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of unanticipated information
in U.S. macroeconomic releases**

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Determinants of the relative price impact of unanticipated information in U.S. macroeconomic releases *

Dieter Hess[†]

July 2003

Abstract

This paper investigates the intraday response of T-bond futures prices to surprises in headline figures of U.S. macroeconomic reports. Analyzing the time series properties and the information content of the macroeconomic news flow, the paper seeks an answer to the question, what determines the relative price impact of releases. Several types of information regarding inflation and economic strength are distinguished and the explanatory power of the type of information is tested against the alternative hypothesis that the timeliness of a release determines its impact.

Keywords: Macroeconomic releases; information processing; T-bond futures

JEL classification: E44, G14, G15

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Contents

1	Introduction	2
2	The impact of information arrival on prices	4
2.1	T-Bond futures price changes and surprises	4
2.2	The content of macroeconomic reports	8
2.3	Determinants of the relative impact of releases	11
3	Empirical results	14
3.1	Data	14
3.2	Estimation of the impact of surprises on price changes	15
3.3	Tests of hypotheses	17
4	Summary and conclusions	21

1 Introduction

Every month, a variety of macroeconomic reports, such as monthly employment figures, consumer prices, and building permits, are released providing brand new information about the state of the economy. Several studies investigate which releases have a significant impact on prices or on volatility in financial markets. However considerably less effort has been devoted to the question why some releases provoke significant market reactions while others seem to be ignored. Based on the analysis of the time series properties of the macroeconomic news flow as well as the information content of the various reports, this paper presents and tests some alternative hypotheses explaining the relative importance of macroeconomic releases. Unlike a regular time series of say temperature measurements obtained from a single meteorological station at the end of each month, several measurements of economic

conditions in a given period are taken from different perspectives. Instead of announcing all these figures simultaneously, macroeconomic reports are released one after another – some with a pronounced time lag. Therefore, the main hypotheses state that the value of information – and hence the price impact – depends on the timeliness of a report and/or the type of information it provides.

From the previous literature it is well known that information arrival has an impact on prices and volatility in financial markets (see e.g., Goodhart and O'Hara 1997 for an overview). Scheduled macroeconomic announcements stand out from the steady flow of information which hits financial markets. For example, Fleming and Remolona (1997) find that out of the 25 largest intraday price changes in the U.S. treasury market all but one occurred after such an announcement. Several studies relate announcements to the volatility patterns found in different financial markets (e.g. Ederington and Lee 1993, Crain and Lee 1995 and Franke and Hess 2000a). Focusing on the persistence of volatility, Bollerslev, Cai, and Song (2000) provide a comprehensive analysis of high- and low-frequency volatility components.¹ Another branch of the literature investigates the price impact of announcements, accounting explicitly for unanticipated information in the headline figures. While early studies focus on daily returns,² more recent studies analyze returns in narrow intraday windows around the announcements in order to separate their impact from other not explicitly observed news, which may arrive occasionally over the course of a trading

¹ Not only volatility is affected by announcements. Fleming and Remolona (1999a) and Balduzzi, Elton, and Green (2001) present evidence for the U.S. Treasury market that trading volume surges and bid-ask spreads widen after a release. Moreover, Franke and Hess (2000a) find that the correlation of intraday price changes of T-bond and Bund futures is significantly increased, Christiansen (2000) finds significantly higher conditional correlations of daily bond returns for different maturities.

² For example, Berkman (1978) and Urich and Wachtel (1981, 1984) analyze money growth announcements, Cook and Korn (1991) and Prag (1994), focus on employment reports. Hardouvelis (1988), Dwyer and Hafer (1989), and Edison (1996), among others, investigate several releases.

day (e.g. Becker, Finnerty, and Kopecky 1996 or Balduzzi, Elton, and Green 2001). As a consequence, a large number of releases are found to have a significant impact on prices in the Treasury market.³

This paper contributes to the previous literature by analyzing the underlying factors that determine the strength of the price impact across different macroeconomic announcements, in particular, the timeliness of the reports and the type of information they provide. Performing a series of tests shows that timeliness alone is not sufficient to explain differences in the impact of releases. Better results are obtained when taking into account that macroeconomic reports provide different types of information, i.e. different indicators of inflation and economic strength.

The remainder of the paper is organized as follows. The next section describes the structure of the macroeconomic release cycle and the content of major releases. Moreover, some hypotheses concerning the relative importance of reports are presented. In section 3, these hypotheses are tested on the basis of a system of equations describing the price impact of surprises in headline figures. Section 4 concludes.

2 The impact of information arrival on prices

2.1 T-Bond futures price changes and surprises

Using narrow five-minute windows around announcements, Chicago Board of Trade (CBOT) T-Bond futures price reactions to unanticipated information in U.S. macroeconomic announcements are investigated.⁴ Let ΔP_i denote the change of

³ Evidence of announcement effects in foreign exchange markets is provided, for example, by Goodhart, Hall, Henry, and Pesaran (1993), Almeida, Goodhart, and Payne (1998), Dominguez (1999) and Andersen, Bollerslev, Diebold, and Vega (2002).

⁴ T-bond futures prices are by far more sensitive to changes in long-term interest rates than to short rate movements. Due to the high duration of the underlying bonds and the short contract

the futures price in the five-minute interval immediately after an announcement at time t_i .⁵ This price change is modelled as a linear function of distinct pieces of news arriving during this five-minute period. In line with previous studies, we focus on the headline figures which summarize the information contained in the reports (e.g. the overall unemployment rate in the employment report; see table 1 for details). The outstanding impact of the headline figures is due to the fact that they are transmitted within seconds to traders on the floor as well as to other market participants via several news agencies.⁶ While most traders probably focus on just the headline numbers, it should be noted that the reports contain a wealth of other information.⁷ Occasionally, the financial press attributes subsequent price movements to these other information factors rather than the headline numbers.

[insert table 1 around here]

A major reason for the focus on headline figures in empirical research is the availability of so-called 'consensus forecasts'. Hence, unanticipated information in an announcement can be measured by the deviation of the announced headline number from the corresponding consensus forecast. To be consistent with the previous literature and to facilitate a comparison of the results, the median forecast of ana-

maturity of the investigated front month contract, bond price movements outweigh the cost-of-carry impact on futures prices by far. For details see, for example, Jarrow (1996).

⁵To be precise, this is the difference between the last trading price observed before t_i and the last price observed within the interval $(t_i, t_i + \Delta t]$, where Δt equals five minutes.

⁶ See, for example, Ederington and Lee (1993) and Fleming and Remolona (1999a) for a detailed description of the dissemination procedure and the strict lock-up rules governing these announcements.

⁷ For example, the employment report also provides information on the development of the total work force, the average hourly earnings or the average number of hours worked. Moreover, the employment figures are broken down by region, race, sex and other factors.

lysts surveyed by Standard and Poors MMS is employed here.⁸ In line with previous studies, it is assumed that the MMS consensus forecasts reflect the market's consensus forecasts and that these forecasts remain unchanged until the report's release. However, it should be noted that the MMS forecast surveys are conducted each Friday morning for the macroeconomic reports being released during the subsequent week. Hence, the markets consensus might be affected by new information arriving in between the survey and the corresponding announcement, even though the MMS forecast remains unchanged. For example, if the PPI report is released prior to the CPI report, a surprise in the PPI report might change the market's forecast of the CPI figure. Nevertheless, this problem should arise only in those cases where a single MMS survey covers both reports.

Also note that some headline figures are revised in subsequent months – typically to account either for late responses or for changes in the seasonal adjustment pattern. Like in most previous studies, these revisions are ignored here. One reason is that revisions relate to the previous months' figures, and hence, provide less important information as compared to the current months' headline figures. Another, more important reason is the lack of separate consensus forecasts for revisions. As a consequence, it is difficult to assess whether and to what extent revisions are anticipated. This is also probably the reason why previous studies have either ignored

⁸ Most previous studies use consensus data from MMS, who were the first to conduct such surveys (as an exception, Moersch 2001 uses Reuters data). The main reason is that MMS provides consensus estimates for a wide range of economic indicators with a substantial history. Nevertheless, it should be noted that there are some limitations. Since the survey is institutional rather than individual, the MMS data do not identify the survey participants. While MMS covers slightly more analysts than other economic surveys, the number of survey participants for a given economic report may vary over time and across different reports. In general, the number of respondents is related to the perceived importance of a report. Consequently, outliers can affect the consensus forecast, especially for the minor reports where fewer economists participate.

revisions or could not find a significant price impact.⁹

Let F_j denote the market's forecast for headline j , represented by the corresponding MMS consensus forecast, and let A_j denote the announced value. $D_{j,i}$ is a dummy variable equal to one if A_j becomes available during the time interval $(t_i, t_i + \Delta t]$, and zero otherwise. The T-bond futures price change may then be written as a function of surprises in headline figures, i.e. $A_j - F_j$,

$$\Delta P_i = \sum_j \alpha_j (A_j - F_j) D_{j,i} + \varepsilon_i . \quad (1)$$

Any other information arriving between t_i and $t_i + \Delta t$ which might surprise market participants and other effects on prices are reflected by the error term ε_i in (1). Since price reactions in very narrow time windows around announcements are investigated, the probability that other information besides the observed releases arrives and affects prices significantly should be fairly small. Note that eq. (1) is analyzed for the three major release times of scheduled macroeconomic announcements, i.e. 8:30, 9:15 and 10:00 a.m. ET (Eastern Time).

According to the well known efficient market hypothesis one would expect that the impact of a surprise is incorporated rapidly in prices, especially since the price response of one of most actively traded futures contracts to widely anticipated headline figures is analyzed here.¹⁰ Hence, it would be rather astonishing to find that a surprise in an 8:30 headline still has an impact on five-minute price changes around 9:15. Since the remainder of this paper analyzes the value of information contained

⁹ As an exception, Krueger (1996) accounts for revisions of the previously released nonfarm payroll figures. However, he finds no significant reaction to these revisions although surprises in the corresponding headline figure have a quite strong return impact.

¹⁰ Information processing in the open outcry system of the CBOT should be very efficient. For a discussion of information diffusion in electronic and floor trading systems see, for example, Franke and Hess (2000b).

in releases, it is rather essential to look at a market that processes information efficiently. Therefore, the following hypothesis is tested as a prerequisite:

H1: Immediate response

If markets process information efficiently, price changes should not be affected systematically by previous announcements (i.e. reports being released 45 or 90 minutes earlier during the day).

Since unanticipated information is measured by the deviation of announcements from analysts' forecasts, another prerequisite for the analysis of the impact of unanticipated information is that market participants are actually surprised by these deviations, i.e. that they are not predictable. Several previous studies provide tests on the performance of analysts' forecasts (see, for example, Pearce and Roley 1985 or Becker, Finnerty, and Kopecky 1996). They suggest that these forecasts are not always efficient, especially if short test periods are used. But at least, most of the time they outperform commonly used time series models (Hardouvelis 1988, Morsch 2001). Hess (2001) largely confirms these results for the sample used in this paper. On the 1% level, the efficiency of analysts' forecasts can be rejected for only 1 out of the 24 headline figures, i.e. for GDP_1 . Splitting the sample period into halves, no consistent pattern of predictability remains.

2.2 The content of macroeconomic reports

This study investigates various U.S. macroeconomic reports which are released on a monthly or quarterly schedule within the floor trading hours of CBOT T-bond futures (see table 1).¹¹ In the remainder of this section, the headline figures of these

¹¹ For a description of individual releases and headline figures see, for example, Rogers (1998).

reports are classified according to the type of information they provide. Basically, unexpected macroeconomic news may lead agents to revise their expectations of nominal interest rates, due to either higher future inflation rates or higher real rates. Previous studies have tried to identify whether an announcement provides information that might alter market participants expectations of real rates or inflation rates.¹² Following Edison (1996), headline figures are categorized into two broad content groups: figures that indicate higher or lower levels of real activity (C1) and others that provide inflation measures (C2).¹³ Identifying relatively homogeneous sets of information constitutes the basis for testing whether the information content helps to explain the relative impact of releases.

Higher levels of real economic activity may be associated with higher real interest rates. If increasing economic activity is coupled with increasing investments, and thus with a higher demand for capital, interest rates should rise given a finite elasticity of capital supply. Information about higher economic activity might also alter agents' expectations of future inflation rates, since inflation could be spurred by an overheating economy. Thus, an unexpected increase in real activity could drive interest rates up through higher real rates and/or higher inflation expectations. Headline figures about economic activity are classified as C1. Since they are rather heterogeneous, three subcategories, i.e. (a) to (c), are distinguished.

C1: Economic activity (and subcategories)

¹² Other studies, for example Dwyer and Hafer (1989), also investigate monetary phenomena. Since money supply figures are released after floor trading hours, i.e. at 4:30 p.m. ET, they are not included here.

¹³ In contrast to studies like Hardouvelis (1988) or Dornau and Schröder (2002), the purpose of this classification is neither to find out which macroeconomic model market participants might have in mind nor to assess the empirical relevance of different models. The sole purpose is to identify reports with a similar information content.

- (a) Overall production level: $ISM_1, IP_1, DGO_1, GDP_1, LI_1, FI_2$.
- (b) Demand for consumption goods: CC_1, RS_1, PI_2 .
- (c) Demand in housing sector: HS_1, NHS_1, CS_1 .

The first subcategory in C1 includes headline figures that provide evidence about the overall production level: The industrial production figure (IP_1 , see table 1), the level of the gross domestic product (GDP_1), the index of the Institute of Supply Management (ISM , formerly $NAPM$), the index of leading indicators (LI), durable goods orders (DGO), and factory orders (FI_2). The second subcategory of figures provides specific information about consumer demand, e.g. the retail sales figure (RS) and personal consumption expenditures (PI_2). In addition, consumer confidence (CC) may permit some conclusions about the future spending behavior of consumers. The third group of related figures covers the demand in the housing sector, i.e. the number of housing starts (HS), new home sales (NHS), and construction spending (CS).

C2: Inflation expectations (and subcategories)

- (a) Measures of past price changes: PPI_2, CPI_2, GDP_2 .
- (b) Early inflation indicators: $E_2, IP_2, ECI_1, FI_1, PC_1, BI_1$.

Classification C2 includes measures of inflation. Two subcategories are distinguished in order to obtain homogeneous information sets. The first subcategory in C2 contains figures measuring past price changes at the very end of the production process, i.e. inflation in finished or almost finished goods. Among them are the monthly

consumer and producer price indices (PPI_2, CPI_2)¹⁴ as well as the price deflator contained in the quarterly GDP report (GDP_2). The second subcategory contains indications of price pressures at earlier stages of the production process and shortages of production factors. While several reports include such information on price pressures, e.g. raw material prices included in the producer price report, only for two headline figures are analysts' forecasts available. These are labor costs (ECI) and productivity (PC). Both, higher than expected wages and lower productivity, might suggest that inflation pressures are building up, especially if wages rise faster than productivity. Shortages of production factors which might translate into price pressures of input factors are indicated, for example, by a stretched capacity utilization (IP_2) or by low inventories (BI_1, FI_1). Furthermore, if a tight labor market gives employees more bargaining power, a lower than expected unemployment rate (E_2) may foreshadow higher wages and, thus, inflation pressures.

2.3 Determinants of the relative impact of releases

This section derives some hypotheses in order to investigate the determinants of the relative impact of releases. The first hypothesis (H2) follows immediately from the very special time series properties of surprises in macroeconomic releases. Compare these reports, for example, to a regular time series of temperature measurements obtained at the end of each month. Instead of drawing one observation for each period, assume that several meteorological stations measure temperature at the same time, but for some technical reason, these figures are not released at the same time. A similar structure is found for macroeconomic reports. There are several

¹⁴ Previous studies use the overall consumer and producer prices indices. Instead, here the less volatile core inflation numbers are employed which exclude food and energy.

macroeconomic reports referring to the same period and measuring similar aspects of economic strength and inflation. However, these figures are not released at the same time but with differing time lags to the reporting period (see figure 1). Therefore, it seems reasonable to assume that the value of the information provided by a report depends on the time lag to the reporting period (hypothesis H2).

H2: Timeliness

The price impact of unanticipated information in a release depends on the time between the announcement of the report and the end of the reference period.

[insert figure 1 around here]

H2 restates an observation previously made by Fleming and Remolona (1997). They find that the four most recent available government reports have the highest impact on five year T-note prices. From this they conclude that the time between the end of the period covered by a report and the announcement helps to explain the impact of a release. However, it may be questioned whether the timeliness of a report is best measured by the number of days determining the time lag. Instead, a report may become 'outdated' due to the fact that other reports which provide similar information are released in advance. This is stated by hypothesis H3:

H3: Sequence

The price impact of unanticipated information in a release decreases with the number of previously released reports for a given reference period.

Note that H2 and H3 are rather similar since both imply a monotonically declining impact of subsequently released reports. However, if one does not find such a strict relation, H2 will provide another testable implication: Reports with a time lag of more than a month should have almost no impact since reports for the following calendar month are already available.

Both, H2 and H3 ignore any differences in the type of information. However, it seems more reasonable to assume that traders differentiate between various aspects of economic strength and inflation in order to assess the equilibrium long-term interest rate. In this case, a formulation of H3 that builds on the content analysis of the previous section (see C1 and C2) seems more appropriate. Therefore, H4 explicitly differentiates between the type of information, hypothesizing that the additional information provided by a report for a given month diminishes with the number of already released reports with a similar content. For example, this would imply that a figure like housing starts HS could have quite a significant impact since it is the first figure shedding light on the demand in the housing sector. In contrast, according to H3 (and H2) the impact of HS should be rather moderate since several other figures - although highlighting different aspects - would be already available.

H4: Sequence within content classes

The price impact of unanticipated information in a release depends on the number of previously released reports with a similar content.

A strong argument in favor of this hypothesis comes from the fact that certain figures repeat to some extent information contained in previously released reports. A rather outdated figure in this sense is the factory orders number (FI_2) since an

earlier estimate can be derived from both, the report on durable good orders which account for over 50% of total factory orders, and the new orders component in the ISM report. Even worse, the ISM report for the subsequent month is already available when FI comes out.

3 Empirical results

3.1 Data

The announcement data set covers 24 headline figures (contained in 19 different U.S. macroeconomic reports) over a six-year period (i.e. Jan. 1994 to Dec. 1999). It includes monthly as well as quarterly reports scheduled during the floor trading hours of T-Bond futures at the Chicago Board of Trade. These are reports which are released at either 8:30, 9:15 or 10:00 a.m. ET. Eliminating two inadvertently early released reports¹⁵ as well as the announcements scheduled around the temporary shutdown of federal agencies in early 1996¹⁶, the sample contains 69 observations for each of the 16 monthly reports and 23 observations for the 3 quarterly reports. Out of the 1497 trading days, on 769 days at least one report is released.

Consensus forecasts for the headline figures in these reports are provided by Standard and Poors MMS. Surprises are obtained by subtracting consensus forecasts from the actual outcomes. For each headline figure standardized surprises are computed dividing surprises by the sample standard deviation of outcomes (i.e. $S_i/Std(A_i)$). Intraday CBOT T-Bond futures data are obtained from the Futures Industry Insti-

¹⁵ These are the Nov. 1998 employment report and the Jan. 1999 PPI report. See Fleming and Remolona (1999b) for details.

¹⁶ Since the whole forecasting process might have been affected by this disruption of macroeconomic reporting, all observations from December 1995 through February 1996 are excluded.

tute. Focusing on the front month contract, i.e. the most actively traded contract, price changes over five minute intervals around 8:30, 9:15, and 10:00 releases are analyzed.

3.2 Estimation of the impact of surprises on price changes

In order to test hypotheses H1 through H4, a system of three equations is estimated, one for each release time:

$$\begin{aligned}\Delta P_{8:30} &= \kappa_1 + \sum_{i=1}^{15} \alpha_i S_i^{(8:30)} + \varepsilon_1 \\ \Delta P_{9:15} &= \kappa_2 + \sum_{i=1}^{15} \beta_i S_i^{(8:30)} + \sum_{i=16}^{17} \alpha_i S_i^{(9:15)} + \varepsilon_2 \\ \Delta P_{10:00} &= \kappa_3 + \sum_{i=1}^{15} \gamma_i S_i^{(8:30)} + \sum_{i=16}^{17} \beta_i S_i^{(9:15)} + \sum_{i=18}^{24} \alpha_i S_i^{(10:00)} + \varepsilon_3\end{aligned}$$

where, $\Delta P_{8:30}$, $\Delta P_{9:15}$, and $\Delta P_{10:00}$ denote five-minute price changes around 8:30, 9:15, and 10:00 releases, respectively. $S_{(.)}^{(time)}$ denotes standardized surprises occurring at a given release time. For example, $S_1^{(8:30)}$ refers to headline figure E_1 , i.e. nonfarm payrolls contained in the employment report which is released at 8:30 a.m. ET. These variables are zero if no such report is announced during a given five-minute interval. Note that price responses to signed surprises are analyzed according to the hypothesized T-bond future reactions which are detailed in table 1.¹⁷

[insert table 2 around here]

¹⁷ For example, since it is hypothesized that T-bond futures prices should fall if the announced nonfarm payroll figure (A_{E_1}) is higher than its forecast (F_{E_1}) a surprise in E_1 is calculated as $-(A_{E_1} - F_{E_1})$. Hence, a positive $S_{(.)}$ should be "good news" for futures prices.

Price changes are regressed on surprises occurring within the corresponding time interval,¹⁸ and in addition, on surprises occurring earlier in a given day.¹⁹ The α_i coefficients capture the immediate price impact of a release, i.e. the price change occurring in the five minute interval around the announcement. The β_i s (γ_i s) capture the impact of headlines being released 45 (90) minutes earlier in a given day. The system of the three equations is estimated by a seemingly unrelated regression (SUR). Generalized least squares estimates are used in order to account for heteroskedasticity across trading days and contemporaneous correlation in the errors across equations. The employed estimation technique yields results that are asymptotically efficient.²⁰ Parameter estimates are provided in table 2. Since signed surprises are used, only positive α_i s are in line with the hypothesized immediate price response. Interestingly, with only one exception the signs of the significant α_i s are indeed positive. This exception is PC_1 . However, the impact of a surprise in PC_1 is quite small. Note that the right hand variables in table 2 are sorted according to the median report time lag (see figure 1). Thus, the ordering reflects the release

¹⁸ This regression approach accounts for the fact that several headline figures may be released simultaneously, which may provide unanticipated and even conflicting information. For example, the most significant macroeconomic report in recent years - the monthly employment report - contains two headline numbers (the unemployment rate and the number of newly created jobs) derived from two separate surveys. Sometimes the forecast errors of these two headline figures conflict with each other.

¹⁹ The announcement time for two reports (i.e. *LI* and *BI*) changes from 8:30 to 10:00 within our sample. Thus, the immediate impact of these releases has been captured in two equations. If these figures are released at 8:30, an α_i coefficient is included in the 8:30 equation, otherwise in the 10:00 equation. However, the corresponding coefficients are restricted to take on the same values in both equations.

²⁰ Efficiency gains are primarily to be expected from the fact that restrictions are imposed across equations. Otherwise, if the error terms in the above given equations are uncorrelated, a separate least squares estimation of the equations yields efficient parameter estimates, assuming well behaved data (see e.g., Dwivedi and Srivastava 1978). The correlation of single equations residuals estimated with ordinary least squares is indeed small but significantly different from zero at the 10% level. Hence, it cannot be taken for granted that the equations are actually unrelated. This is confirmed on the 10% level by a test on the diagonality of the variance-covariance matrix of the first-stage residuals (see e.g., Baltagi 1999, Ch. 10).

sequence of the reports.

3.3 Tests of hypotheses

A prerequisite for an analysis of the value of information is to test whether the T-bond futures market processes information efficiently. As a minimum requirement previous releases should have no systematic impact on current prices. Thus, the β_i 's and γ_i 's should be zero (hypothesis H1). In fact, on the basis of a Wald test the hypothesis $\hat{\beta}_i, \hat{\gamma}_i = 0$ cannot be rejected (see table 3, line 3).²¹ In contrast, from the rejection of the hypothesis $\hat{\alpha}_i = 0, \forall i = 1, \dots, 24$ (table 3, line 2) it can be concluded that unanticipated information leads to a significant price reaction immediately after its release.

A much more critical question for the analysis pursued here is whether this impact differs across releases. Whether the immediate impact of surprises is different across releases can be tested on the basis of the restriction $\hat{\alpha}_i = \theta^*$, i.e. whether the individual first-stage parameters α_i can be replaced by a common second-stage parameter θ^* . Taking into account the variance-covariance matrix of parameters estimated in the first stage, an asymptotically consistent and efficient estimate of θ^* can be obtained by means of asymptotic least squares (see e.g., Gouriéroux and Monfort 1995, Ch. 9). Results of this estimation are given in the right hand panel of table 3 (line 2). Being unable to reject the restriction $\hat{\alpha}_i = \theta^*$ would imply that all the releases have virtually the same immediate price impact, and thus would provide strong evidence against any of the three hypotheses (H2 to H4). However, this is not the case. The restriction $\hat{\alpha}_i = \theta^*$ is strongly rejected by the highly significant χ^2 statistics.

²¹ The same result is obtained testing whether the β_i 's are zero and separately whether the γ_i 's are zero (Hess 2000).

In contrast, the restrictions for the lagged price impact hold ($\hat{\beta}_i, \hat{\gamma}_i = \theta^*$) and the estimated common parameter ($\hat{\theta}^*$) is not significantly different from zero (line 3).

[insert table 3 around here]

Hypotheses H2 to H4, all imply a monotonically decreasing impact of releases. H2 relates the impact to the time lag of a release, H3 to the number of previously released reports. H4 conditions on the sequence within content categories. In order to obtain a formal test of these hypotheses, again an asymptotic least squares estimation is performed imposing certain constraints on the parameters estimated in the first stage. For example, a strict form of H2 (timeliness) postulates that the impact of releases declines linearly with their time lag of a release τ_i . This results in the restrictions $\alpha_i = \theta_0^* + \theta_1^* \tau_i, \forall i = 1, \dots, 24$. Given that these restrictions hold, one can test whether $\hat{\theta}_1^*$ is significantly negative, as it is suggested by H2. Results of this estimation are given in table 4, line (1). Line (2) shows results for H3 (sequence) stating that the impact of surprises decreases with the number of previously released reports for the same reporting period, n_i , i.e. $\alpha_i = \theta_0^* + \theta_1^* n_i$. Line (3) to (7) provide results for H4 (sequence within content categories), i.e. $\alpha_i = \theta_0^* + \theta_1^* c_{i,j}$, where $c_{i,j}$ represents the number of previously released figures falling into the same category j as headline i .

[insert table 4 around here]

Judging from the estimated slope coefficients $\hat{\theta}_1^*$ in table 4, the impact of these releases seems to be decreasing. These coefficients are all negative and all but one highly significant. This would support all three hypotheses if not several of the sets of

restrictions were rejected by the corresponding χ^2 statistics. Especially, hypotheses H2 and H3 are strongly rejected. This suggests that although the impact of successive releases may be decreasing with n_i as well as t_i , assuming that the impact decreases linearly is too restrictive. In contrast, the results for H4 are slightly more favorable. At least the restriction of a linearly decaying impact within content categories cannot be rejected for two of the five categories (i.e. C1b and C2a). But again, for the remaining three categories this restriction is too strong.

In order to obtain more evidence, some less rigorous implications of the hypotheses are tested in the remainder of this section. For example, hypothesis H2 implies that releases with a time lag larger than one month should have no impact since information for the subsequent report period is already available. Interestingly, all but one of the reports being released within the first month after the end of the reporting period (i.e. *CC* to *NHS*, see figure 1) are significant, most of them at the 1% level (see table 2). In contrast, out of the remaining seven headline figures which are released in the second month (i.e. *LI* to *TRD*) only two are significant. Nevertheless, on the basis of a Wald test the hypothesis that their impact as a group is zero has to be rejected. So, according to this test H2 has to be rejected again. Note that the implications for hypothesis H3 are quite similar.

Turning to hypothesis H4, instead of imposing linear restrictions on the coefficients one may perform a series of pairwise t-tests on the difference of coefficients within a content category. If the impact of reports decreases strictly within a content group, for each pair of successive reports the difference between consecutive coefficients should be significantly positive. It is not surprising that this very strong result is obtainable for only one of the five content categories, since the restriction of a

linear decay in the coefficients was already rejected for three of them. Nevertheless, strong evidence of a decreasing price impact can be found investigating a somewhat less strict formulation of H4: The first or second release within a content category should have a higher price impact than all the subsequent releases. Table 5 displays the results of pairwise comparisons of the first and the second headline figure in a given content category with the subsequently released headlines falling into the same category.²²

[insert table 5 around here]

As can be seen from table 5, in none of the categories is the first release's impact outweighed by subsequent releases. At worst, its impact is insignificantly lower than that of the second release (category C1c 'Housing sector'). For three of the five categories, the first release has a significantly higher impact than all others. In a fourth category (again, C1c), there is no significant difference between the first and second release, but both dominate the third. There remains only one category in which subsequent releases do not have a significantly lower impact (C2a 'past price changes'). However, even this category does not provide evidence against hypothesis H4 since the impact of subsequent releases is decreasing, too, although not significantly. Hence, the sequences of pairwise t-tests given in table 5 support hypothesis H4.

Overall, hypothesis H4 cannot be rejected if one does not demand that the impact of subsequent releases declines strictly linearly. A similar result cannot be obtained for

²² Tests for hypotheses H2 and H3 are omitted since the first two releases, i.e. *ISM* and *CC* have a significantly lower impact than the following ones. Thus, H2 and H3 are easily rejected again by this test.

Hypothesis H2 are H3 since both, the first and second release have a considerably lower impact than several subsequent releases. Thus, the type of information plays a substantial role in explaining the relative impact of unanticipated information in macroeconomic releases on T-bond futures price changes.

4 Summary and conclusions

T-bond futures prices like bond prices are driven mainly by market participants' expectations of real interest rates and future inflation rates. Therefore, the set of headline figures in scheduled macroeconomic releases is divided into two broad content categories, news related to inflation expectations and news related to economic activity. Among them five subcategories are distinguished. Interestingly, all but one of the significant coefficients capturing the immediate futures price response to surprises show the correct sign, i.e. the introduced information classification may well explain the direction of futures price changes.

Investigating the sequence of releases without differentiating for content, at best some weak evidence can be obtained that the mere sequence or the timeliness of the reports matters (hypotheses H3 and H2). On the one hand, the rather strict implication of a monotonically linearly decaying impact has to be rejected. But on the other hand, the response to releases coming out in the first month after the end of the reporting period is stronger than the impact of releases announced in the second month. Nevertheless, the releases in the second month are still significant as a group although this information should be rather outdated since several reports for the subsequent month are already available.

Test results are much more favorable if headline figures are differentiated by the type

of information. The rather strong hypothesis of a strictly linearly decreasing impact within content categories cannot be rejected for two of the five categories. More importantly, a pairwise comparison of the impact of surprises reveals that the first and/or second release within a given content category has the strongest price impact. This leads to the conclusion that both the timeliness and the type of information are important determinants of the relative impact of releases (hypothesis H4). On the one hand, this result suggests that market participants consider different aspects of inflation and economic growth to be relevant in order to assess the equilibrium long-term interest rate. On the other hand, it implies that the information value of an additional release for a given reporting period decreases with the number of already available figures providing a similar content. For example, market participants seem to learn enough from the first two housing figures about the strength of demand in that sector, and thus the subsequently released figure has almost no price impact.

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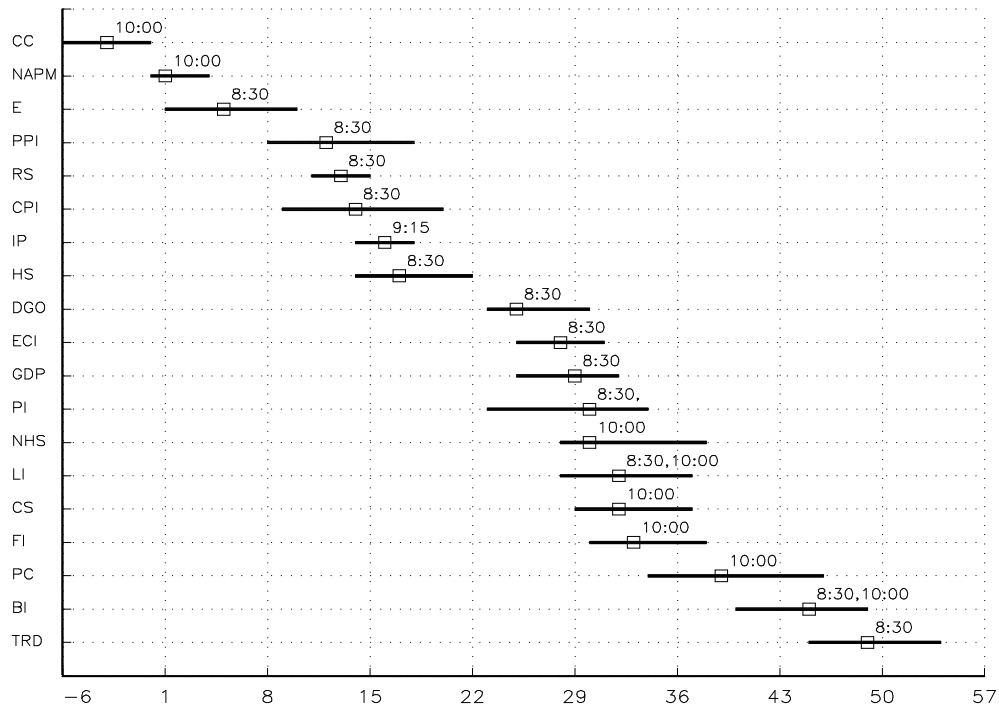
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Figure 1: Timeliness of reports



For each report the number of calendar days between the announcement and the end of the reference month is displayed (see table 1 for abbreviations). For monthly (quarterly) releases this is the end of the calendar month (quarter). The median time lag is indicated by a square. A solid line reveals the range between the minimum and maximum number of days. Announcement times are also provided. While most of the reports are released always at the same time, either 8:30, 9:15, or 10:00 a.m. ET, the time schedule of *LI* and *BI* changes within the sample period, i.e. January 1994 to December 1999. Note that Releases during the government shutdown period in early 1996 are excluded. The release cycle is opened by the report on consumer confidence which is released usually during the last week of the reference month. It is followed by the ISM report which usually appears at the first business day of the succeeding month.

Table 1: Headline figures in macroeconomic reports and hypothesized reactions to unanticipated information.

Abbr.	Headline figure	Reporting agency ^a	Higher outcomes signal higher interest rates due to			Hypothesized price response of T-Bond futures
			already higher prices	higher consumer demand	supply bottlenecks	
<i>CC</i> ₁	Consumer confidence index	CB		+		—
<i>ISM</i> ₁	Overall ISM index	ISM	+	+	+	—
<i>E</i> ₁	Nonfarm payrolls	BLS			+	—
<i>E</i> ₂	Unemployment rate				—	+
<i>PPI</i> ₂	PPI ex. food and energy	BLS	+			—
<i>RS</i> ₁	Retail sales	CENS		+		—
<i>CPI</i> ₂	CPI ex. food and energy	BLS	+			—
<i>IP</i> ₁	Industrial production	FED		+		—
<i>IP</i> ₂	Capacity utilization				+	—
<i>HS</i> ₁	Housing starts	CENS		+	+	—
<i>DGO</i> ₁	Durable goods orders	CENS		+		—
<i>ECI</i> ₁	Employment cost index	BEA	+			—
<i>GDP</i> ₁	Real GDP			+		—
<i>GDP</i> ₂	GDP deflator		+			—
<i>PI</i> ₁	Personal income	BEA		+		—
<i>PI</i> ₂	Consumption expenditures			+		—
<i>NHS</i> ₁	New home sales	CENS		+		—
<i>LI</i> ₁	Index of leading indicators	BEA				—
<i>CS</i> ₁	Construction spendings	CENS		+		—
<i>FI</i> ₁	Factory inventories	CENS			—	+
<i>FI</i> ₂	Factory orders			+		—
<i>PC</i> ₁	Productivity	BEA			—	+
<i>BI</i> ₁	Business inventories	CENS			—	+
<i>TRD</i> ₁	Trade deficit	CENS		—		+

For each report, headline figures, reporting agency, and hypotheses concerning the reaction of T-Bond futures prices to surprises in these figures are given. "+" ("—") indicates a positive (negative) reaction to a higher than expected announcement of individual figures. For example, a higher than expected consumer confidence index suggests stronger consumer demand which might translate into price pressures. Thus, a positive impact on interest rates ("+") and a negative impact on T-bond futures prices ("—") is to be expected.

^a BEA: Bureau of Economic Analysis, BLS: Bureau of Labor Statistics, CB: Conference Board, CENS: Bureau of the Census, FED: Federal Reserve Board, TRES: Department of the Treasury, ISM: Institute of Supply Management (formerly, NAPM)

Table 2: Results of an iterative seemingly unrelated regression (SUR)

Signed variable	Release time	8:30 equation		9:15 equation		10:00 equation	
– CC_1	10:00					α_{18}	11.287 ***
– ISM_1	10:00					α_{19}	13.763 ***
– E_1	8:30	α_1	13.201 ***	β_1	– .610 ***	γ_1	.201
+ E_2	8:30	α_2	22.732 **	β_2	1.108 ***	γ_2	.527
– PPI_2	8:30	α_3	6.725 ***	β_3	.349 **	γ_3	– .327 ***
– RS_1	8:30	α_4	5.801 ***	β_4	– .065	γ_4	.317 ***
– CPI_2	8:30	α_5	5.883 ***	β_5	.315	γ_5	– .212 **
– IP_1	9:15			α_{16}	.197	β_{16}	–1.428 ***
– IP_2	9:15			α_{17}	17.274 ***	β_{17}	2.557 ***
– HS_1	8:30	α_6	5.494 ***	β_6	– .208	γ_6	– .687 ***
– DGO_1	8:30	α_7	4.353 ***	β_7	.018	γ_7	– .355 ***
– ECI_1	8:30	α_8	3.086	β_8	.750	γ_8	– .039
– GDP_1	8:30	α_9	6.575 *	β_9	1.462 ***	γ_9	– .135
– GDP_2	8:30	α_{10}	6.320 **	β_{10}	.005	γ_{10}	1.927
– PI_1	8:30	α_{11}	1.937 *	β_{11}	.487 ***	γ_{11}	– .905
– PI_2	8:30	α_{12}	–1.776	β_{12}	– .105 **	γ_{12}	– .903
– NHS_1	10:00					α_{20}	7.345 ***
– LI_1	8:30,10:00	α_{13}	.154	β_{13}	– .576 ***	γ_{13}	4.151
– CS_1	10:00					α_{21}	– .873
+ FI_1	10:00					α_{22}	– .402
– FI_2	10:00					α_{23}	4.559 ***
+ PC_1	10:00					α_{24}	– .139 **
+ BI_1	8:30,10:00	α_{14}	.189	β_{14}	– .558	γ_{14}	–1.053 ***
+ TRD_1	8:30	α_{15}	.349 ***	β_{15}	.043	γ_{15}	.050
Adjusted R^2			.309		.120		.226
BG(30)			17.484		26.877		28.270

Five minute price changes are regressed on standardized signed surprises (i.e. $S_{i,t}/Std(A_i)$), based on a system of three equations, one for each release time, i.e. 8:30, 9:15, and 10:00. Parameters of the system are estimated accounting for heteroskedasticity and contemporaneous correlation in the errors across equations. Estimated constants are omitted since they are insignificant (see table 3). Parameter tests are based on the heteroscedasticity consistent White variance-covariance matrix. Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. The sample period is 1/94–12/99, including 1497 trading days. There are 69 observations for each monthly report, and 23 for each quarterly report, resulting in 769 days on which at least one report is released. Breusch-Godfrey (BG) tests have been performed for several lag lengths. Since none of these is able to detect autocorrelation in residuals, test statistics are displayed only for the largest lag length, i.e. 30 days. Adjusted R^2 s are provided for each equation. The system-wide R^2 measure according to McElroy (1977) is $R_*^2 = .226$.

Table 3: Wald tests and Asymptotic Least Squares.

Est. no.	Wald tests		Asymptotic least squares estimates		
	Imposed restrictions	χ^2 test on imposed restrictions	Imposed restrictions	2 nd stage parameter estimates	χ^2 test on imposed restrictions
(1)	$\hat{\kappa}_i = 0$	$\chi^2_{(3)} = 2.48$	$\hat{\kappa}_i = \theta^*$	$\hat{\theta}^* = 0.014$	$\chi^2_{(2)} = 2.39$
(2)	$\hat{\alpha}_i = 0$	$\chi^2_{(24)} = 1261.10^{***}$	$\hat{\alpha}_i = \theta^*$	$\hat{\theta}^* = 3.266^{***}$	$\chi^2_{(23)} = 795.25^{***}$
(3)	$\hat{\beta}_i, \hat{\gamma}_i = 0$	$\chi^2_{(32)} = 38.13$	$\hat{\beta}_i, \hat{\gamma}_i = \theta^*$	$\hat{\theta}^* = -0.004$	$\chi^2_{(31)} = 38.13$

Each line displays test results for a given set of parameters. The left hand side panel shows Wald tests restricting the given parameter set to zero, i.e. $\hat{\kappa}_i = 0$, for $i = 1, 2, 3$ (line 1), $\hat{\alpha}_i = 0$, $i = 1, \dots, 24$ (line 2), and $\hat{\beta}_i = 0$, $i = 1, \dots, 17$ as well as $\hat{\gamma}_i = 0$, $i = 1, \dots, 15$ (line 3). The $\chi^2_{(\nu)}$ test statistic with ν degrees of freedom is given as well. The right hand panel displays an alternative test: Instead of restricting a set of parameters to zero, these parameters are restricted to a common value θ^* which is estimated on the basis of asymptotic least squares. Significance tests of $\hat{\theta}^*$ are constructed from the asymptotic variance-covariance matrix of restricted parameters. A test of the null hypothesis that the set of restrictions holds is obtained on the basis of the asymptotically $\chi^2_{(\nu)}$ distributed statistic (for details see e.g., Gouriéroux and Montfort 1995, Ch. 9, 18). ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 4: Test of hypotheses H2 to H4 by means of asymptotic least squares

Est. no.	Imposed restrictions	2 nd stage parameter estimates		χ^2 test on imposed restrictions
		$\hat{\theta}_0^*$	$\hat{\theta}_1^*$	
(1)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* \tau_i$	9.646 ^{***}	-0.244 ^{***}	$\chi_{(22)}^2 = 329.47^{***}$
(2)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* n_i$	9.468 ^{***}	-0.478 ^{***}	$\chi_{(22)}^2 = 298.39^{***}$
(3)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* c_{i,1}$	7.539 ^{***}	-1.398 ^{***}	$\chi_{(4)}^2 = 132.23^{***}$
(4)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* c_{i,2}$	12.217 ^{***}	-6.882 ^{***}	$\chi_{(1)}^2 = 0.67$
(5)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* c_{i,3}$	9.398 ^{***}	-4.951 ^{***}	$\chi_{(1)}^2 = 21.55^{***}$
(6)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* c_{i,4}$	6.594 ^{***}	-0.497 [*]	$\chi_{(1)}^2 = 0.28$
(7)	$\hat{\alpha}_i = \theta_0^* + \theta_1^* c_{i,5}$	6.717 ^{***}	-1.707 ^{***}	$\chi_{(4)}^2 = 83.21^{***}$

Each line displays results of an asymptotic least squares estimation for a given set of linear restrictions. Line (1) and (2) provide tests for hypothesis H2 and H3, respectively, by restricting estimated first stage parameters $\hat{\alpha}_i$ as a linear function of τ_i , i.e. the time lag of a release, and n_i , i.e. the number of previous releases. Results for H4 are given in lines (3) to (7) testing whether the $\hat{\alpha}_i$'s may be expressed as a linear function of $c_{i,j}$, i.e. the number of previous releases within a given content category $j = 1, \dots, 5$ (corresponding to classification C1a, C1b, C1c, C2a, and C2b, respectively). A test of the null hypothesis whether the constraints hold is obtained on the basis of the asymptotically $\chi_{(\nu)}^2$ distributed statistic with ν degrees of freedom. All statistics are constructed from the asymptotic variance-covariance matrix of restricted parameters (see e.g. Gourieroux and Montfort 1995, Ch. 9, 18). ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 5: Test of hypothesis H4 by means of sequential pairwise t-tests

C1a: Overall production			C2a: Past price changes		
	ISM_1	IP_1		PPI_2	CPI_2
IP_1	13.565 ***		CPI_2	0.841	
DGO_1	9.410 ***	-4.155	GDP_2	0.405	-0.436
GDP_1	7.188 ***	-6.377			
LI_1	13.608 ***	0.043	C2b: Early indicators		
FI_2	9.204 ***	-4.361		E_2	IP_2
C1b: Consumption goods			IP_2	5.458 ***	
	CC_1	RS_1	ECI_1	19.646 ***	14.188 ***
RS_1	5.486 ***		FI_1	23.134 ***	17.676 ***
PI_2	13.063 ***	7.577 ***	PC_1	22.871 ***	17.413 ***
C1c: Housing sector			BI_1	22.543 ***	17.085 ***
	HS_1	NHS_1			
NHS_1	-1.851				
CS_1	6.366 ***	8.217 ***			

Tests on a decreasing impact of subsequent releases in individual content categories. The first and second headline figure is compared with all subsequently released figures within a given content category. Differences between estimated coefficients are displayed for each of the five content categories. A positive entry indicates that the impact of the previously released headline (i.e. the headline figure given on top) is larger than the impact of the report released subsequently (i.e. the headline figure to the left). A significantly positive (negative) difference according to a one-sided t-test at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. Standard errors of the differences are constructed from the estimated White variance-covariance matrix of parameters.

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