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Structural breaks in the U.S. inflation process: a further investigation

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The selection procedure of Bai and Perron (*Econometrica*, 1998, **66**, 47–78), based on a sequence of tests for multiple structural changes, is used to explore the empirical evidence of the instability by selecting the number of breaks and their locations for the post-war monthly U.S. inflation rate. The obtained results indicate that the U.S. inflation process is unstable after June 1982 as there is a break at the beginning of the 1990s. This conclusion contradicts that of Ben Aïssa and Jouini (*Applied Economics Letters*, 2003, **10**, 633–6), who show that using some information criteria, the evolution curve of U.S. inflation was flattened during the last 20 years, making the process stable. Hence this points to the fact that the procedure used is more powerful than the information criteria in detecting changes.

I. INTRODUCTION

The econometrics literature holds an important volume of works related to the problem of structural change. In the context of multiple shifts, Bai and Perron (1998) estimate by least-squares multiple structural changes in a linear model, and propose some tests for the case with no trending regressors and a selection procedure based on a sequence of tests to estimate consistently the number of breaks. In the context of detecting the number of changes in the level or trend of series, Yao (1988), Yao and Au (1989), and Yin (1988) consider a meanshift model and estimate the number of changes using the Bayesian information criterion. The literature of testing for unit roots has been affected by the problem of the number of changes in the level or trend of a series. In this context, Perron (1989) has carried out standard tests of the unit root hypothesis against trend-stationary alternatives with a break in the trend occurring at the 1929 Great Crash or at the 1973 Oil-Price Shock using macroeconomic time series. In the same context, Zivot and Andrews (1992) consider a variation of Perron's tests in which the break date is unknown. Ben Aïssa and Jouini (2003) evoke the instability problem in the U.S. inflation when the change affects the level and the persistence of an autoregressive process of order 1 and estimate the number of breaks and their locations using some information criteria. They find economic explanations showing why in the selected dates there are changes in the U.S. inflation process and their results show that the evolution curve of U.S. inflation was flattened after June 1982 since it is noted that this reduction in extent of inflation is stable and durable.

In this paper we are interested in detecting the number of breaks and their locations for the post-war monthly U.S. inflation rate using the selection procedure of Bai and Perron (1998) based on a sequence of tests for multiple structural changes. We compare our results to those obtained by Ben Aïssa and Jouini (2003). The second section presents the structural change model and the estimation method. Section III defines a sequential test for multiple breaks. Section IV presents the selection procedure based on this test. Section V is the heart of the paper in which we report the results of the selection procedure. Unlike Ben Aïssa and Jouini (2003), these results indicate that the U.S. inflation process was not flattened during the last 20 years since the procedure used detects a break date at the beginning of the 1990s. The last section concludes the paper.

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II. THE MODEL AND ESTIMATORS

Consider the following pure structural change model where all the coefficients are subject to change:

$$y_t = z_t' \delta_j + u_t, \qquad t = T_{j-1} + 1, \ldots, T_j, \tag{1}$$

for $j = 1, \ldots, m+1$, $T_0 = 0$ and $T_{m+1} = T$. y_t is the observed dependent variable, $z_t \in \Re^q$ is a vector of covariates, δ_j is the corresponding vector of coefficients with $\delta_i \neq \delta_{i+1}$ $(1 \leqslant i \leqslant m)$, and u_t is the disturbance. The parameter m is the number of changes. The break dates $(T_1, \ldots, T_m)$ are explicitly treated as unknown and for $i = 1, \ldots, m$, we have $\lambda_i = T_i/T$ with $0 < \lambda_1 < \cdots < \lambda_m < 1$. Bai and Perron (1998) impose some restrictions on the possible values of the break dates. Indeed, they define the following set for some arbitrary small positive number ε:$\Lambda_\varepsilon = \{(\lambda_1, \ldots, \lambda_m); |\lambda_{i+1} - \lambda_i| \geqslant \varepsilon, \lambda_1 \geqslant \varepsilon, \lambda_m \geqslant 1 - \varepsilon\}$ to restrict each break date to be asymptotically distinct and bounded from the boundaries of the sample as there are not enough observations to identify all the subsample parameters. Let $\delta = (\delta_1', \delta_2', \ldots, \delta_{m+1}')'$.

The estimation method considered is that based on the least-squares principle proposed by Bai and Perron (1998). For each m-partiton $(T_1, \ldots, T_m)$, denoted $\{T_j\}$, the associated least-squares estimate of δ_j is obtained by minimizing the sum of squared residuals $\Sigma_{i=1}^{m+1} \Sigma_{t=T_{i-1}+1}^{T} (y_t - z_t'\delta)^2$. Let $\hat{\delta}(\{T_j\})$ denote the resulting estimate. Substituting it in the objective function and denoting the resulting sum of squared residuals as $S_T(T_1, \ldots, T_m)$, the estimated break dates $(\hat{T}_1, \ldots, \hat{T}_m)$ are such that

$$(\hat{T}_1, \ldots, \hat{T}_m) = \arg \min_{(T_1, \ldots, T_m)} S_T(T_1, \ldots, T_m), \tag{2}$$

where the minimization is taken over all partitions $(T_1, \ldots, T_m)$ such that $T_i - T_{i-1} \geqslant [\varepsilon T]$.[1] Thus the break point estimators are global minimizers of the objective function. Finally, the regression parameter estimates are the associated least-squares estimates at the estimated m-partition $\{\hat{T}_j\}$, i.e. $\hat{\delta} = \hat{\delta}(\{\hat{T}_j\})$. For our empirical illustration, we use the efficient algorithm developed in Bai and Perron (2003a) based on the principle of dynamic programming, which allows global minimizers to be obtained using a number of sums of squared residuals that is of order $O(T^2)$ for any $m \geqslant 2$.

III. THE TEST STATISTIC

Bai and Perron (1998) consider a test of the null hypothesis of l structural breaks against the alternative that an additional change exists. The test would be based on the difference between the sum of squared residuals obtained with l breaks and that obtained with $(l+1)$ breaks. The limiting distribution of this test statistic is, however, difficult to obtain and we then pursue a different strategy. For the model with l changes, the estimated break dates, denoted by $(\hat{T}_1, \ldots, \hat{T}_l)$, are obtained by a global minimization of the sum of squared residuals. The adopted strategy proceeds by testing each $(l+1)$ segment (obtained using the estimated partition $(\hat{T}_1, \ldots, \hat{T}_l)$) for the presence of an additional break. The test amounts to the application of $(l+1)$ tests of the null hypothesis of stability against the alternative hypothesis of a single break. It is applied to each segment $[\hat{T}_{i-1}+1, \hat{T}_i]$ for $i = 1, \ldots, l+1$, and with $\hat{T}_0 = 0$ and $\hat{T}_{l+1} = T$. The estimates $\hat{T}_i$ need to be obtained by a global minimization of the sum of squared residuals, all that is required is that the break fractions $\hat{\lambda}_i = \hat{T}_i/T$ converge to their true values at rate T.[2] We conclude for a rejection in favor of a model with $(l+1)$ breaks if the sum of squared residuals obtained from the estimated model with l changes is sufficiently larger than the overall minimal value of the sum of squared residuals (over all segments where an additional change is included) and the break point thus selected is the one associated with this overall minimum. More precisely, the test is defined by

$$\sup F_T(l+1|l) = \Big\{ S_T\Big(\hat{T}_1, \ldots, \hat{T}_l\Big) - \min_{1 \leqslant i \leqslant l+1} \inf_{\tau \in \Lambda_{i,\eta}} \times S_T\Big(\hat{T}_1, \ldots, \hat{T}_{i-l}, \tau, \hat{T}_i, \ldots, \hat{T}_l\Big) \Big\} / \hat{\sigma}^2, \tag{3}$$

where $\Lambda_{i,\eta} = \{\tau; \hat{T}_{i-1} + (\hat{T}_i - \hat{T}_{i-1})\eta \leqslant \tau \leqslant \hat{T}_i - (\hat{T}_i - \hat{T}_{i-1})\eta\}$, $S_T(\hat{T}_1, \ldots, \hat{T}_{i-1}, \tau, \hat{T}_i, \ldots, \hat{T}_l)$ is the sum of squared residuals resulting from the least-squares estimation from each m-partition $(T_1, \ldots, T_m)$, and $\hat{\sigma}^2$ is a consistent estimator of σ^2 under the null hypothesis.

Asymptotic critical values were provided by Bai and Perron (1998) for a trimming $\varepsilon = 0.05$ $(M = 9)$[3] for q ranging from 1 to 10, and Bai and Perron (2003b) present additional critical values for $\varepsilon = 0.10$ $(M = 8)$, 0.15 $(M = 5)$, 0.20 $(M = 3)$ and 0.25 $(M = 2)$.

[1] $[\varepsilon T]$ is interpreted as the minimal number of observations in each segment. From Bai and Perron (2003a), if the tests are not required and the estimation is the sole concern, then the minimal number of observations in each segment can be set to any value greater than q.

[2] We can also use the sequential one-at-a-time estimates which imply break fractions that converge at rate T (Bai, 1997).

[3] Note that M is the maximum possible number of breaks.

IV. THE SELECTION PROCEDURE

To select the number of breaks and their locations, Bai and Perron (1998) propose a method based on the sequential application of the sup $F_T(l+1|l)$ test using the sequential estimation of the breaks. The procedure to estimate the number of breaks is the following. Start by estimating a model with a small number of breaks that are thought to be necessary (or with no break). Then perform parameter-constancy tests for every subsample (those obtained by cutting off at the estimated breaks), adding a break to a subsample associated with a rejection using the test sup $F_T(l+1|l)$. This process is repeated by increasing l sequentially until the test fails to reject the null hypothesis of no additional structural break. The final number of breaks is thus equal to the number of rejections obtained with the parameter-constancy tests plus the number of breaks used in the initial round. There are some works in the literature which use this sequential selection procedure. Among these works we find Bai and Perron (2003a) and Jouini and Boutahar (2003).

A distinct advantage of this procedure is that, unlike the information criteria, it can directly take into account the effect of possible serial correlation in the errors and heterogenous variances across segments. Note that the existence of breaks in the variance could be exploited to increase the precision of the break date estimates (Bai and Perron, 2003a).

V. CHANGES IN THE PERSISTENCE OF U.S. INFLATION

We discuss an application of the procedure outlined above. For the purpose of comparing our results to those of Ben Aïssa and Jouini (2003), we use the same post-war monthly U.S. inflation series (seasonally adjusted) covering the period 1956:1–2002:9 (yielding 561 observations) and obtained from the St. Louis Reserve Federal Bank database. We also adopt the same modelling strategy, namely in $AR(1)$ process with drift to describe the time series and our approach is directly oriented at the issue of looking for multiple structural changes in the level and the persistence of the series, i.e. $z_t = (1, y_{t-1})'$. The trimming ε takes value 0.10,[4] the maximum permitted number of breaks is set at $M = 5$ and the sequential procedure uses a 5% significance level. To impose the minimum structure on the data, we allow for different distributions of the both the regressors and the errors in the different subsamples. The results are as follows.

Estimators	$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{T}_4$
Break dates	1967:7	1973:9	1982:6	1990:10
95% C.I.[5]	(1966:4–1968:2)	(1973:3–1975:4)	(1981:1–1983:4)	(1987:10–1993:5)

Note that the estimated break dates remain unchanged whatever the nature of the distributions of the regressors and the errors across segments and even if we use a 5% trimming. The results obtained by Ben Aïssa and Jouini (2003) using some information criteria are as follows.

Estimators	$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$
Break dates	1967:5	1973:9	1982:6
95% C.I.	(1966:3–1967:11)	(1973:3–1975:3)	(1981:7–1982:12)

We remark that the first three break dates are similar for the two approaches and are precisely estimated since the corresponding 95% confidence intervals cover a few months before and after. These break dates are associated with large magnitudes of jumps (see the graph of the series). On the other hand, the date 1990:10 has a large 95% confidence interval and is associated with small break size. Thus the estimate precision of the break dates highly depends on the size of the jump.

From the results of Ben Aïssa and Jouini (2003), we observe that the evolution curve of inflation in the U.S.A. was flattened during the last 20 years, since it is noted that this reduction in extent of inflation is stable and durable. A feature of substantial importance is that the sequential procedure chooses an additional break date located in 1990:10 making the U.S. inflation process unstable after 1982:6. A look at the graph of the series might confirm the selection of the date 1990:10 as a break since we observe that the series may be affected by structural breaks as there is an anomalous behavior at the beginning of the 1990s.

Thus our results contrast with those of Ben Aïssa and Jouini (2003). This points to the fact that the sequential procedure is more powerful than the information criteria in detecting shifts in the level and the persistence of a series even when the break is associated with small magnitude of change[6] and that these criteria are biased downward since

[4] By this value, the minimal number of observations in each segment is the same as for the information criteria used by Ben Aïssa and Jouini (2003).
[5] These confidence intervals are obtained using the asymptotic distribution of the break date estimators given in Bai and Perron (1998).
[6] Note that the date 1990:10 is associated with a very small magnitude of change since the two estimated means of the corresponding segments are, respectively, 0.185 and 0.193.

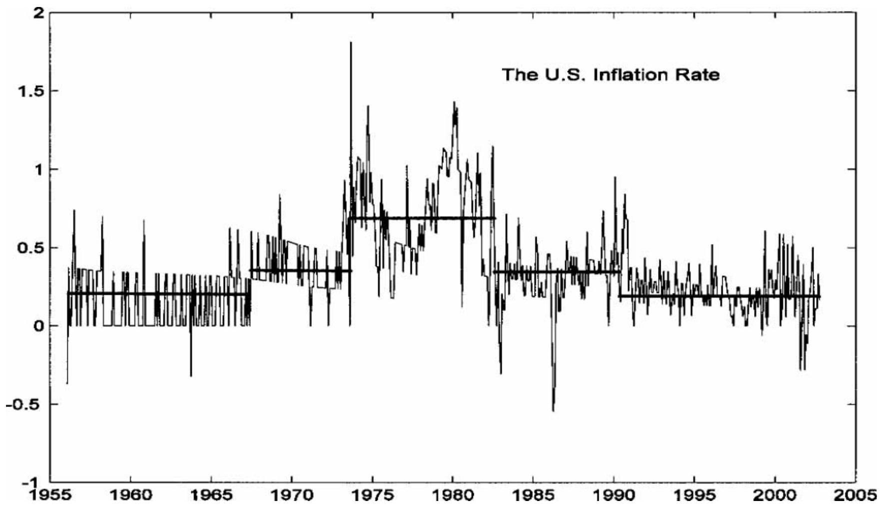

Fig. 1

they often have tendency to underestimate when the model is difficult to identify (Jouini and Boutahar, 2003).

The results of the two approaches give reason for thinking that they are very significant since the breaks coincide with important facts and economic events. Indeed, the first three dates may be linked to major events in the International Monetary System and the two Oil-Price Shocks.[7] The last date 1990:10 corresponds to a temporary noise related to the launching of the Gulf War.[8] Indeed, some temporary anxieties are caused by this war concerning the duration and the volume of defence spending. But, the Americans had very quickly done the difference between the Vietnam War and the Gulf War which is conducted by an international coalition and its financing was principally supported by the Kuwait and the Saudi Arabia.

VI. CONCLUSION

The paper has examined the question of instability of the U.S. inflation process using Bai and Perron's sequential selection procedure. The results obtained are significant since the breaks coincide with important economic events. Moreover, they indicate that the U.S. inflation process is perturbed at the beginning of the 1990s. This conclusion contrasts with that of Ben Aïssa and Jouini (2003), who show that using some information criteria, the same process is stable during the last 20 years since the evolution curve of inflation was flattened during this period.

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[7] For more economic explanations showing why in these selected dates there are changes in the inflation process, the readers are referred to Ben Aïssa and Jouini (2003).

[8] This is obvious since as we see in the graph of the series, there is a light perturbation at the beginning of the 1990s.