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**The Expectations Hypothesis of the Term  
Structure of Interest Rates:  
Evidence for Germany**

by

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**THE EXPECTATIONS HYPOTHESIS OF THE TERM STRUCTURE OF INTEREST  
RATES: EVIDENCE FOR GERMANY**

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**ABSTRACT**

In this paper we examine the expectations hypothesis of the term structure (EHT) using a newly constructed monthly database of zero coupon bond yields from the German Government bond market. We use data at the short end of the maturity spectrum (maturities less than two years) and employ two approaches to predict future movements in shorter-term interest rates: one based on the yield spread, the other based on the forward-spot rate spread. We find that for the period considered, 1983:11-1994:12, both spreads contain substantial information for predicting future interest rate movements. Moreover, the results are perfectly consistent with the implications of the EHT, as far as the value of the coefficient of the spread is concerned. This means that in Germany the spread can be used as an important indicator for the conduct of monetary policy.

*Keywords:* expectations hypothesis, forward rate, information, interest rate, term structure.  
*JEL classification:* C22, E43, G14

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## 1. INTRODUCTION

The Expectations Hypothesis of the Term Structure (EHT) and the implications for the information content have been extensively tested by using U.S. data, while only little evidence exists for other countries.<sup>1</sup> The empirical evidence for the U.S. is in general against the EHT (see Rudebush(1995) for a summary of different U.S. studies), whereas results outside the U.S. are mixed, depending on the country and the period considered. This paper presents some evidence for Germany based on data newly derived from estimated term structures. The procedure that we adopted to estimate the term structure is described in section 3, and it is based on German Government bond data provided by the Karlsruher Kapitalmarkt Datenbank (KKMDB).<sup>2</sup> Earlier studies for Germany using different data have found some support for the information content of the term structure, whereas the results are not always consistent with the EHT, in terms of the coefficient value of the spread (see, for instance, Jondeau and Ricart(1996) and Gerlach and Smets(1995) which use Euro-rates). The data used in this paper seem to give stronger results than those obtained in previous studies, and generally support the EHT.

In this paper the EHT is tested by employing two approaches: one uses the spread between the long rate and the short rate to predict future movements in shorter-term interest rates; the other uses the spread between the forward rate and the spot rate to predict changes in the spot rate. The analysis is conducted by means of standard regressions with monthly data over the period 1983(11)-1994(12). Our data suggest that both the long-short rate and the forward-spot rate spreads are very powerful predictors of future interest rate changes in accordance with the EHT. These results strongly contrast with previous evidence for the U.S. An explanation for this difference could be found in the argument put forward by Mankiw and Miron (1986), and later supported by further empirical evidence for other countries (see among others, Kugler(1988),

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<sup>1</sup> Recently empirical evidence for some European countries has been proposed. Hurn et al.(1995) and Rossi(1996) test the EHT for the UK using interbank interest rates. Engsted and Tangaard(1995) and Engsted(1996) investigate the predictive power of the Danish term structure using zero-coupon bond yields and money market rates respectively. Dahlquist and Jonsson(1995) focus on the information content of the Swedish short forward rates.

<sup>2</sup> The same data set was used in a previous study (Boero, Madjlessi and Torricelli, 1996) but in a slightly different context.

Engsted and Tanggaard(1995) and Engsted, 1996), whereby the predictive power of the spread is stronger under monetary targeting than under interest rate targeting. While interest rate targeting has been the primary target of monetary policy in the U.S., the German monetary authorities have mainly followed a policy of monetary targeting during the period considered (see Schächter and Stokman(1995) and Deutsche Bundesbank, 1995). So, our results reinforce the above argument.

The paper is organised as follows. Section 2 describes the theory and introduces the regressions used in the empirical analysis. Section 3 presents the data and the procedure adopted for the estimation of the term structure, and briefly discusses the time series properties of the variables. Section 4 reports the results from the regression equations used to test the EHT and the information content of the spread. Section 5 summarises the main findings.

## **2. THE EXPECTATIONS THEORY OF THE TERM STRUCTURE**

The EHT can be expressed in many alternative ways.<sup>3</sup> In the present paper we take two main approaches: the yield spread approach and the forward-spot spread approach.

The former is based on the EHT contention that current long-term interest rates should equal the market expectation of the average level of current and future short-term interest rates plus a constant term premium, which is null in the so called pure EHT. As a consequence, the yield spread, i.e. the spread between a long and a short interest rate, should predict future changes in the short rate. To test this implication, we follow Rudebusch(1995) in limiting ourselves to two types of evidence: evidence from spreads between one-period and two-period yields and evidence from spreads between an arbitrary h-period rate and a one-period rate.<sup>4</sup>

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<sup>3</sup> See Cox et al.(1981) for a discussion of inconsistencies among various versions of the EHT.

<sup>4</sup> Most of the above cited papers follow Campbell and Shiller(1991) in discussing a linearised version of the EHT, that allows to derive regression equations which are more general but also more cumbersome than those two presented in Rudebusch(1995). We think that this choice eases the exposition and yet allows a proper discussion of the EHT.

Let  $r(h)_t$  be the yield on h-period zero coupon bond,  $r(2h)_{t+1}$  the yield on a zero-coupon with double time to maturity and  $\pi(2h)$  a constant term premium on the latter, then the EHT asserts that:

$$r(2h)_t = 1/2[r(h)_t + E_t r(h)_{t+1}] + \pi(2h) \quad (1)$$

The assumption of Rational Expectations implies:

$$r(h)_{t+1} = E_t r(h)_{t+1} + \varepsilon_{t+1} \quad (2)$$

where  $\varepsilon_t$  is the expectational error which is orthogonal to the information available at time t.

After rearrangements, (1) and (2) provide the following regression equation:

$$1/2[r(h)_{t+h} - r(h)_t] = \alpha + \beta(r(2h)_t - r(h)_t) + u_{t+h} \quad (3)$$

where  $u_t = \varepsilon_t / 2$  and the EHT implies that  $\beta = 1$  and  $\alpha = -\pi(2h)$ .

The EHT can be also more generally stated as follows:

$$r(h)_t = 1/h \left[ r_t + \sum_{i=1}^{h-1} E_t r_{t+i} \right] + \pi(h) \quad (4)$$

where  $r(h)_t$  and  $r_{t+1}$  are the h- and one-period rates respectively and  $\pi(h)$  is a constant term premium on the longer rate.

Eq. (4) can be rewritten, after some rearrangements, in the form of the following regression equation:

$$\frac{1}{h} \sum_{i=0}^{h-1} r_{t+i} - r_t = \alpha + \beta (r(h)_t - r_t) + u_{t+h-1} \quad (5)$$

where here  $u_t \equiv \varepsilon_t$  and  $\varepsilon_{t+h-1} = \frac{1}{h} \sum_{i=0}^{h-1} r_{t+i} - \frac{1}{h} \sum_{i=0}^{h-1} E_t r_{t+i}$  is the expectational error.

As for eq. (3), the EHT implies that  $\beta = 1$  and  $\alpha = -\pi(h)$ .

The forward-spot yield spread approach is based on that version of the EHT stating that forward rates are (unbiased ) predictor of future short rates. More specifically:

$$E_t r_{t+h-1} = f_t(h-1, h) + \phi \quad (6)$$

where  $r_t$  is the one-period rate,  $f_t(n-1, n)$  denotes the one-period forward rate, i.e. the rate at trade date  $t$  for a loan from settlement date  $t+n-1$  to maturity date  $t+n$  and  $\phi$  is a constant forward term premium, which is null in the unbiased version of EHT.

It follows that the corresponding regression tests take the following form:

$$r_{t+h-1} - r_t = \alpha + b [f_t(h-1, h) - r_t] + \varepsilon_{t+h-1} \quad (7)$$

where  $\varepsilon_{t+h-1}$  is the usual expectational error orthogonal to the information available at time  $t$ .

Testing the EHT implies testing the following restrictions:  $\alpha = \phi$  and  $b=1$ .

In section 4, we empirically perform the yield spread analysis by testing the restriction on  $\beta$  in equations (3) and (5) and the forward-spot spread analysis by testing the restriction on  $b$  in equation (7). It is to be noticed that tests on  $\alpha = 0$  and  $a = 0$  correspond to testing the pure form and the unbiased form of the EHT respectively.

### 3. THE DATA AND TESTS FOR STATIONARITY

#### 3.1 The data

In order to perform the empirical tests of the EHT, we have constructed a new database<sup>5</sup> by estimating 134 monthly term structures of interest rates using a sample of German Government bond data. The data include bonds with maturities from five to ten years and span the period from 1983:11 - 1994:12. The estimation procedure follows the non-linear regression approach suggested by Chambers, Carleton and Waldman (CCW) (1984). For a fixed estimation date  $t=0$ , the yield to maturity  $r_0(t_i)$  of a zero coupon bond maturing at  $t_i$  is assumed to take the following polynomial form:

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<sup>5</sup> To our knowledge, the EHT has not been previously tested for Germany on pure discount bond yields. Other studies use either Euro-rates (Jondeau and Ricart(1996), Gerlach and Smets, 1996) or Bundesbank bond yield data (Gerlach, 1995). Yet, the Bundesbank provides the term structure of internal rate of returns of default-free bonds, which is flawed with the coupon bias.

$$r_0(t_i) = \sum_{j=1}^l a_j t_i^{j-1} \quad (8)$$

and accordingly the discount function from time  $t_i$  to time zero,  $B_0(t_i)$ , becomes an exponential polynomial:

$$B_0(t_i) = \exp\left(-\sum_{j=1}^l a_j t_i^j\right) \quad (9)$$

The following statistical model is then used to estimate the parameters of the discount function on the basis of the  $m$  observed coupon bond prices:

$$B_0(k_s, t_n) = \sum_{i=1}^{n-1} \left[ k_s \exp\left(-\sum_{j=1}^l a_j t_i^j\right) \right] + (100 + k_s) \exp\left(-\sum_{j=1}^l a_j t_n^j\right) + \varepsilon_s, \quad (10)$$

where  $k_s$  denotes the constant coupon payment of the  $s$ -th coupon bond ( $s=1, \dots, m$ ),  $t_i, (i=1, \dots, n)$  is the time at which the coupon is payable and is measured in years from the estimation date.

We have estimated the parameters  $a_j, (j=1, \dots, l)$  in (10) trying different degrees for the polynomial. In order to assess the goodness of fit of the various estimates, we have compared their Mean Absolute Deviation (MAD) which is defined as follows:

$$MAD = \frac{1}{m} \sum_{s=1}^m |\varepsilon_s| \quad (11)$$

where:  $\varepsilon_s$  is the price deviation and is defined as the difference, in DM, between the observed market price of bond  $s$  and its present value calculated on the basis of the estimated rates. An exponential polynomial of degree 8 has provided the best fit: exponential polynomials of degree less than 8 display much bigger MAD, whereas exponential polynomials of higher degrees do not imply a significant enhancement of the goodness of fit.<sup>6</sup>

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<sup>6</sup> For more details on the estimation procedure and a comparative evaluation between CCW and cubic splines methods, see Madjlessi(1996).



### 3.2 Tests for unit roots

The empirical study to be carried out in the next section, based on regressions of the type described by equations (3), (5) and (7), requires stationarity of the variables, so unit root tests have been carried out to establish the order of integration of each series. The tests used for this analysis are the Augmented Dickey-Fuller (Dickey and Fuller, 1979) (ADF) and Phillips-Perron (Phillips, 1987, and Phillips and Perron, 1988) (PP) tests. The series used in the empirical analysis are changes in interest rates for different maturities and at different horizons, spreads between longer and shorter rates, and spreads between forward and spot rates. The tests suggest that, in general, the levels of interest rates are non stationary I(1) series, while changes in interest rates and spreads are stationary. Changes in interest rates at longer horizons than those reported in this study and spreads between maturities at the longer end of the term structure are not all unambiguously stationary.<sup>7</sup> The empirical analysis below has been conducted with series for which stationarity was unambiguously detected.

## 4. TESTING THE EXPECTATIONS HYPOTHESIS

In this section we test the Expectations Hypothesis of the term structure by running the three regression equations derived in section 2. We start with regressions (3) and (5) which we report here for convenience:

$$1/2[r(h)_{t+h} - r(h)_t] = \alpha + \beta(r(2h)_t - r(h)_t) + u_{t+h} \quad (3)$$

$$\frac{1}{h} \sum_{i=0}^{h-1} r_{t+i} - r_t = \alpha + \beta(r(h)_t - r_t) + u_{t+h-1} \quad (5)$$

The first regression predicts changes in the  $h$ -period interest rate  $r(h)$   $h$ -periods ahead by using as predictor the spread between the  $2h$ -period rate and the  $h$ -period rate. For example, the spread between the 6-month rate and the 3-month rate today should predict the change in the 3-month rate 3 months ahead. For this formulation we consider forecast horizons from 1 to 9

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<sup>7</sup> Details on the numerical results of the individual tests are available upon request.

months. The second regression uses the 1-period interest rate  $r_t$  as the basic short rate and predicts its average change over the forecast horizon  $h$  with the spread between the  $h$ -period rate and the 1-period rate. For instance, the spread between the 9-month rate and the 1-month rate today should predict the average change of the 1-month rate over 9 months. For this formulation we consider forecast horizons up to 24 months.

**Table 1**

Estimated regression:  $\frac{1}{2}[r(h)_{t+h} - r(h)_t] = \alpha + \beta[r(2h)_t - r(h)_t] + u_{t+h}$

$r(h)$ = shorter term interest rate;  $r(2h)$ = longer term interest rate

$h$ =forecast horizon and short rate term

estimation period: 84.9-94.12; number of observations: 124

h months	$\frac{1}{2}[r(h)_{t+h} - r(h)_t]$ dependent var.	$r(2h)_t - r(h)_t$ spread	$\beta$	R <sup>2</sup>	Wald test $\beta=1$
1	$\frac{1}{2}[r(1)_{t+1} - r(1)_t]$	$r(2)_t - r(1)_t$	0.88***	0.15	F=0.32
3	$\frac{1}{2}[r(3)_{t+3} - r(3)_t]$	$r(6)_t - r(3)_t$	0.63***	0.19	F=6.95***
6	$\frac{1}{2}[r(6)_{t+6} - r(6)_t]$	$r(12)_t - r(6)_t$	0.98***	0.25	F=0.01
9	$\frac{1}{2}[r(9)_{t+9} - r(9)_t]$	$r(18)_t - r(9)_t$	0.93***	0.16	F=0.04

\*\*\* indicates statistical significance at the 1% level, \*\* at the 5% and \* at the 10%

In both regressions we test two hypotheses:  $H_0: \beta=0$ , i.e. there is no information content in the spread for future changes in the short rates, and  $H_0: \beta=1$ , which predicts a one-to-one relationship between the spread and future interest rate changes, as implied by the EHT. The results of this analysis are reported in Tables 1 and 2. Due to overlapping data, the equations are estimated by

OLS with corrections based on Newey-West (1987) for a moving average of order  $h-1$ , where  $h$  is the forecasting horizon (in months), and for conditional heteroscedasticity.<sup>8</sup>

<b>Table 2</b>				
Estimated regression: $\frac{1}{h} \sum_{i=0}^{h-1} r_{t+i} - r_t = \alpha + \beta(r(h)_t - r_t) + u_{t+h-1}$				
$r$ = one-month interest rate; $r(h)$ = $h$ -month interest rate				
$h-1$ =forecast horizon				
estimation period: 1985.2 1994.12; number of observations: 119				
h months	$r(h)_t - r_t$ spread	$\beta$	R <sup>2</sup>	Wald test $\beta=1$
2	$r(2)_t - r_t$	0.98***	0.17	F=0.01
3	$r(3)_t - r_t$	0.75***	0.22	F=2.44
6	$r(6)_t - r_t$	0.71***	0.35	F=6.82***
9	$r(9)_t - r_t$	0.80***	0.47	F=3.79*
12	$r(12)_t - r_t$	0.88***	0.51	F=1.44
15	$r(15)_t - r_t$	1.00***	0.53	F=0.002
24	$r(24)_t - r_t$	1.30***	0.47	F=2.63

\*\*\* indicates statistical significance at the 1% level, \*\* at the 5% and \* at the 10%

Differently from similar regressions for the U.S. (see Rudebusch (1995) for a summary), our analysis with German data shows statistically highly significant predictive power of the spread for

<sup>8</sup> Regressions with longer forecast horizons and spreads than those in tables 1 were performed (for example  $h=12$  and spread  $r(24)-r(12)$  for regression (3)), but the results are not reported here as in those cases both the dependent and the independent variables were found to be non-stationary. Also, the Newey-West correction becomes less reliable when the degree of overlap is large.

the shorter-term rates and support the EHT. The results given in Table 1 and 2 indicate that the coefficient of the spread is significantly different from zero at the 1% level in all cases. These results confirm those obtained in an earlier study for Germany (see Boero, Madjlessi and Torricelli, 1996) where the analysis was conducted with the same data, but using different regression contexts. Tables 1 and 2 also show that estimates of  $\beta$  are always close to the theoretical value of 1. The last column reports the Wald test for this hypothesis and indicates that it cannot be rejected at the 1% level in most cases. The only exceptions are the regressions with  $h=3$  and spread  $r(6)-r(3)$  in Table 1, and  $h=6$  and spread  $r(6)-r_t$  in Table 2. Moreover, for  $h=9$  and spread  $r(9)-r_t$  the hypothesis is rejected at the 10% level.

As for Table 2, the overall result is in line with other empirical findings where a U-shaped relationship between the value of  $\beta$  and the width of the maturity spread is found (see Campbell and Shiller(1991), Rudebusch(1995) and Campbell, Lo and MacKinley, 1997). Rudebusch(1995) suggests that the interest rate targeting behaviour of the Federal Reserve is responsible for such a U-shaped pattern of the predictive ability of the yield curve.

In summary, both Table 1 and Table 2 present only a case where the EHT is rejected at the 1% level, concerning respectively the 6-3 month spread (and hence predictions over the 3-month rate) and the 6-1 month spread (and hence predictions over the one-month rate in six months). What interpretation could be given to this result? An appealing explanation for the two isolated failures in Table 1 and 2 could hinge on the existence of time a varying term premium in the 6-month rate, which would partly obscure the information content of the spread implied by the EHT (see Torricelli(1995) and Boero, Madjlessi and Torricelli(1996)). This explanation is appealing in that it offers a unique rationale for both Table 1 and Table 2 failures. Yet, since our results are generally supportive of constant or even null term premia (the constant, not reported in the tables, is never significantly different from zero at the 1% level, and this reinforces the validity of the

EHT in its pure form), the existence of a time-varying term premium only for a peculiar maturity seems to be rather ad hoc.

A more plausible explanation is based on the existence of an indirect influence of German monetary policy on the 6-3 month maturity spectrum.<sup>9</sup> The fact that the monetary policy may weaken the implication of the EHT at the 3-month maturity may be attributed to the maturity range of the two instrumental rates used by the Bundesbank, i.e. the discount and the Lombard rate.<sup>10</sup> A rationale for the obscured predictive power of the 6-1 month spread, and to, a minor extent, of the 9-1 month spread, is to be found somewhere else: specifically, the open market operations of the Bundesbank, which occasionally used three-, six- and nine-month bills known as Bulis (Bundesbank-Liquiditäts-U-Schätze).

To reinforce our findings, we conduct a third analysis based on regression equation (7):

$$r_{t+h-1} - r_t = \alpha + \beta(f_t(h-1, h) - r_t) + \varepsilon_{t+h-1}$$

where  $r_{t+h-1}$  and  $r_t$  are the one-month rate at date  $t+h-1$  and  $t$  respectively, and  $f_t(h-1, h)$  is the one-month forward rate at date  $t$  for time  $h-1$ . In these regressions we use the spread between the 1-month forward rate and the 1-month spot rate to predict changes in the spot rate over  $h-1$  periods, with  $h = 3, 6, 9, 12$  and 15 months. The results are similar to those reported in Tables 1 and 2.

The slope coefficient is always significantly different from zero at the 1% level, so there is significant predictive power of the forward-spot spread (see also the  $R^2$ 's), and tests on the restriction  $\beta=1$  implied by the EHT are unable to reject the hypothesis at the 1% level in all cases. Only in two cases:  $h=3$  and spread  $f(2,3)-r_t$ , and  $h=15$  and spread  $f(14,15)-r_t$ , the hypothesis is rejected at the 5% and 10% levels respectively. Like in the previous regressions, the constant,

<sup>9</sup> This explanation has already been proposed to justify similar anomalies in other studies (Hurn et al., 1995) based on interbank rates. However, it should be stressed that in our case since we are dealing with Government bond market rates and not with interbank rates, which are naturally more related to monetary policy instrumental rates.

<sup>10</sup> The discount and the Lombard rate are used by the Bundesbank to perform its refinancing policy. The former is used to discount bills of exchange, which are payable in no more than three months and no less than seven days. The latter is the rate at which commercial banks may borrow, against certain securities, for no longer than three months. They represent a floor and a ceiling respectively for the Repo (repurchase agreement) rate, which is set by the Bundesbank via its open market interventions. See Deutsche Bundesbank(1995).

which is not tabulated, is never significantly different from zero at the 1% level, in accordance with the unbiased version of the EHT.

<b>Table 3</b>				
Estimated regression: $r_{t+h-1} - r_t = a + b [f_t(h-1, h) - r_t] + \varepsilon_{t+h-1}$				
$r$ = one-month interest rate; $f$ = one-month forward interest rate				
$h-1$ = forecast horizon				
estimation period: 1985.3-1994.12; number of observations: 118				
h months	$f_t(h-1, h) - r_t$ spread	$\beta$	$R^2$	Wald test $\beta=1$
3	$f(2,3)_t - r_t$	0.68***	0.26	F=6.21**
6	$f(5,6)_t - r_t$	0.83***	0.42	F=2.38
9	$f(8,9)_t - r_t$	0.97***	0.47	F=0.04
12	$f(11,12)_t - r_t$	1.30***	0.41	F=0.70
15	$f(14,15)_t - r_t$	1.35***	0.42	F=3.23*

\*\*\* indicates statistical significance at the 1% level, \*\* at the 5% and \* at the 10%

Overall, our results provide stronger support for the validity of the EHT than that obtained in similar studies for Germany, using different data. For example, Jondeau and Ricart(1996), using Euro-rates for three countries, France, Germany and the U.S., are able to accept the hypothesis that  $\beta=1$  only rarely for Germany, while the study by Gerlach and Smets(1995), which is also based on Euro-rates for different countries, produces more favourable results for Germany, although these are based on limited evidence (three cases only, equivalent to our regression (5) with  $h=3, 6$  and  $12$ ). Finally a note on the  $R^2$ 's. In Tables 1, 2 and 3 their values range between

0.15 and 0.53. These are much higher values than those reported in earlier studies for the U.S. and also with respect to previous results for Germany.

## 5. CONCLUSIONS

Most of the empirical literature on the EHT of the term structure is based on data for the U.S. In the present paper we have tested the EHT for the case of Germany. The new database used in this analysis, obtained from estimates of the term structure, provide very clear results which are stronger than those obtained with other available interest rate data. We employed two approaches to predict future movements in short term rate: one based on the yield spread, the other based on the forward-spot spread. The major findings are as follows: the German term structure is rather consistent with the EHT and the hypothesis that the slope of the term structure does not contain information for future changes in interest rates is rejected in all cases considered. These results contrast with earlier studies with U.S. data where the general finding is against the EHT. An interesting interpretation for this difference can be found in the argument suggested by Mankiw and Miron (1986) whereby the ability of the spread to predict future interest rate movements is enhanced in the presence of a money supply target policy and is diminished under interest rate stabilisation. As monetary targeting has been the primary target of monetary policy in Germany, while the U.S. have followed a policy of interest rates targeting, according to the conclusion in Mankiw and Miron, the data should be more supportive of the EH in Germany than in the United States. A similar result to that obtained in this paper, for countries outside the U.S., can be found, inter alia, in Kugler(1988) for Sweden, and Engsted and Tanggaard(1995) for Denmark.

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104. Giovanni Bonifati [1994] "Progresso tecnico, investimenti e capacità produttiva", pp. 30
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106. Margherita Russo [1994] "Unit of investigation for local economic development policies", pp. 25
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109. Marcello D'Amato and Barbara Pistoiesi [1995] "Modelling wage growth dynamics in Italy: 1960-1990", pp. 38
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111. Paolo Bosi [1995] "Regionalismo fiscale e autonomia tributaria: l'emersione di un modello di consenso", pp. 38
112. Massimo Baldini [1995] "Aggregation Factors and Aggregation Bias in Consumer Demand", pp. 33
113. Costanza Torricelli [1995] "The information in the term structure of interest rates. Can stocastic models help in resolving the puzzle?" pp. 25

114. Margherita Russo [1995] "Industrial complex, pôle de développement, distretto industriale. Alcune questioni sulle unità di indagine nell'analisi dello sviluppo." pp. 45
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121. Giuseppe Marotta [1995] "Il credito commerciale in Italia: una nota su alcuni aspetti strutturali e sulle implicazioni di politica monetaria" pp. 20
122. Giovanni Bonifati [1995] "Progresso tecnico, concorrenza e decisioni di investimento: una analisi delle determinanti di lungo periodo degli investimenti" pp. 25
123. Giovanni Bonifati [1995] "Cambiamento tecnico e crescita endogena: una valutazione critica delle ipotesi del modello di Romer" pp. 21
124. Barbara Pistoresi e Marcello D'Amato [1995] "La riservatezza del banchiere centrale è un bene o un male? Effetti dell'informazione incompleta sul benessere in un modello di politica monetaria." pp. 32
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128. Carlo Alberto Magni [1996] "Repeatable and a tantum real options a dynamic programming approach" pp. 23
129. Carlo Alberto Magni [1996] "Opzioni reali d'investimento e interazione competitiva: programmazione dinamica stocastica in optimal stopping" pp. 26
130. Carlo Alberto Magni [1996] "Vaghezza e logica fuzzy nella valutazione di un'opzione reale" pp. 20
131. Giuseppe Marotta [1996] "Does trade credit redistribution thwart monetary policy? Evidence from Italy" pp. 20
132. Mauro Dell'Amico e Marco Trubian [1996] "Almost-optimal solution of large weighted equicut problems" pp. 30
133. Carlo Alberto Magni [1996] "Un esempio di investimento industriale con interazione competitiva e avversione al rischio" pp. 20
134. Margherita Russo, Peter Börkey, Emilio Cubel, François Lévêque, Francisco Mas [1996] "Local sustainability and competitiveness: the case of the ceramic tile industry" pp. 66
135. Margherita Russo [1996] "Camionetto tecnico e relazioni tra imprese" pp. 190
136. David Avra Lane, Irene Poli, Michele Lalla, Alberto Roverato [1996] "Lezioni di probabilità e inferenza statistica" pp. 288
137. David Avra Lane, Irene Poli, Michele Lalla, Alberto Roverato [1996] "Lezioni di probabilità e inferenza statistica - Esercizi svolti -" pp. 302
138. Barbara Pistoresi [1996] "Is an Aggregate Error Correction Model Representative of Disaggregated Behaviours? An example" pp. 24
139. Luisa Malaguti e Costanza Torricelli [1996] "Monetary policy and the term structure of interest rates", pp. 30
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148. Maria Elena Bontempi e Roberto Golinelli [1996] "Le determinanti del leverage delle imprese: una applicazione empirica ai settori industriali dell'economia italiana" pp. 31
149. Paola Bertolini [1996] "L'agricoltura et la politique agricole italienne face aux recents scenarios", pp. 20
150. Enrico Giovannetti [1996] "Il grado di utilizzo della capacità produttiva come misura dei costi di transizione. Una rilettura di 'Nature of the Firm' di R. Coase", pp. 65
151. Enrico Giovannetti [1996] "Il I° ciclo del Diploma Universitario Economia e Amministrazione delle Imprese", pp. 25
152. Paola Bertolini, Enrico Giovannetti, Giulia Santacaterina [1996] "Il Settore del Verde Pubblico. Analisi della domanda e valutazione economica dei benefici", pp. 35
153. Giovanni Solinas [1996] "Sistemi produttivi del Centro-Nord e del Mezzogiorno. L'industria delle calzature", pp. 55
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155. Paolo Silvestri, Giuseppe Catalano, Cristina Bevilacqua [1996] "Le tasse universitarie e gli interventi per il diritto allo studio: la prima fase di applicazione di una nuova normativa" pp. 159
156. Sebastiano Brusco, Paolo Bertossi, Margherita Russo [1996] "L'industria dei rifiuti urbani in Italia", pp. 25
157. Paolo Silvestri, Giuseppe Catalano [1996] "Le risorse del sistema universitario italiano: finanziamento e governo" pp. 400
158. Carlo Alberto Magni [1996] "Un semplice modello di opzione di differimento e di vendita in ambito discreto", pp. 10
159. Tito Pietra, Paolo Siconolfi [1996] "Fully Revealing Equilibria in Sequential Economies with Asset Markets" pp. 17
160. Tito Pietra, Paolo Siconolfi [1996] "Extrinsic Uncertainty and the Informational Role of Prices" pp. 42
161. Paolo Bertella Farnetti [1996] "Il negro e il rosso. Un precedente non esplorato dell'integrazione afroamericana negli Stati Uniti" pp. 26
162. David Lane [1996] "Is what is good for each best for all? Learning from others in the information contagion model" pp. 18
163. Antonio Ribba [1996] "A note on the equivalence of long-run and short-run identifying restrictions in cointegrated systems" pp. 10
164. Antonio Ribba [1996] "Scomposizioni permanenti-transitorie in sistemi cointegrati con una applicazione a dati italiani" pp. 23
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168. Elena Bonfiglioli, Paolo Bosi, Stefano Toso [1996] "L'equità del contributo straordinario per l'Europa" pp. 20
169. Graziella Bertocchi, Michael Spagat [1996] "Il ruolo dei licei e delle scuole tecnico-professionali tra progresso tecnologico, conflitto sociale e sviluppo economico" pp. 37