adopt the five parameters version, allowing for asymmetry also in the scale parameters (a). The choice is justified by the fact that the joint evidence on scale and tail parameters on either side of the distribution allows to give an explanation of the dynamic pattern observed in the empirical moments with respect to the rate of growth of GDP.

at deepening our knowledge of the mechanisms generating the characteristic correlations betweeen higher moments of the empirical distribution of the rates of growth and the business cycle. The approach, which consists in fitting the distribution function to the empirical data and to analyse the dynamic properties, in terms of stability and stationarity, has been widely exploited by other studies. The novelty in this paper, largely made possible by the fact that in this context we are coping with an asymmetric distribution, will be determined by the fact that we will relate the estimated parameters to a measure of the business cycle, namely the rate of growth of the GDP, in order to observe how macroeconomic fluctuations impact on firms lying on either side of the distribution.

Table 3 and 4 report the estimated parameters for UK and US (with the respective descriptive statistics), which are plotted in Figure 3 and 4 respectively.

Insert Table 3 *and* 4 about *here*

Insert Figure 3 *and* 4 about *here*

Most of the times the shape parameters b_l and b_r lye within the range $[1, 2]$, even though it must be pointed out that for both UK and US the estimated parameters never seem to match the two benchmarks discussed above. The right shape parameter seems to be constantly bigger than the left counterpart both for UK and US. In the UK case we observe an average b_l of 1.377 and an average b_r of 1.734, while for US b_l averages to 1.167 and b_r to 1.727. Relying on the estimated parameters we can envisage in both UK and US an estimated density characterised by a high degree of asymmetry, which has a right hand side closer to a Gaussian, and better approximated on the left hand side by a Laplace. Figure 5 and 6 plot the shape and the scale parameter of each side against their counterparts: clearly the resulting points do not accumulate along the 45° degrees line, confirming the presence of a remarkable degree of asymmetry. Furthermore, estimates of the tail parameters exceed the Gaussian benchmark in correspondence of periods of macroeconomic "turbulence", although increments of b_l and b_r above the threshold of 2 are not synchronised: in the case of UK the estimated b_l exceeds the threshold in 1975 and 1980-81, while the estimated b_r exceeds 2 in 1973, 1986-89 and 1997-98. As regards US, estimated b_l has its periods of maximum in 1974 and 1981, while estimated b_r exceeds the threshold in 1972-7, 1983-1987 and 1993-1998. As it is possible to infer from this observation, the estimated b_r appears to be somewhat more persistent in both cases and the intuition is confirmed from the analysis of the autocorrelation function presented in Tables 5 and 6.

Insert Table 5 *and* 6 about *here*

Insert Figure 5 *and* 6 about *here*

The same observation applies to the estimated scale parameters and to the mean: all the parameters display a remarkable variability, particularly for UK. In both cases the left hand side of the distribution, described in the present context by b_l and a_l, appears to display more variability. It is also possible to observe that both the scale parameters and the left shape parameter for US clearly exhibit a deterministic upward sloping trend, while the mean of the estimated density exhibits a downward sloping trend, which will be taken into consideration in the analysis of stationarity. The upward trend in the shape parameters is consistent with the kurtosis of the empirical distribution (Figure 2), which stabilizes during the last part of the sample at a low level. An upward sloping trend in the shape parameters, although bounded in the range $[1, 2]$, could be interpreted as the sign that the density is moving from the Laplace towards the Gaussian benchmark.

Table 7 and 8 report the correlations among the estimated parameters.

$Insert\ Table\ 7\ and\ 8$ about $here$

As regards UK, a strong positive correlation between the tail and the scale parameter of each side (around 0.90 in both sides) can be observed. A moderate negative correlation (-0.43) is observed both between the two tail parameters and the two scale parameters (-0.16). The mean growth rate parameter displays a low correlation with both the scale parameters and the left tail parameter, while it appears to be almost uncorrelated with the right tail parameter.

Shifting the attention to US estimates, it is possible to observe that the strong positive correlation between scale and tail parameters on either side is observable also in this case (around 0.90 also in this case). The tail parameters appear to be uncorrelated while the scale parameters have in this case a positive correlation (0.48). Scale and tail parameters of either side have in this case a negative correlation with the mean rate of growth.

2.1 Dynamic Analysis

In this subsection we study the dynamic properties of the estimated parameters of the asymmetric Subbotin distribution. From the observation of the autocorrelation functions (AC) reported in Table 5 and 6 it is possible to observe that in the case of UK some form of autocorrelation, probably up to the first order, is present in b_r and a_r, while the left counterparts appear to be moderately correlated with their own first order lags. In the case of US autocorrelation is present in all the series but b_l, which does not appear to be serially correlated. We now turn to the evidence delivered by the partial autocorrelation functions (PAC), in order to determine whether it is possible to discriminate between any pure autoregressive or moving average process in the data. The PAC of a pure $AR(p)$ should cut off at lag p, while the PAC of a pure moving average process should gradually decline to zero: the last case is never detectable both in UK and US data. In any case the corresponding Q values confirm the visual impression arisen from the analysis of the AC and of the PAC functions of the occurrence of serial correlation in the parameters of interest. Furthermore, any form of autocorrelation disappears after taking first differences of the series.

Another important issue is non stationarity: this aspect is extremely important in order to assess the properties of the estimated distribution in terms of invariance and to proceed with the analysis of the responsiveness of the parameters of the same distribution to macroeconomic fluctuations, in order to avoid any spurious regression. We carry out an Augmented Dickey-Fuller test in which the lag-length is automatically selected relying on the Schwartz criterion: we have also taken into consideration the presence of any deterministic part in the specification of the test from the observation of the series: as we have already observed, a deterministic trend clearly emerges in all the parameters but b_l for US and a_r in the case of UK. The presence of a unit root in the underlying processes for UK parameters is detected in the case of a_r and b_r: the null hypothesis cannot be rejected at any significance level for a_r, while it can be rejected only at 10% significance level for b_r. As regards US the null hypothesis must be rejected in all the cases. However, it must be pointed out that the response of the simple Dickey-Fuller statistic[13] of the parameters of interest would have led to the acceptance of the null hypothesis of non stationarity in most of the cases. Results are reported in Table 9 and 10.

Insert Table 9 *and* 10 about *here*

After these preliminary inspection we want to draw the attention to the responsiveness of the parameters to macroeconomic fluctuations, captured by the GDP rate of growth. The analysis aims at determining which side of the distribution, described by the scale and the shape parameters, appears to be more responsive to macroeconomic shocks, and hence to find a rationale for the observed dynamic pattern of higher empirical moments detected by Higson et al. (2002, 2004). Relying on the evidence provided by the descriptive statistics and by the dynamic analysis of the series of interest, we specify the following regression

$$(1 - \eta_1 a(L))y_t = \alpha + \beta t + \gamma g_t + \varepsilon_t \tag{4}$$

where y_t represents the parameter of interest, g_t is the rate of growth of the real GDP and ε_t is a serially uncorrelated error term. The results of the estimation for UK and US are reported in Tables 11 and 12.

Insert Table 11 *and* 12 about *here*

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[13] However it must be considered that the Dickey-Fuller statistic does not allow to cope with problems of dynamic mis-specification.

As one would expect, both for UK and US, the estimated left tail and scale parameters have a negative response to relative changes in GDP, while the estimated right parameters have a pro-cyclical pattern. What is striking is that in both cases the marginal response of b_l and a_l is in absolute value bigger than the marginal response estimated for b_r and a_r, respectively. A positive response of b_r to macroeconomic fluctuations means that the right tail of the distribution, composed by firms growing at a very fast pace, becomes thinner in expansion, leading the distribution to move towards a Gaussian benchmark. The opposite conclusion must be drawn for the left tail, composed by extremely declining firms, which appear to be more vulnerable over the phases of the business cycle. Since the scale parameter is a measure of the width of the distribution, evidence of a pro-cyclical right scale parameter and of a counter-cyclical left scale parameter means that during expansions dispersion around the mean on the right hand side increases, while it decreases on the left side: hence during expansions the right half of the distribution is better approximated by a Gaussian benchmark, which is characterised by a higher dispersion around the mean than the Laplace benchmark, that is more peaked and fits better the left half of the distribution. The overall response of the width of the distribution, approximated by the algebraic sum of the relative responses of the scale parameters on either side, implies that, consistently with Higson et al. (2002, 2004), dispersion will decrease in expansion and will increase in recession. The evidence on the overall responses in the tails and in the scale of the distribution can be related to the evidence of a pro-cylical kurtosis and of a counter-cycical skewness and standard deviation of the empirical distribution, as pointed out by Higson et al. (2002, 2004). We can envisage a mechanism for which firms growing at a lower than mean rate (hence lying on the left side) are more responsive to macroeconomic fluctuations and in expansion move towards the mean, while in recessions they move further: the effect is captured through the marginal response of the left scale parameter, which is negative (counter-cyclical) and in absolute value bigger than the marginal response of the right counterpart (which is positive and hence pro-cyclical). Such a mechanism shed more light on the mechanisms underlying the evidence provided by Higson et al. (2002, 2004). But our results allow to move a step forward: Higson et al. (2002, 2004) base their interpretation of the occurrence of a counter-cyclical skewness on the possibility that firms with lower than mean growth rate are more responsive to aggregate shocks, while firms lying on either tail of the distribution are relatively insulated from macroeconomic turbulence. The evidence of a left tail of the distribution which appears to be more responsive than the right one does not contradict the results provided by Higson et al. (2002, 2004) and allows to explain why pro-cyclical kurtosis emerges. The explanation relies on the fact that the overall response of the tails of the distribution to a relative change in the GDP, captured by the algebraic sum of the marginal responses of b_r and b_l to g_t, is negative and hence the distribution becomes relatively more peaked during expansions and exhibits a lower *4th* central moment during recessions.

Thus, the joint evidence of the occurrence of a counter-cyclical skewness and of a pro-cyclical kurtosis is confirmed by our analysis and find a common root in the greater responsiveness of firms growing at a lower than mean rate to macroeconomic shocks than firms growing at a bigger than mean rate, and of a greater responsiveness of the left tail relative to the right one. To conclude, the visual impression of the resulting density, expressed by the diagram reported in Figure 8, is that during expansion phases we will observe a left hand side closer to a Laplace density, with a fat tail and more peaked than a Normal, and a right hand side closer to a Gaussian benchmark, with greater standard deviation and a thinner tail: the overall result will be a density characterised by a negative skewness. Opposite results hold during recession phases (see Figure 8.b).

Insert Figure 8 about *here*

It might be argued that the rate of growth of real GDP is a rather crude measure of the business cycle. For this reason we have replicated the empirical exercise stated by equation (4) by considering as cyclical component the output gap, which has been obtained by detrending the series of the output through a Kalman filter technique. In particular, the technique implemented is based on Kuttner's (1994) bivariate model, which involves a Phillips-curve regression. Kuttner's (1994) model associates to a classical decomposition a regression whose regressors include unobserved quantities such as the output gap and its lags. The implementation is based on state-space models, with the model parameters estimated by exact maximum likelihood. The technique involves running the Kalman recursions with de Jong's diffuse initialisation (de Jong (1991)[14]), and a smoother that produces the unobserved quantities.

The results of the estimation for each Subbotin parameter, reported in Tables 13 and 14 , confirm the empirical evidence detected in the case of the regression of the same parameters on the rate of growth of real GDP. Focusing on the tails, both for UK and US, the response of b_l to an increase in output gap is negative, denoting an increase in the degree of kurtosis of the left tail; opposite evidence holds for b_r, which in every case has in absolute value a smaller response than the one detected for the left tail.

Insert Table 13 *and* 14 about *here*

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[14] The diffuse Kalman filter, introduced by de Jong (1991), serves at the exact initialisation of the filter when the state vector contains non-stationary elements. This feature avoids specifying an initial set of priors to initialise the algorithm. When the transition equation is non-stationary, the unconditional distribution of the state vector is not defined. This means that, unless good informative priors are available, the initial distribution of the state vector must be specified in terms of a diffuse (non-informative) prior. For details concerning the initialisation we refer the reader to the original paper.

2.1.1 The Financial Accelerator as a Driver of the Dynamics of the Distribution

In line with several authors[15] who have analysed the implications of financial structure for the dynamics of firms' rate of growth distribution, we argue that the greater responsiveness of the left tail of the distribution can be determined by financing constraints, which appear to be more relevant to declining firms.

In order to find empirical support for our conjecture, we now consider one of the theoretical mechanisms that have been formalised by the literature on the credit view of the MPTM, widely regarded as the financial accelerator[16]. Over the last decade, theoretical macroeconomic frameworks have stressed the importance of financial factors in generating, propagating and amplifying macroeconomic fluctuations. The choice of the financial accelerator as a possible transmission channel of aggregate shocks is principally due to the fact that more recent models featuring a financial accelerator have been developed to the point where they are now useful for providing a quantitative assessment of how much this mechanism might contribute to explaining aggregate fluctuations.

The main ingredients at the root of the mechanism are the following. First, there is some friction present in the financial market, often due to the presence of asymmetric information or to monitoring costs. This imperfections of the market mechanism introduce a wedge between the cost of external funds and the opportunity cost of internal funds, which is widely recognised as "the premium for external funding". The premium is an endogenous variable and depends inversely on the balance sheet strength of the borrower. Finally, borrowers' financial positions depend positively on aggregate economic activity (e.g. in a boom, asset values and cash flows rise relative to debt, and vice-versa in a downturn). The procyclical behavior in borrowers' financial positions implies countercyclical movement in the premium for external funding[17]. This countercyclical movement in the premium serves at amplifying borrower's spending.

In order to empirically detect possible asymmetries in the propagation of shocks to firms growing at different rates, we consider as explanatory variable the high bond yield spread. Gertler and Lown (1999) successfully identify the vertical spread between corporate bonds of differing risk as a proxy for the way in which the financial accelerator works to propagate shocks, both real and nominal. Gertler and Lown (1999) justify the choice of the spread between the high yield bond rate and the corresponding safe interest rate as informational

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[15] See for instance Cabral and Mata (2003) and Battacharjee et al. (2004).

[16] See Bernanke et al. (1999).

[17] Bernanke et al. (1999) have emphasised that external finance is more expensive than internal finance and that since the cost to get external funds is positively affected from the presence informative asymmetries between borrowers and lenders, the external finance premium should be inversely proportional to the level of net worth. This evidence implies that, if in presence of downturns or contractionary monetary policy actions agency costs increase and consequently financial intermediaries increase collateral requirements, then the fraction of loans allotted to high agency cost borrowers should consequentely decrease: this phenomenon has been defined *flight-to-quality effect*.

variable on the business cycle on the basis of two reasons: firstly, they claim that the spread might be a suitable measure of overall financial conditions, which can offer a way to detect evidence of the role of credit market frictions in the amplification and propagation of business cycles, along the lines suggested by the recent theoretical work on the financial accelerator; secondly, they consider the increasing evidence on the use of financial indicators in relation to their informational content for forecasting and policy, providing evidence of the high yield spread as one of the most reliable indicators. In our case we define the vertical spread as the difference between Moody's seasoned Baa corporate bond yield and 10 years treasury bond yield: the spread is denoted by s_t in the following equation and it has been plotted in Figure 9.

$$(1-\eta_1 a(L))y_t = \alpha + \beta t + \gamma s_t + \varepsilon_t \tag{5}$$

As in the previous case, y_t represents the parameter of interest, while ε_t is a serially uncorrelated error term. Estimation results of equation (5) for US have been reported in Table15.

Insert Table 15 about *here*
Insert Figure 9 about *here*

From this empirical exercise it clearly emerges that the vertical spread has no explanatory power for the right parameters a_r and b_r, given that the corresponding t-ratio statistic falls in the acceptance region for the null hypothesis ($H_0: \ \gamma = 0$), which probably means that financial accelerator does not affect the dynamics of firms growing at a positive pace.

On the contrary, the spread has a strong positive impact on the left tail parameter b_l, which is in line with what we might expect on theoretical grounds. Given that the spread (which is a proxy for the premium for external funds) has a counter-cyclical behaviour, a positive sign of the parameter γ in the estimated equation for b_l means that an increase in the premium, which is usually associated with a declining aggregate economy, determines a decrease in the degree of kurtosis of the left tail, which is perfectly in line with the results obtained from previous analyses on the impact of aggregate activity on the distribution.

This simple empirical exercise shows how actually a financial accelerator mechanism might be at work in the dynamics of the firms' rate of growth distribution.

Conclusions

The present work has focused on the dynamic properties of the distribution of the rate of growth for quoted UK and US companies. As regards the higher moments of the empirical distribution, we support the evidence provided by Higson et al. (2002, 2004) of a negative correlation between the rate of growth of the GDP and the standard deviation and skewness of the distribution, while Kurtosis exhibits a procyclical pattern.

In order to observe the presence of any asymmetry in the response of the distribution to macroeconomic shocks, we fit the asymmetric Subbotin distribution introduced by Bottazzi and Secchi (2003). The choice of the Subbotin distribution as instrument for imposing structure on the available data is determined by the fact that such distribution encompasses as special cases (depending on the values assumed by the shape parameter b) the two main benchmarks considered by the theoretical literature on the firms' rate of growth distribution: the Gaussian distribution, postulated by Gibrat, and the Laplace distribution, which has been introduced by Stanley et al. (1996), Amaral et al. (1997) and Bottazzi and Secchi (2003) in order to consider a fat-tailed distribution that has been found to fit better the data.

The estimated parameters of interest appear quite volatile both for UK and US, particularly in the case of the right scale and shape parameters. All the US estimated parameters but the left tail one are characterised by the occurrence of a deterministic positive trend.

The resulting distributions appear quite skewed, never being close to the two proposed benchmarks, but showing significant departures during period of greater macroeconomic turbulence. Some serial correlation, generally limited to the first order, arises from the analysis of the AC and the PAC functions. As regards the analysis of stationarity, our study highlights the presence of a unit root in the underlying process of most of the UK and US parameters, while the augmented version of the test is able to detect the presence of a unit root only for the right parameters of UK.

We then focus on the responsiveness of the parameters to macroeconomic fluctuations, which are described by the GDP rate of growth. The analysis aims at determining which side of the distribution, described by the scale and the shape parameters, appears to be more responsive to macroeconomic shocks, and hence to find a rationale for the observed dynamic pattern of higher empirical moments detected by Higson et al. (2002, 2004).

As one would expect, both for UK and US, the estimated left tail and scale parameters have a negative response to relative changes in GDP, while the estimated right parameters have a pro-cyclical pattern. What is striking is that in both cases the marginal response of b_l and a_l is bigger than the marginal response estimated for b_r and a_r, respectively. A positive response of b_r to macroeconomic fluctuations means that the right tail of the distribution, composed by firms growing at a very fast pace, becomes thinner in expansion, moving towards a Gaussian benchmark. Opposite conclusions must be drawn for the left tail, composed by extremely declining firms, which appear to be more vulnerable over the phases of the business cycle. As the scale parameter is a measure of the width of the distribution, evidence of a pro-cyclical right scale parameter and of a counter-cyclical left scale parameter means that during expansions dispersion around the mean on the right hand side increases, while it decreases on the left side: hence during expansions the right half of the distribution is better approximated by a Gaussian benchmark, which is characterised by an higher dispersion around the mean than the Laplace benchmark, that is more peaked and fits better the left half of the distribution. The overall response of the width of the distribution, approximated by the algebraic sum of the relative responses of the scale parameters a_l and a_r implies that, consistently with Higson et al. (2002, 2004), dispersion will decrease in expansion and will increase in recession. Furthermore, Higson et al. (2002, 2004) base their interpretation of the occurrence of a counter-cyclical skewness on the possibility that firms with lower than mean growth rate are more responsive to aggregate shocks, while firms lying on either tail of the distribution are relatively insulated from macroeconomic variation. The evidence of a left tail of the distribution which appears to be more responsive than the right one does not contradict the results provided by Higson et al. (2002, 2004) and allows to explain why pro-cyclical kurtosis emerges. The explanation relies on the fact that the overall response of the tails of the distribution to a relative change in the GDP, captured by the algebraic sum of the marginal responses of b_r and b_l to the rate of rgowth of GDP, is negative and hence the distribution becomes relatively more peaked during expansions and exhibits a lower $4th$ central moment during recessions.

The paper supports the evidence provided by Battacharjee et al. (2004) and Higson et al. (2002, 2004), who claim that extremely declining and growing firms appear to be substantially insulated from movements in interest rate and in GDP relative to lower than medium rate growing firms: this mechanism explains why counter-cyclical skewness emerges. We move also a step forward showing that the left tail parameter (inversely related to the kurtosis) and the scale parameter (positively related to the standard deviation) of the fitted asymmetric distribution are more responsive to changes in the GDP relative to their right counterparts: this evidence completes the puzzle and explains why counter-cyclical standard deviation and pro-cyclical kurtosis emerge.

In line with Cabral and Mata (2003) and Battacharjee et al. (2004), although with some theoretical departures, we argue that the greater responsiveness of the left tail of the distribution can be determined by financing constraints, which appear to be more relevant to declining firms. Cabral and Mata (2003) start from the observation that financial constraints are a significant determinant of firms' investment decisions and that in particular this statement seems to be true for young firms. Battacharjee et al. (2004) assume a different perspective and show how the monetary transmission mechanism mainly affects medium range growing quoted firms. The authors argue that the credit view of the monetary policy transmission mechanism (MPTM) could provide an explanation of the stylised facts highlighted, arguing that firms growing in the medium range are the ones likely to rely more on external finance and hence are the ones more affected in terms of production and investment decisions by marginal changes in the cost of external finance. This new evidence is somehow in contrast with the classical credit view of the MPTM, which predicts that the impact of monetary decisions propagated through the credit market (both for the lending and the balance sheet channel) should have a grater effect on smaller firms, which are the ones likely to rely more on external finance.

On the basis of the evidence we have provided, we argue that in a regime of equity rationing (See Mayers and Majluf (1984)), extremely declining firms are severely constrained in the access to external finance both on the equity and on the credit market, thus they cannot exploit the new business opportunities that come in an expansion phase due to the lack of liquidity. On the other hand, firms growing at an extremely fast pace can account on a sufficient degree of internally generated funds and in any case can offer good collaterals on the credit market: however, as Higson et al. (2002) point out, it can be the case that these firms are overstretched and have little slack to meet the higher demand that recovery brings. Opposite implications hold in a recession phase. This mechanism can explain the greater responsiveness to business fluctuations of the left tail of the distribution of rates of growth relative to the right one and hence the occurrence of pro-cyclical kurtosis in the data.

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Table 1

Descriptive Statistics: UK Rates of Growth of Sales, 1968-1997

Year	Mean	Std. Dev.	Skewness	Kurtosis	CvM	Observations
1968	0.039	0.107	0.134	4.669	**3.877**	1453
1969	0.028	0.111	0.257	4.175	**3.854**	1800
1970	0.016	0.108	-0.025	5.180	**11.714**	1790
1971	0.006	0.101	-0.031	5.352	**13.944**	1756
1972	0.014	0.105	-0.134	5.051	**13.390**	1728
1973	0.074	0.115	0.261	3.706	**9.685**	1786
1974	0.025	0.112	0.114	4.988	**12.156**	1785
1975	-0.048	0.119	-0.411	4.111	**12.167**	1753
1976	0.012	0.110	-0.119	4.843	**12.654**	1742
1977	0.028	0.109	0.165	4.839	**12.702**	1756
1978	0.015	0.103	0.027	5.745	**14.939**	1717
1979	0.001	0.104	0.184	5.754	**15.455**	1777
1980	-0.046	0.117	-0.114	4.484	**12.039**	1790
1981	-0.053	0.126	-0.285	3.970	**13.993**	1770
1982	-0.004	0.112	-0.204	5.447	**15.794**	1777
1983	0.018	0.118	0.112	5.285	**15.788**	1785
1984	0.045	0.119	0.232	4.924	**14.859**	1740
1985	0.031	0.121	0.196	4.826	**15.825**	1771
1986	0.044	0.127	0.314	4.361	**15.824**	1717
1987	0.041	0.127	0.309	4.330	**15.930**	1694
1988	0.060	0.129	0.439	3.956	**15.885**	1684
1989	0.050	0.133	0.217	3.994	**14.772**	1753
1990	0.012	0.130	0.097	4.479	**14.625**	1797
1991	-0.027	0.126	-0.026	4.423	**14.548**	1786
1992	-0.010	0.121	-0.033	5.134	**18.387**	1783
1993	0.018	0.115	0.059	5.264	**18.212**	1757
1994	0.040	0.118	0.146	4.789	**17.105**	1765
1995	0.045	0.116	0.434	4.651	**17.700**	1797
1996	0.034	0.117	0.342	5.018	**19.264**	1790
1997	0.029	0.120	0.359	4.556	**18.890**	1787

Table 2

Descriptive Statistics: US Rates of Growth of Sales, 1951-1998

Year	Mean	Std. Dev.	Skewness	Kurtosis	CvM	Observations
1951	0.002	0.105	0.536	6.032	**9.599**	1032
1952	0.045	0.100	0.457	5.570	**7.571**	1060
1953	0.000	0.101	-0.386	5.563	**7.937**	1052
1954	0.075	0.108	0.412	4.147	**4.534**	1060
1955	0.067	0.102	0.766	5.125	**6.939**	1077
1956	0.027	0.101	0.545	6.107	**10.266**	1110
1957	-0.009	0.112	-0.185	5.679	**9.360**	1134
1958	0.073	0.100	0.761	4.178	**6.413**	1187
1959	0.038	0.098	0.608	5.081	**7.598**	1225
1960	0.051	0.118	0.153	4.370	**6.406**	2378
1961	0.069	0.115	0.084	4.747	**7.088**	2047
1962	0.049	0.112	0.014	4.973	**7.467**	2329
1963	0.071	0.116	-0.078	4.517	**5.351**	2554
1964	0.084	0.116	-0.044	4.460	**4.099**	2679
1965	0.095	0.117	0.023	4.112	**3.525**	2806
1966	0.049	0.122	0.211	3.992	**5.897**	2972
1967	0.075	0.125	-0.019	4.069	**5.226**	3027
1968	0.073	0.123	0.104	4.050	**6.740**	3256
1969	0.015	0.133	-0.020	3.807	**5.759**	3468
1970	0.026	0.135	-0.107	4.049	**7.361**	3569
1971	0.072	0.125	-0.107	4.217	**5.648**	3719
1972	0.108	0.125	-0.284	3.977	**1.537**	3768
1973	0.078	0.145	-0.327	3.489	**2.070**	4135
1974	-0.027	0.158	0.020	3.003	**2.349**	5481
1975	0.020	0.142	-0.108	3.520	**5.458**	5610
1976	0.054	0.137	-0.345	3.997	**6.635**	5636
1977	0.065	0.134	-0.355	3.925	**5.071**	5527
1978	0.068	0.141	-0.290	3.742	**4.829**	5300
1979	0.028	0.149	-0.177	3.337	**3.760**	5136
1980	0.016	0.151	-0.009	3.292	**4.492**	5157
1981	-0.046	0.155	0.191	3.197	**2.832**	5009
1982	0.008	0.161	-0.042	3.074	**4.370**	5168
1983	0.066	0.153	-0.233	3.309	**3.059**	5180
1984	0.019	0.161	-0.045	3.136	**4.109**	5202
1985	0.027	0.168	-0.144	3.024	**3.642**	5141
1986	0.054	0.161	-0.285	3.162	**2.720**	5435
1987	0.059	0.157	-0.300	3.310	**4.118**	5481
1988	0.039	0.152	-0.200	3.331	**4.910**	5513
1989	0.023	0.151	-0.090	3.347	**5.380**	5543
1990	-0.006	0.153	0.129	3.259	**4.428**	5632
1991	0.019	0.153	0.004	3.269	**5.677**	5716
1992	0.044	0.154	-0.129	3.204	**4.548**	5897
1993	0.063	0.150	-0.183	3.247	**3.257**	6552
1994	0.081	0.155	-0.344	3.237	**1.945**	6626
1995	0.072	0.155	-0.233	3.215	**3.684**	7000
1996	0.066	0.154	-0.227	3.308	**4.907**	7000
1997	0.047	0.157	-0.143	3.287	**10.831**	6988
1998	0.048	0.146	-0.057	3.636	**23.685**	6987

Table 3

Asymmetric Subbotin Parameters: ML Estimation for UK

Year	**bl**	**br**	**al**	**ar**	**mean**	**loglikelihood**
1968	0.984	1.749	0.073	0.126	-0.002	-0.768
1969	1.450	1.244	0.100	0.100	0.033	-0.732
1970	1.058	1.317	0.092	0.104	0.010	-0.700
1971	1.251	1.533	0.098	0.110	-0.002	-0.706
1972	1.238	1.682	0.107	0.114	0.014	-0.663
1973	1.014	2.578	0.088	0.153	0.056	-0.680
1974	1.552	1.337	0.131	0.103	0.061	-0.607
1975	2.333	1.456	0.163	0.110	-0.030	-0.560
1976	1.572	1.554	0.134	0.107	0.041	-0.603
1977	1.309	1.665	0.110	0.121	0.033	-0.629
1978	1.292	1.234	0.109	0.094	0.036	-0.689
1979	1.176	1.299	0.091	0.113	-0.019	-0.677
1980	2.123	1.165	0.144	0.107	-0.038	-0.589
1981	3.211	1.108	0.206	0.102	-0.003	-0.505
1982	1.539	1.270	0.137	0.101	0.025	-0.584
1983	1.205	1.543	0.112	0.133	0.010	-0.540
1984	1.003	1.728	0.100	0.141	0.032	-0.566
1985	1.169	1.538	0.114	0.133	0.030	-0.525
1986	1.089	2.277	0.107	0.181	0.008	-0.476
1987	1.131	2.465	0.108	0.190	0.001	-0.465
1988	1.051	3.169	0.099	0.213	0.010	-0.489
1989	1.108	3.167	0.115	0.211	0.007	-0.437
1990	1.450	1.985	0.130	0.171	-0.013	-0.423
1991	1.884	1.771	0.130	0.169	-0.075	-0.445
1992	1.505	1.439	0.131	0.137	-0.021	-0.474
1993	1.384	1.510	0.130	0.123	0.035	-0.527
1994	1.052	1.913	0.110	0.143	0.037	-0.544
1995	1.138	1.877	0.103	0.148	0.033	-0.562
1996	1.080	1.721	0.103	0.148	0.014	-0.536
1997	1.260	2.183	0.109	0.174	-0.005	-0.496

Table 4

Asymmetric Subbotin Parameters: ML Estimation for US

Year	bl	br	al	ar	mean	loglikelihood
1951	1.299	0.930	0.098	0.092	0.011	-0.712
1952	0.905	1.121	0.072	0.092	0.042	-0.822
1953	1.273	1.189	0.114	0.079	0.032	-0.737
1954	0.860	1.350	0.072	0.104	0.072	-0.803
1955	0.856	1.154	0.058	0.101	0.049	-0.859
1956	0.902	0.887	0.071	0.085	0.024	-0.810
1957	1.228	0.855	0.118	0.077	0.029	-0.671
1958	0.871	1.308	0.053	0.107	0.046	-0.900
1959	1.144	1.170	0.076	0.096	0.032	-0.821
1960	1.048	1.199	0.087	0.105	0.040	-0.701
1961	0.720	1.236	0.066	0.108	0.035	-0.780
1962	0.883	1.130	0.076	0.095	0.036	-0.779
1963	0.771	1.230	0.073	0.102	0.050	-0.770
1964	0.729	1.720	0.067	0.131	0.032	-0.767
1965	0.827	1.694	0.069	0.131	0.049	-0.751
1966	1.192	1.429	0.090	0.122	0.025	-0.666
1967	0.875	1.412	0.083	0.121	0.046	-0.671
1968	0.833	1.575	0.073	0.135	0.021	-0.691
1969	1.368	1.245	0.123	0.109	0.028	-0.574
1970	1.101	1.240	0.110	0.112	0.026	-0.572
1971	0.817	1.602	0.079	0.131	0.028	-0.675
1972	0.807	2.512	0.079	0.161	0.048	-0.687
1973	1.087	2.595	0.115	0.170	0.042	-0.506
1974	2.359	1.563	0.189	0.135	0.011	-0.401
1975	1.325	1.526	0.125	0.128	0.019	-0.520
1976	0.996	1.594	0.106	0.124	0.039	-0.584
1977	0.962	1.844	0.101	0.135	0.038	-0.600
1978	0.970	1.940	0.104	0.150	0.031	-0.543
1979	1.363	1.854	0.134	0.146	0.021	-0.466
1980	1.397	1.738	0.127	0.155	-0.006	-0.451
1981	2.558	1.242	0.188	0.125	-0.002	-0.425
1982	1.640	1.685	0.157	0.152	0.013	-0.381
1983	1.164	2.270	0.123	0.171	0.033	-0.450
1984	1.420	1.933	0.138	0.172	-0.007	-0.383
1985	1.535	2.045	0.159	0.170	0.021	-0.342
1986	1.375	2.452	0.148	0.173	0.041	-0.392
1987	1.149	2.230	0.130	0.168	0.033	-0.425
1988	1.182	1.954	0.124	0.158	0.014	-0.451
1989	1.191	1.843	0.118	0.161	-0.011	-0.453
1990	1.608	1.542	0.136	0.150	-0.018	-0.437
1991	1.306	1.684	0.124	0.156	-0.007	-0.439
1992	1.228	2.080	0.123	0.171	0.008	-0.434
1993	1.124	2.565	0.111	0.188	0.007	-0.471
1994	1.187	3.148	0.126	0.193	0.038	-0.449
1995	1.051	2.802	0.112	0.200	0.009	-0.445
1996	1.051	2.737	0.114	0.199	0.006	-0.439
1997	1.241	2.489	0.134	0.190	0.012	-0.381
1998	1.225	2.384	0.131	0.179	0.026	-0.412

Table 5

Autocorrelation Function, Partial Autocorrelation Function and Q-stat for UK

	bl			**br**			**al**			**ar**			**mean**		
LAG	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat
1	0.397	0.397	5.5257	0.58	0.58	11.802	0.476	0.476	7.9528	0.719	0.719	18.163	0.275	0.275	2.6562
2	-0.082	-0.284	5.7668	0.364	0.042	16.617	-0.054	-0.362	8.0571	0.605	0.181	31.434	-0.181	-0.278	3.848
3	-0.201	-0.06	7.2776	0.131	-0.144	17.263	-0.156	0.076	8.9709	0.432	-0.118	38.423	-0.232	-0.107	5.8615
4	-0.165	-0.082	8.3411	-0.047	-0.126	17.348	-0.138	-0.136	9.7135	0.246	-0.182	40.779	-0.013	0.056	5.8681
5	0.021	0.101	8.3582	-0.087	0.031	17.655	0.054	0.229	9.8312	0.122	-0.035	41.38	-0.017	-0.123	5.8794

Table 6

Autocorrelation Function, Partial Autocorrelation Function and Q-stat for US

	bl			**br**			**al**			**ar**			**mean**		
LAG	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat	AC	PAC	Q-stat
1	0.372	0.372	7.0494	0.784	0.784	31.389	0.608	0.608	18.901	0.87	0.87	38.668	0.491	0.491	12.327
2	0.093	-0.052	7.5028	0.531	-0.217	46.096	0.426	0.088	28.356	0.741	-0.066	67.34	0.283	0.054	16.494
3	0.061	0.051	7.7015	0.405	0.187	54.834	0.467	0.284	40.004	0.641	0.045	89.274	0.137	-0.028	17.498
4	0.149	0.132	8.9191	0.353	0.04	61.638	0.529	0.241	55.283	0.593	0.153	108.46	0.216	0.193	20.032
5	0.224	0.144	11.717	0.315	0.03	67.176	0.485	0.097	68.41	0.548	-0.012	125.21	0.251	0.11	23.552

Table 7

Correlation between Subbotin parameter estimates: UK

	al	**ar**	**bl**	**br**	**mean**
al	1.000				
ar	-0.168	1.000			
bl	0.906	-0.358	1.000		
br	-0.274	0.919	-0.438	1.000	
mean	-0.276	-0.221	-0.389	0.011	1.000

Table 8

Correlation between Subbotin parameter estimates: US

	al	**ar**	**bl**	**br**	**mean**
al	1.000				
ar	0.489	1.000			
bl	0.887	0.178	1.000		
br	0.346	0.941	0.018	1.000	
mean	-0.587	-0.401	-0.573	-0.147	1.000

Table 9: Augmented Dickey-Fuller (ADF) test statistic for UK

	bl	**br**	**al**	**ar**	**mean**
ADF	-3.504	-2.871	-4.255	-2.626	-4.151
Crtitical Values					
1% level	-3.662	-3.662	-3.670	-4.285	-3.670
5% level	-2.960	-2.960	-2.964	-3.563	-2.964
10% level	-2.619	-2.619	-2.621	-3.215	-2.621
p-value	0.015	0.060	0.002	0.272	0.003

Table 10: Augmented Dickey-Fuller (ADF) test statistic for US

	bl	**br**	**al**	**ar**	**mean**
ADF	-4.612	-4.334	-4.664	-4.731	-6.330
Crtitical Values					
1% level	-3.574	-4.166	-4.161	-4.166	-4.161
5% level	-2.924	-3.509	-3.506	-3.509	-3.506
10% level	-2.600	-3.184	-3.183	-3.184	-3.183
p-value	0.001	0.006	0.003	0.002	0.000

Table11

Effect of aggregate GDP on the Subbotin parameters: OLS estimation for UK

	bl	**br**	**al**	**ar**
Constant	1.365	0.373	0.087	0.017
t-stat	7.100	1.860	6.500	1.300
Deterministic Trend				
t-stat				
Lagged Dependent Variable(-1)	0.268	0.616	0.412	-0.317
t-stat	2.270	5.940	3.830	-2.410
Lagged Dependent Variable(-2)				
t-stat				
GDP Rate of Growth	-15.197	13.807	-0.765	0.669
t-stat	-5.930	5.220	-5.990	4.650
R-Squared	0.627	0.681	0.665	0.477
DW	2.530	2.330	2.180	2.080
LM-test	1.960	0.598	0.795	1.531
p-value	0.161	0.558	0.462	0.235

Table12

Effect of aggregate GDP on the Subbotin parameters: OLS estimation for US

	bl	**br**	**al**	**ar**
Constant	1.086	0.422	0.059	0.052
t-stat	8.540	2.820	3.130	4.450
Deterministic Trend	0.009	0.018	0.001	0.002
t-stat	2.620	3.340	3.220	4.150
Lagged Dependent Variable(-1)		0.435	0.237	0.314
t-stat		3.210	2.240	2.070
Lagged Dependent Variable(-2)				
t-stat				
GDP Rate of Growth	-4.752	3.105	-0.183	0.096
t-stat	-2.310	1.980	-1.960	2.300
R-Squared	0.230	0.736	0.500	0.869
DW	1.850	1.630	1.950	1.860
LM-test	1.432	1.598	0.010	0.971
p-value	0.250	0.215	0.991	0.387

Table13

Effect of Kalman Filtered GDP on the Subbotin parameters: OLS estimation for UK

	bl	**br**	**al**	**ar**
Constant	1.088	0.978	0.082	0.003
t-stat	4.120	3.830	4.350	0.710
Deterministic Trend				
t-stat				
Lagged Dependent Variable(-1)	0.211	0.453	0.301	-0.308
t-stat	2.070	3.180	1.880	-1.810
Lagged Dependent Variable(-2)				
t-stat				
Output Gap	-15.750	13.335	-0.732	0.504
t-stat	-2.180	2.500	-2.630	1.890
R-Squared	0.535	0.484	0.387	0.250
DW	2.480	2.030	2.290	2.190
LM-test	3.265	0.332	2.250	0.583
p-value	0.057	0.721	0.126	0.565

Table14

Effect of Kalman Filtered GDP on the Subbotin parameters: OLS estimation for US

	bl	**br**	**al**	**ar**
Constant	0.944	0.499	0.052	0.049
t-stat	13.100	3.810	5.710	5.230
Deterministic Trend	0.009	0.017	0.001	0.001
t-stat	3.490	3.690	4.680	5.090
Lagged Dependent Variable(-1)	0.551	0.464	0.249	0.387
t-stat	4.320	4.040	2.390	3.430
Lagged Dependent Variable(-2)		-0.412		-0.283
t-stat		-2.840		-1.890
Output Gap	-16.224	10.292	-1.112	0.513
t-stat	-6.520	3.880	-6.280	4.990
R-Squared	0.551	0.788	0.733	0.915
DW	2.230	2.010	2.200	2.050
LM-test	2.311	1.010	0.719	0.237
p-value	0.112	0.3785	0.497	0.791

Table15

Effect of Vertical Spread on the Subbotin parameters: OLS estimation for US

	bl	**br**	**al**	**ar**
Constant	0.702	0.647	0.052	0.056
t-stat	6.280	3.250	4.640	4.230
Deterministic Trend		0.020	0.001	0.002
t-stat		3.240	4.200	4.180
Lagged Dependent Variable(-1)		0.426	-0.178	0.337
t-stat		2.980	-0.950	2.300
Lagged Dependent Variable(-2)				
t-stat				
Vertical Spread	0.489	-0.168	0.043	-0.005
t-stat	4.500	-1.350	3.420	-1.000
R-Squared	0.315	0.724	0.596	0.867
DW	2.070	1.930	1.970	1.760
LM-test	1.465	1.980	2.560	2.125
p-value	0.243	0.158	0.086	0.133

Figure 1

Moments of the empirical distribution against the rate of growth of GDP: UK

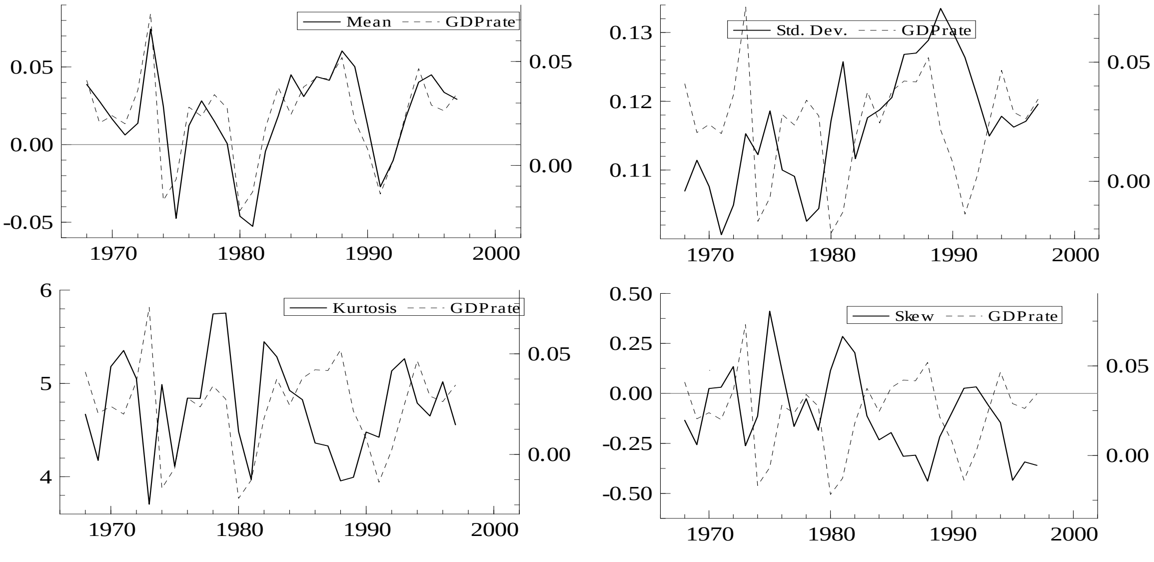


Figure 2
Moments of the empirical distribution against the rate of growth of GDP: US

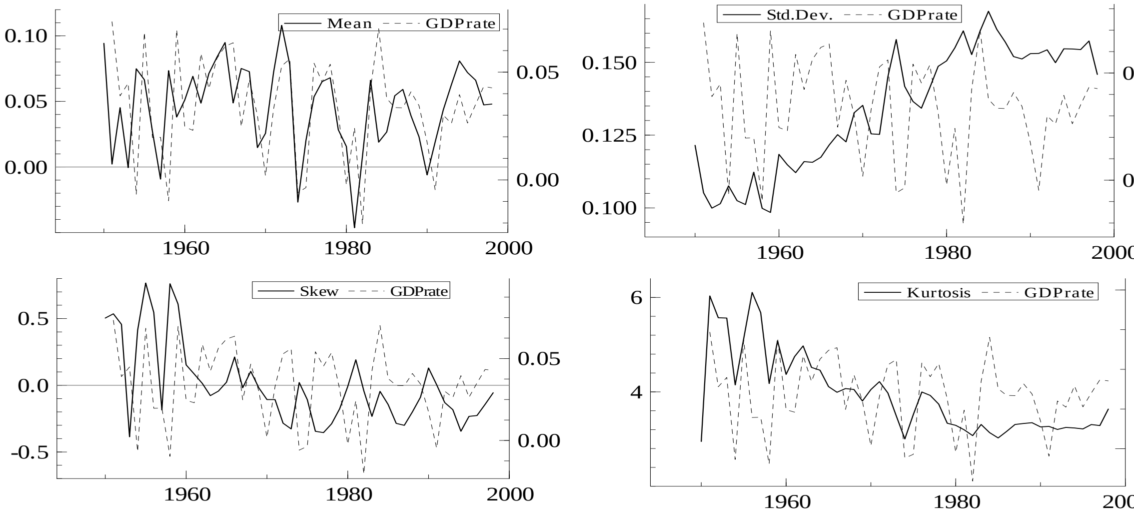


Figure 3: Estimated Subbotin parameters for UK

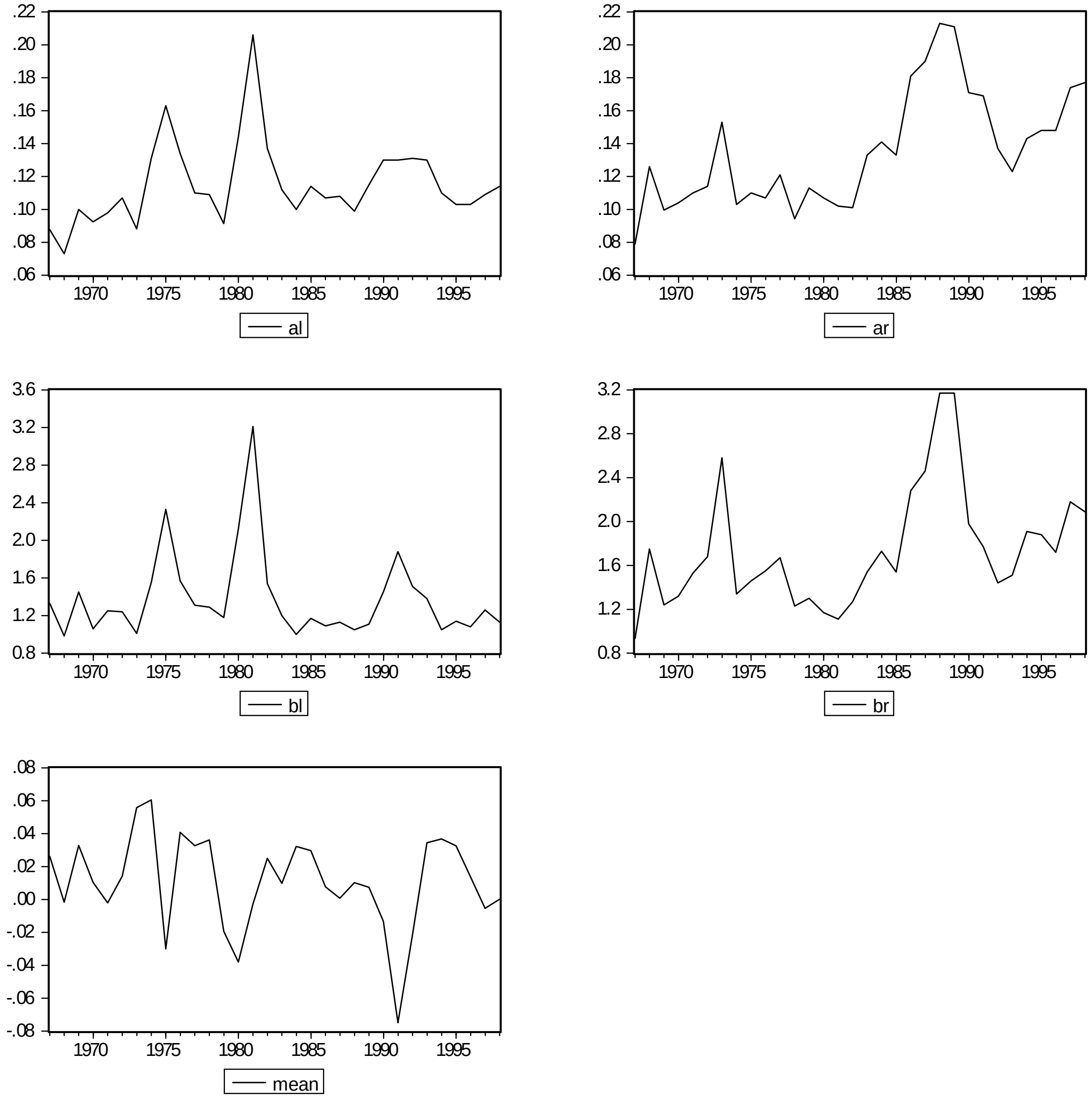


Figure4: Estimated Subbotin parameters for US

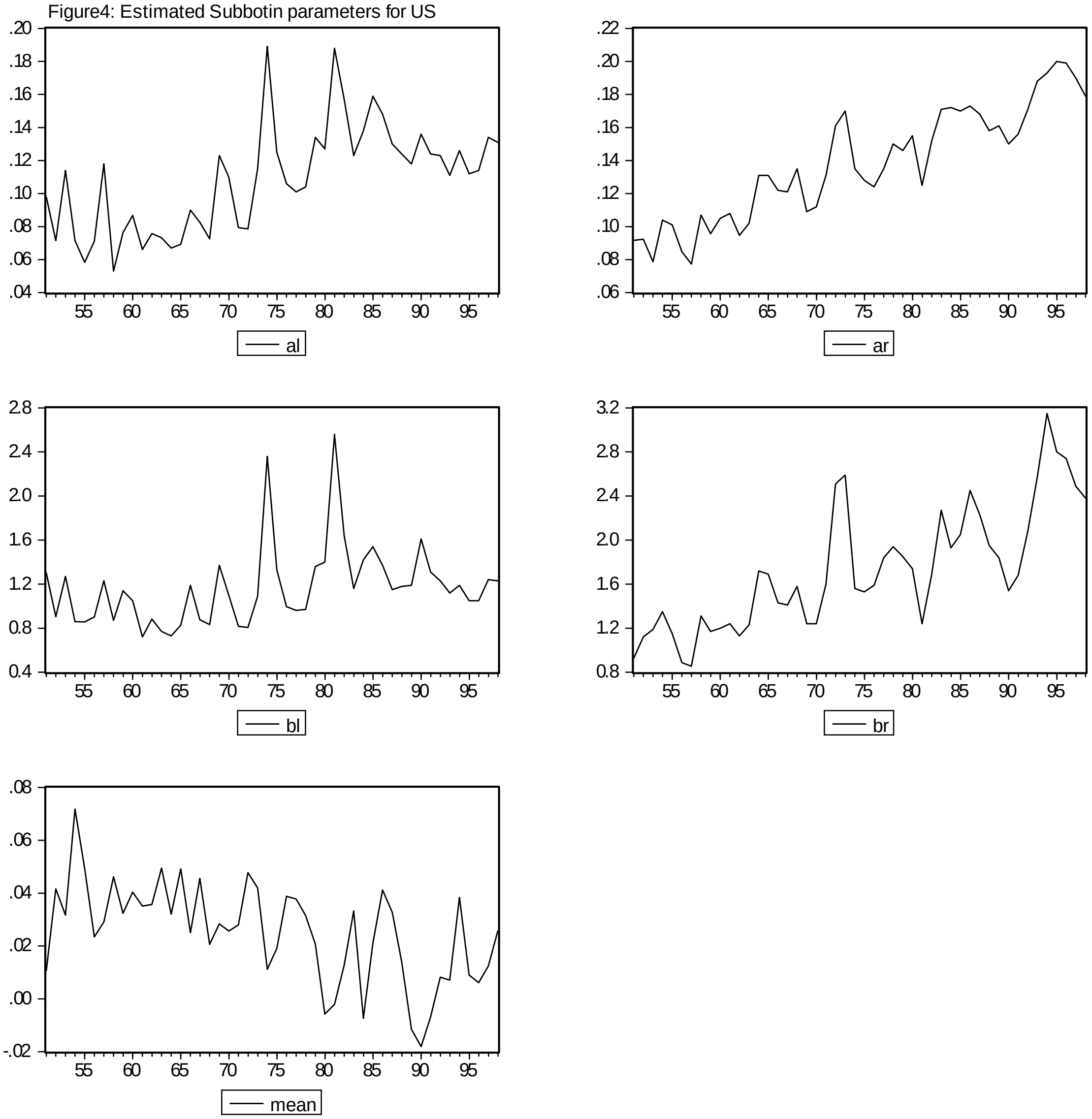


Figure 5: Scatter plot of right and left Subbotin scale and shape parameters for UK

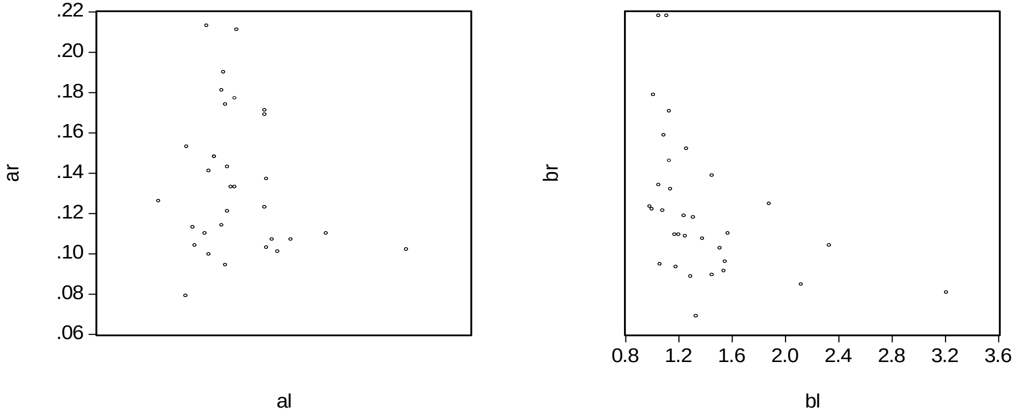


Figure 6: Scatter plot of right and left Subbotin scale and shape parameters for US

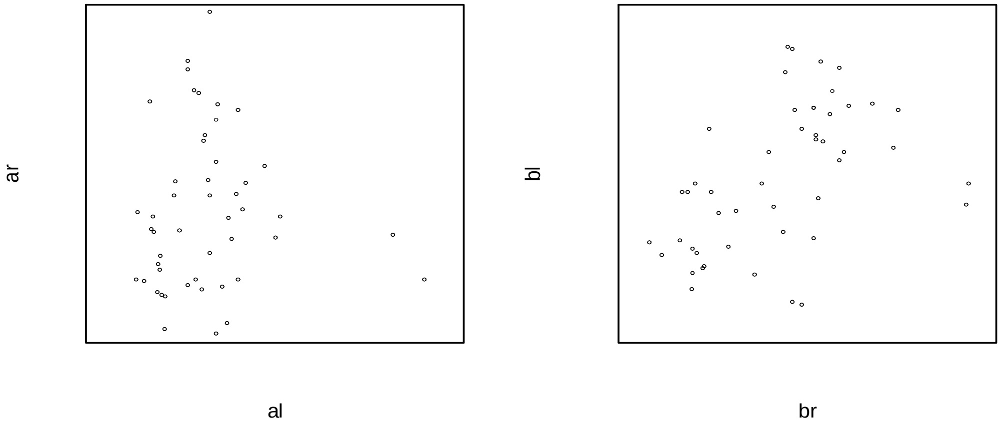
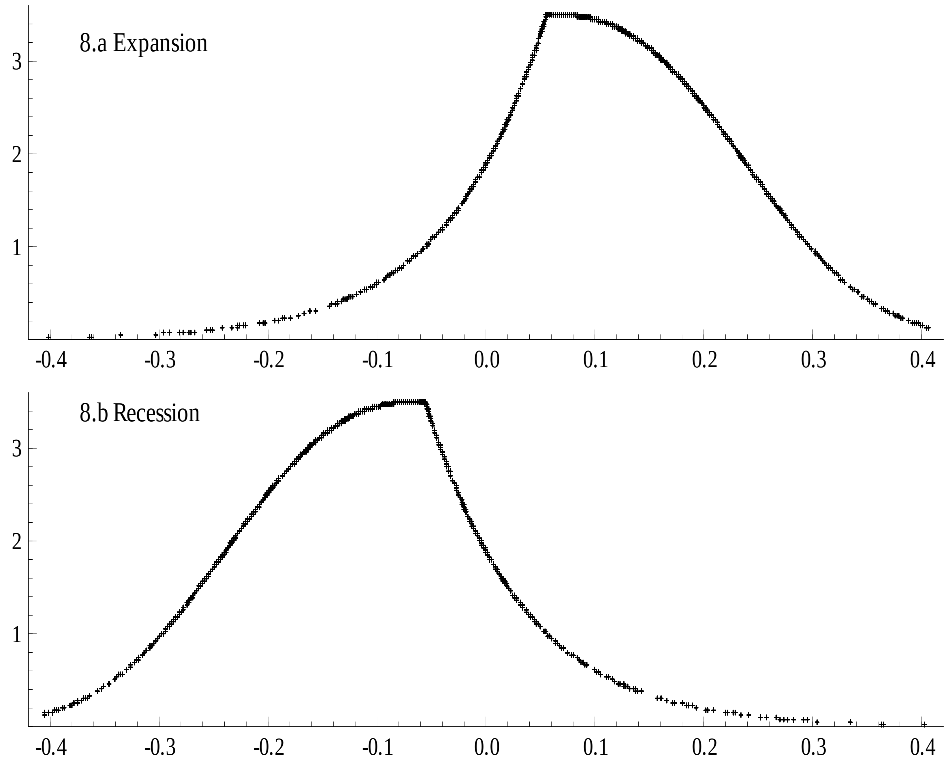


Figure 8: Benchmarks of the distribution during expansion and recession



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