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In 2004 all publications will carry a motif taken from the €100 banknote.

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Abstract

This paper analyses the effects of US monetary policy on stock markets. We find that, on average, a tightening of 50 basis points reduces returns by about 3%. Moreover, returns react more strongly when no change had been expected, when there is a directional change in the monetary policy stance and during periods of high market uncertainty. We show that individual stocks react in a highly heterogeneous fashion and relate this heterogeneity to financial constraints and Tobin's q. First, we show that there are strong industry-specific effects of US monetary policy. Second, we find that for the individual stocks comprising the S&P500 those with low cashflows, small size, poor credit ratings, low debt to capital ratios, high price-earnings ratios or high Tobin's q are affected significantly more. The use of propensity score matching allows us to distinguish between firm- and industry-specific effects, and confirms that both play an important role.

JEL classification: G14, E44, E52.
Keywords: monetary policy; stock market; credit channel; Tobin's q; financial constraints; S&P500; propensity score matching.

Non-technical summary

The relationship between monetary policy and equity prices is still not well understood in the literature. As the first step of our analysis, the paper asks whether and how monetary policy affects equity markets by looking at the returns of the S&P500 index on days of monetary policy decisions of the Federal Reserve since the change of its disclosure practices in 1994 and until 2003. We find strong and highly significant effects of US monetary policy shocks on equity returns: an unexpected tightening of 50 basis points is estimated to decrease US equity returns by about 3% on the day of the monetary policy announcement. Moreover, we find strong asymmetries in these effects: equity returns react more strongly to monetary policy shocks (1) when changes by the FOMC are unexpected, (2) when there is a directional change in the monetary policy stance of the Fed, and (3) during periods of high equity market volatility.

In the literature on the credit channel of monetary policy transmission, most of the work has focused on the role of various information asymmetries: firms for which less information is publicly available may find it more difficult to access credit when credit conditions become tighter. If a credit channel is at work for firms that are quoted on stock markets, one would expect that their stock prices respond to monetary policy in a heterogeneous fashion, with the prices of firms that are subject to relatively larger informational asymmetries reacting more strongly. The reason is that their expected future earnings are affected more due to constraints on the supply of their goods. Alternatively, prices might react more strongly if the demand for firms' products differs across sectors.

This paper analyses both effects, and aims to distinguish their respective contributions to the overall stock market response. In a first step, we present evidence that the individual firms included in the S&P500 index react in a remarkably heterogeneous fashion to US monetary policy shocks. Second, we investigate whether we can identify industry-specific effects of monetary policy. It is found that cyclical sectors, such as technology, communications and cyclical consumer goods, react two to three times stronger to monetary policy than less cyclical sectors.

As a third step, we test whether monetary policy has a stronger effect on the equity returns of firms that are financially constrained and/or have good investment opportunities. We find strong empirical support for this hypothesis using various proxies for financial constraints, with large differences in the effects of monetary policy across firms. We show that firms with low cashflows, small size, poor credit ratings, low debt to capital ratios,

high price-earnings ratios or a high Tobin's q are affected significantly more by US monetary policy. For instance, monetary policy affects firms with poor cashflows almost twice as much as firms with high cashflows.

Finally, after presenting evidence for the presence of industry- and firm-specific effects, we aim to disentangle the two. Since the firm-specific variables are highly correlated with the industry affiliation, we use a novel empirical methodology in this literature, based on propensity score matching, to properly distinguish between the industry-specific and firm-specific factors. The results suggest that it is in particular the industry-specific effects that explain a large share of the different reactions of firms to US monetary policy shocks.

1. Introduction

One central argument of James Tobin's seminal 1969 *Journal of Money, Credit and Banking* paper was that "financial policies" can play a crucial role in altering what later became known as Tobin's q, the market value of a firm's assets relative to their replacement costs. Tobin emphasized that in particular monetary policy can change this ratio. This 1969 *JMCB* paper together with another of his contributions (Tobin 1978) became a key element in the formulation and understanding of the stock market channel of monetary policy transmission. Tobin's argument in this work was that a tightening of monetary policy, which may result from an increase in inflation, lowers the present value of future earning flows and hence depresses equity markets.

The second part of Tobin's argument, namely the relationship between monetary policy and equity prices, is still not very well understood. On the one hand, it has proven difficult to properly identify monetary policy, since monetary policy may be endogenous in that central banks might react to developments in stock markets. Considerable progress has recently been made in this respect. Rigobon and Sack (2002, 2003) develop a methodology that exploits the heteroskedasticity present in financial markets to identify monetary policy shocks, while Kuttner (2001) and Bernanke and Kuttner (2003) derive monetary policy shocks through measures of market expectations obtained from federal funds futures contracts. In this paper, we will employ a methodology similar to Bernanke and Kuttner (2003), by identifying monetary policy shocks through market expectations obtained from surveys of market participants.

As the first step of our analysis, the paper asks whether and how monetary policy affects equity markets by looking at the returns of the S&P500 index on days of monetary policy decisions of the Federal Reserve since the change of its disclosure practices in 1994 and until 2003. We find strong and highly significant effects of US monetary policy shocks on equity returns: an unexpected tightening of 50 basis points is estimated to decrease US equity returns by about 3% on the day of the monetary policy announcement. Moreover, we find strong asymmetries in these effects: equity returns react *more* strongly to monetary policy shocks (1) when changes by the FOMC are unexpected, (2) when there is a directional change in the monetary policy stance of the Fed, and (3) during periods of high equity market volatility.

Despite the recent progress in understanding the overall stock market response to monetary policy, more research is needed to understand why individual stocks react so differently to monetary policy shocks, and what the driving force is behind this reaction. The recent paper by Bernanke and Kuttner (2003) shows that very little of the market's reaction can be attributed to the effect of monetary policy on the real rate of interest. Rather, the response of stock prices is driven by the impact on expected future excess returns and to some extent on expected future dividends. In this paper, we go a step further by analyzing which factors of these expectations are important for understanding the large heterogeneity in the reaction of individual stocks to monetary policy.

In the literature on the credit channel of monetary policy transmission, Bernanke and Blinder (1992) and Kashyap, Stein and Wilcox (1993) show that a tightening of monetary policy has a particularly strong impact on firms that are highly *bank-dependent borrowers* as banks reduce their overall supply of credit. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) argue that worsening credit market conditions affect firms also by weakening their *balance sheets* as the present value of collateral falls with rising interest rates, and that this effect can be stronger for some firms than for others. Both arguments are based on *information asymmetries*: firms for which less information is publicly available may find it more difficult to access bank loans when credit conditions become tighter as banks tend to reduce credit lines first to those customers about whom they have the least information (Gertler and Hubbard 1988, Gertler and Gilchrist 1994). For instance, Thorbecke (1997) and Perez-Quiros and Timmermann (2000) show that the response of stock returns to monetary policy is larger for small firms.

If a credit channel is at work for firms that are quoted on stock markets, one would expect that their stock prices respond to monetary policy in a heterogeneous fashion, with the prices of firms that are subject to relatively larger informational asymmetries reacting more strongly. The reason is that their expected future earnings are affected more, since these firms will find it harder to access funds following a monetary tightening, which should lead to a constraint of the *supply* of their goods.

Another differentiation of the response of stock prices to monetary policy is likely to be related to the response of the *demand* for firms' products. Firms that produce goods for which demand is highly cyclical or interest-sensitive should see their expected future earnings be affected relatively more following a monetary policy move. These effects are not based on the credit channel; rather, they arise through the interest-rate channel. Therefore, one would expect that the differentiation of responses to monetary policy is not only dependent on the firm-specific characteristics, but also on those of the industry to which the firm is affiliated.

This paper analyses both effects, and aims to distinguish their respective contributions to the overall stock market response. In a first step, we present evidence that the individual firms included in the S&P500 index react in a remarkably, highly heterogeneous fashion to US monetary policy shocks. Second, we investigate whether we can identify *industry-specific effects* of monetary policy. It is found that cyclical sectors, such as technology, communications and cyclical consumer goods, react two to three times stronger to monetary policy than less cyclical sectors.

As a third step, we test whether monetary policy has a stronger effect on the equity returns of firms that are financially constrained and/or have good investment opportunities. We use a measure of Tobin's q as a proxy of investment opportunities, which is an important corollary of the analyzed financial constraint variables. We find strong empirical support for this hypothesis using various proxies for financial constraints and investment opportunities, with large differences in the effects of monetary policy across firms. We show that firms with low cashflows, poor credit ratings, low debt to capital ratios, high price-earnings ratios or a low Tobin's q are affected significantly more by US monetary policy. For instance, monetary policy affects firms with poor cashflows or low debt almost twice as much as firms with high cashflows or high debt.

Finally, after presenting evidence for the presence of industry- and firm-specific effects, we aim to disentangle the two. Since the firm-specific variables are highly correlated with the industry affiliation, we use a novel empirical methodology in this literature, based on propensity score matching, to properly distinguish between the industry-specific and firm-specific factors. The results suggest that it is in particular the industry-specific effects that explain a large share of the different reactions of firms to US monetary policy shocks.

The paper proceeds as follows. Section 2 presents the data employed in this study and discusses some conceptual issues important for the empirical analysis. Our empirical results for the overall S&P500 index are reported in Section 3. Section 4 tests the role of the interest rate channel, credit channel and of Tobin's q for the response of equity markets to US monetary policy. Section 5 introduces the propensity score matching methodology and reports the respective results. Section 6 concludes.

2. Monetary policy and equity markets: conceptual issues and data

An important issue that arises when measuring the effect of monetary policy on equity markets is the correct *identification of monetary policy*. Many papers in this literature (e.g., Lamont, Polk and Saa-Requejo 2001, Perez-Quiros and Timmermann 2000) use changes in market interest rates or official rates as their measures of monetary policy. The problem with these measures, however, is that changes in interest rates can coincide with changes in business cycle conditions and other relevant economic variables. It is therefore not clear whether the effect attributed to monetary policy in those papers reflects other factors. A number of studies have therefore followed the example of Christiano, Eichenbaum and Evans (1994) and extract monetary policy shocks as the orthogonalized innovations from VAR models. Thorbecke (1997) employs this methodology and finds that for the period 1953-90 the response of US stock returns to monetary policy shocks, based on federal fund rates, differs significantly across industries and that small firms' returns react much more strongly than those of large firms. Patelis (1997) also employs a related methodology and arrives at very similar results, but also shows that the overall explanatory power of monetary policy for stock returns is rather low. Conover, Jensen and Johnson (1999) look at 16 industrialized countries and find that equity markets in several of these markets react both to the local as well as to the US "monetary environment", i.e. to changes in monetary policy.

A central shortcoming of this methodology is, however, that it is subject to an *endogeneity* bias, i.e. monetary policy shocks that are extracted from structural VAR models or from changes in interest rates using monthly or quarterly frequencies are unlikely to be purely exogenous. Rigobon and Sack (2002, 2003) have shown convincingly that monetary policy reacts to stock market developments in a way that consistently takes the impact of stock market movements on aggregate demand into account. The essence of Rigobon and Sack's argument is that causality between interest rates and equity prices runs in both directions. They show that not accounting for this endogeneity may introduce a significant bias in empirical estimations of the reaction of equity returns to monetary policy.

To identify monetary policy shocks more accurately, several papers have conducted *event studies* based on higher frequency observations, mostly daily data, analyzing how equity markets react to monetary policy. A seminal paper employing such an event-study methodology is that of Cook and Hahn (1989), who test whether changes to the federal funds rate affected asset prices during the period 1974-1979. Thorbecke (1997) uses the same methodology but extends the data also to the early Greenspan period 1987-94 and finds that the US equity index indeed reacted significantly to changes in the federal funds rate on days when such changes took place.

Other event studies looking at the link between monetary policy and equity returns are those of Bomfim (2001), Durham (2002), Jensen and Johnson (1995) and Lobo (2000). For instance, Lobo (2000) finds for the period 1990-98 that tightenings in the federal funds and/or discount rate had a stronger effect on equity markets than monetary policy easings. Bomfim (2001) shows that volatility of equity markets tends to be relatively lower on days before and higher on days after monetary policy decisions.

One shortcoming of the existing event-study literature about monetary policy and equity markets is that monetary policy changes are simply measured as changes of policy rates on days of FOMC meetings. Kuttner (2001) has shown that on the day of announcements, markets react mostly not to the announcements *per se*, but to their *unexpected* component that is not already priced into the market. This argument is consistent with the *efficient market hypothesis* that asset prices should reflect all information available at any point in time.

The empirical methodology we use in this paper falls into the category of event studies. For the period from February 1994 to February 2003 - i.e. since the Fed discloses decisions concerning the fed funds rate target - we analyze the effect of the *surprise* component of monetary policy decisions on equity returns on the days of their announcement. This surprise is measured as the difference between the announcement of the FOMC decision and the market expectation. The expectations data for monetary policy decisions originates from a Reuters poll among market participants, conducted on Fridays before each FOMC meeting. We use the mean of the survey as our expectations measure although using the median yields similar econometric results.

Employing standard techniques in the literature (e.g. Gravelle and Moessner, 2001), we test for unbiasedness and efficiency of the survey data. Tables A1 and A2 show the results for the respective tests for the forecasts of monetary policy announcements. We find that the survey expectations are of good quality as they prove to be unbiased and efficient. As shown previously (Ehrmann and Fratzscher 2002, 2003) and also tested here in this paper, the survey-based measures perform very similar to expectations data based on federal funds futures, as employed by Kuttner (2001) and Bernanke and Kuttner (2003).

For our measure of stock market returns, we use the returns of the S&P500 index, and of the 500 individual stocks therein as in early 2003, with Bloomberg as the source. This allows us to cover a broad spectrum of industries and firms, and thus to get at the issue of industry- and firm-specific effects of monetary policy. We calculate the daily returns as the log-difference of the daily closing quotes.

Obviously, there are various issues in the measurement of both the monetary policy surprises and the daily stock returns that merit discussing. Since the Reuters surveys are conducted on Fridays prior to the FOMC meetings, they cannot capture any change in market expectations that occurs in between. However, we are comforted by the fact that results are robust to the use of market expectations derived from the Fed funds futures market, where this issue does not arise.

Regarding the measure of stock returns, the choice of a daily frequency aims at striking a balance between identifiability of exogenous monetary policy surprises and estimation of sustained stock market effects. At lower frequencies, as we have argued above, it is difficult to disentangle the response of monetary policy to stock markets and thus to identify monetary policy surprises. Higher frequency data, as used e.g. by Andersen et al. (2003) for exchange rates, on the other hand, might capture overshooting effects that quickly disappear. We therefore assume that effects found on a daily basis are likely to reveal the longer-run impact in a more reliable fashion.

Our sample covers 79 meetings of the FOMC, from February 4th, 1994 to January 29th, 2003. The beginning of the sample coincides with a change in FOMC practices: since 1994, the FOMC announces the fed fund target rate in openness, whereas before, the market needed to infer the target rate from the Fed's behavior. We delete the unscheduled meeting of September 17th, 2001, where the FOMC decided to cut interest rates by 50 basis points in response to the events of September 11th, for the unusual circumstances of this interest rate decision. Not all stocks are observed for the full sample period; on average, we observe stocks for 71 of the FOMC meeting days.

3. Overall stock market reaction to monetary policy

As a first pass at the stock market effects of monetary policy, we test whether and how the S&P500 index responds to surprises. The econometric model used is formulated as follows:

$$r_t = \alpha + \beta s_t + \varepsilon_t \qquad (1)$$

where r_t denotes the stock market return on day *t*, and s_t the monetary policy surprise.[1]

Table 1 around here

The first row of table 1 shows that a monetary tightening of 100 basis points lowers stock market returns by 5.5%, significant at the 1%-level. However, this is an average effect over time, and it can be expected to vary considerably, e.g. depending on the circumstances in which monetary policy is acting or the type of action of monetary policy. In order to test for such time-varying monetary policy effects, we will split the sample of surprises into two subsets $s_{1,t}$ and $s_{2,t}$ according to various criteria, enter both in the regression separately, and test for the statistical difference of the two parameters (β_1 and β_2) with an F-test.[2] The model therefore changes to

$$r_t = \alpha + \beta_1 s_{1,t} + \beta_2 s_{2,t} + \varepsilon_t \qquad (2)$$

Since the monetary policy surprise covers cases where interest rates were changed, but markets expected a different magnitude (or no change), as well as cases where interest rates were left unchanged, but markets had expected a move, we first test whether these cases lead to different stock market reactions. The coefficients are reported in the second row of table 1. It turns out that stock returns are affected significantly only in the former case, i.e. when there is a change in monetary policy rates. In these cases, the response of stock markets is slightly higher than average: returns fall by about 6% in a response to an unexpected change by 100 basis points.

Conditional on there being a change in policy rates, the magnitude of the stock market response is even stronger in certain circumstances. If the market had not expected any change in policy rates (i.e., the survey expectations were equal to zero), returns are estimated to change by 9%. An even stronger effect is found if the policy move initiates a directional change, i.e. in case of the first tightening after a period of easings, or vice versa. A similar effect has been found for t-bill rates (Demiralp and Jorda, 2002). Since the Fed usually changes interest rates several times in the same direction before it reverses its stance, a first tightening after a series of easings (or vice versa) contains valuable

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[1] As expected, lagged values of the stock market return proved to be insignificant, and were therefore not included. The estimated parameter for the intercept is generally insignificant. All regressions in this section are performed with heteroskedasticity-robust standard errors. The estimates are performed for the sample of FOMC meeting days only.

[2] For a set of related tests see Bernanke and Kuttner (2003). Their results are similar to our findings.

information about the future course of monetary policy. This is reflected in the response of both equity and t-bill markets. The difference is highly significant.

The effect of monetary policy is also stronger in an environment of increased market uncertainty. We have tested for this by splitting the surprises into subsets, depending whether market volatility over the last month has been low (below the 10^{th}, 50^{th} or 80^{th} percentile of the overall distribution of volatility over the full sample), or high (above the various thresholds). If market volatility is high, we estimate stronger responses, as shown in rows 5 to 7 of table 1. As a matter of fact, the response is only significant if volatility is high. Monetary policy signals are therefore more influential when market uncertainty is high.

Finally, we have tested whether positive surprises lead to different responses than negative surprises. A positive surprise implies that monetary policy has tightened more or loosened less than expected, or has not moved whereas the market expected a loosening. It turns out that a negative surprise (i.e. a loosening relative to market expectations) has larger effects.

The last row of table 1 reports the results of a model where we introduce both the surprise component and the expected component of a monetary policy announcement. This allows us to test for the quality of the expectations measure. We would expect no reaction of the stock market to the expected component of a monetary policy decision on the day of the announcement, since markets should already have priced the information. This is indeed what we find.

Tables A3 to A4 in the appendix contain robustness checks for these results. Table A3 defines the market expectation by the median of the Reuters survey, as opposed to the mean as we have defined it here. Table A4 uses monetary policy surprises as calculated by Kuttner (2001), which are derived from federal funds futures markets, i.e. are market-based rather than survey-based as the measure used in this paper. All results are qualitatively, and generally quantitatively extremely robust.

In summary, the analysis of the reaction of the S&P500 shows a strong effect of monetary policy on equity returns. Moreover, there are large asymmetries in the reaction of equity returns depending on the nature and type of the monetary policy news. We next analyze the whether the effect of monetary policy varies across firms.

4. Industry effects, the credit channel and Tobin's q

We now turn to the question of *which* firms are affected particularly strongly by monetary policy. Our sample of firms comprises the 500 individual stocks that currently constitute the S&P500. As a starting point, we use the empirical model of equation (1) and regress each firm's return series individually on our monetary policy surprises. We find a glaring and large heterogeneity in the response across the 500 stocks in the S&P500 index. Figure 1 shows the distribution of the estimated parameters. They range from -0.44 to +0.15, with a mean of –0.06 and a median of –0.05. The distribution is strongly skewed towards the left. Overall, these results show that the stock market response to monetary policy is highly asymmetric. Understanding and explaining this asymmetry and heterogeneity is the focus of the remainder of the paper.

Figure 1 around here

As to the empirical methodology, to carry out the analysis in a panel framework of 500 stocks, we will turn to panel regressions of the form

$$r_{i,t} = \alpha + \beta_1 s_t + \beta_2 s_t x_{i,t} + \tau x_{i,t} + \varepsilon_{i,t} \tag{3}$$

where $x_{i,t}$ denotes some firm-specific characteristic, which can be either time-varying (e.g. its size or its cash flow to income ratio), or fixed over time (e.g. its industry affiliation). If this variable varies with the stock price (e.g. the price-earnings ratio), we enter it with one lag to avoid problems with endogeneity of the regressors.

Contrary to most of the literature on stock market effects, we decided not to run estimates on a stock by stock basis, and then explain the coefficients in a cross-sectional regression, although the time-series dimension of our sample would have allowed us to do so. Rather, we decided to pool the data for two reasons. First, many of our firm-specific characteristics are time-varying. In a cross-sectional regression, we could not account for changes in these characteristics over time. Second, pooling allows us to take into account a potential cross-sectional correlation of residuals, which we consider a realistic assumption for stock market data: a high residual in one stock is likely to be accompanied by high residuals in other stocks. To account for this dependence across observations, we estimate equation (3) via OLS using panel-corrected standard errors (PCSE). This estimator corrects for heteroskedasticity and assumes that residuals are contemporaneously correlated across panels, and estimates the covariance of the OLS coefficients as

$$\hat{V} = (X'X)^{-1} X' \Omega X (X'X)^{-1} \quad (4)$$

where Ω is the covariance matrix of the residuals:

$$\Omega = \Sigma_{mxm} \otimes I_{T_i x T_i}$$

where I is an identity matrix and Σ the m by m panel-by-panel covariance matrix of the residuals, formulated as

$$\hat{\Sigma}_{ij} = \frac{\varepsilon_i ' \varepsilon_j}{T_{ij}} \quad (5)$$

where ε_i and ε_j are the residuals for panels i and j from equation (3) and T_{ij} is the number of residuals between the panels that can be matched by time period.

This variance estimator corrects for the dependence across observations. Neglecting such correlation will lead to decreased estimates of the variance and to a serious overestimation of the significance of parameters. As a matter of fact, this effect turns out to be important.

The results are extremely robust to other changes in the model specification, no matter whether we allow for fixed effects or not, or run the model over all trading days and use feasible GLS to allow for the presence of AR(1) autocorrelation within panels. We experimented using a lag of stock returns; however, it never turned out significant, confirming the validity of the efficient market hypothesis in this context. Similarly, using further lags of the monetary policy surprise does not add any explanatory value – the effects are priced into the market within one day.

We checked for robustness with respect to pure time effects by calculating the mean of all stock returns on a daily basis, and by subtracting this daily mean from each stock, again day by day. This does control for pure time effects in the same way a full set of time dummies would do. All results are robust to this treatment.

Finally, we conducted several other robustness checks. Most importantly, excluding large outliers of monetary policy surprises yields qualitatively similar results for the estimates. Moreover, we repeated the analysis using monetary policy surprises as calculated by Kuttner (2001) and used in Bernanke and Kuttner (2003), which are derived from federal funds futures markets, i.e. are market-based rather than survey-based as the measure used in this paper. All results are qualitatively, and generally quantitatively extremely robust.[3]

4.1 Industry-specific effects

The effect of monetary policy on stock market returns is likely to differ across industries for various reasons. The interest-sensitivity of the demand for products differs. Furthermore, if monetary policy affects exchange rates, tradable goods industries are likely to be affected more strongly. Finally, changes in the cost of capital induced by monetary policy are more important for capital-intensive industries. All these factors imply that expected future earnings are affected in a heterogeneous fashion across industries, which should be reflected in the responsiveness of stock returns. We would therefore expect firms in cyclical industries, capital-intensive industries, and industries that are relatively open to trade to be affected more strongly.

There is only relatively little evidence of the cross-sectional dimension of monetary policy effects in the literature to date. Exceptions are Dedola and Lippi (2000) and Peersman and Smets (2002), who analyze the effect of identified VAR shocks on sectoral production indices for five OECD countries and seven countries of the euro area, respectively. Ganley and Salmon (1997) and Hayo and Uhlenbruck (2000) similarly analyze industry effects in the UK and Germany. In a similar fashion to the tests employed in this paper, Angeloni and Ehrmann (2003) analyze cross-sectional responses of stock market returns to monetary policy in the euro area. For the US, to our knowledge only Bernanke and Kuttner (2003) perform a similar analysis. Overall, the findings of this literature support the hypotheses expressed above.

Tables 2 and 3 around here

Tables 2 and 3 report results for a breakdown of 9 sectors and 60 industry groups, sorted by the magnitude of monetary policy effects. The left-hand columns report results of the panel version of equation (1), where we repeatedly run regressions with stocks of one sector only. In order to get an assessment of the differences across sectors, we also report results from model (3), where all stocks enter, regardless of their industry affiliation. We run this model repeatedly, each time redefining the industry dummy x_i to capture stocks with different

[3] See tables A3 and A4 in the appendix.

industry affiliations.[4] The second panels of tables 2 and 3 report the corresponding results for β_2. In that sense, the set of results shown in the second panels controls for market movements, and aims to estimate how sensitive stock returns of a given industry are to monetary policy *relative* to the market return. In other words, we are interested in understanding whether sector affiliation can help to explain what is commonly known as *"β"* in the capital asset pricing model, the covariability of a stock with the returns of the index on the occasion of a monetary policy surprise.

Stock returns of firms in the technology, communication and cyclical consumer goods industries are more responsive than the average stock, whereas non-cyclical consumer goods, energy and utilities are industries that respond below average, where the differences are always estimated at a 1% significance level. Industries whose reaction to monetary policy shocks is around the average are the basic materials, industrial and financial sectors. Overall, this supports the hypothesis that cyclical and capital-intensive industries are affected most. Looking at the finer disaggregation presented in table 3, this impression gains further support. Highly non-cyclical sectors like food, agriculture or beverages respond *less*, whereas firms in semiconductors, internet, telecommunications, computers and software, to name a few, react more strongly than the average. Like in figure 1, the effects vary considerably also in magnitude: whereas stock returns in the semiconductor industry drop by more than 20%, there are even industries that show a positive response, such as the beverages sector.

4.2 *Firm-specific effects*

The literature on the credit channel of monetary policy implies that the effect of monetary policy on firms tends to be asymmetric. In particular, firms that are *financially constrained* are likely to be affected more strongly by changes in interest rates than firms that are less constrained. Consistent with and building on Fama and French's (1995) evidence that small firms' equity returns are distinct from those of larger firms, Perez-Quiros and Timmermann (2000) use the size of firms as a proxy for credit constraints. Analyzing monthly equity returns of size-sorted equity portfolios during the period 1954-97, they indeed find that smaller firms' returns are much more affected by monetary policy tightening and during recessions than those of larger firms. Using the size of firms as a proxy for the degree of

[4] Since there is no cross-sectional variation in s_t, estimating model (1) including individual stocks should yield identical results as estimating these models using returns of unweighted industry indices. Indeed, estimating the models using such industry indices produces identical point estimates and standard errors.

credit constraints has been widespread. For instance, Gertler and Hubbard (1988) and Gertler and Gilchrist (1994) show that small firms are more dependent on bank loans. Nevertheless, a number of papers point out that size is only an imperfect proxy for the degree of credit constraints and attempt to find other, more direct measures. Lamont, Polk and Saa-Requejo (2001), building on work by Kaplan and Zingales (1997), use a qualitative measure for financial constraints from information in firms' annual reports in fulfillment of SEC requirements and regulations.[5] Lamont, Polk, and Saa-Requejo (2001) find for the period 1968-97 that financially constrained firms exhibit a significant degree of co-movements in terms of stock returns, and that this common factor cannot be attributed to the size of firms or other characteristics such as industry-specific effects. The important finding of their paper for our purpose is that they do not detect evidence that financially constrained firms react more strongly to changes in monetary policy or to business cycle conditions than less constrained ones.

To analyze the role of the credit channel, we borrow from the literature ideas of several proxies for the degree of financial constraints of firms. Following Kaplan and Zingales (1997), we define the term "financial constraint" to imply a wedge between internal and external financing of a firm's investment. Firms with stronger financial constraints are those that find it relatively more difficult to raise funds to finance investment. First, we look at the *size* of firms, using the *number of employees* as well as the *market value* of firms as our size variables.

Second, we follow the example of Lamont, Polk and Saa-Requejo (2001) and Kaplan and Zingales (1997) and use several more direct measures of financial constraints: the cash flow to income ratio and the ratio of debt to total capital. The underlying rationale for including these two measures is that a firm can finance investment either by raising funds *internally* - by using existing cashflows generated - or *externally* - via bank loans or capital markets. In theory, our priors are that firms with large cashflows should be more immune to changes in interest rates as they can rely more on internal financing of investment. One may expect that firms with a lower ratio of debt to capital are affected more by monetary policy because they are more bank-dependent and bank-dependent borrowers are hit more strongly

[5] More precisely, Kaplan and Zingales (1997) test whether various capital and book ratios – the cash flow to capital ratio, Tobin's q (proxied by firms' market to book ratios), and the three ratios of debt, of dividends and of cash holdings to total capital – are systematically related to their qualitative measure of financial constraints. They do find a significant relationship for most of these variables, though the finding for q is ambiguous, as discussed above in Section 1. The main focus on the paper by Kaplan and Zingales (1997) is on the link between investment and financial constraints, and does not analyse equity markets.

by a change in the supply of credit (Bernanke and Blinder 1992, Kashyap, Stein and Wilcox 1993).

Moreover, we include the price-earnings ratio in our analysis. Finally, we employ Moody's investment rating and Moody's bank loan rating as two measures of financial constraints. We would expect that firms with a better rating should find it easier to obtain financing of their investments and therefore should be less affected by changes in monetary policy.

Tables 4-5 around here

Table 4 provides some summary statistics of the various measures of financial constraints after correcting for outliers, to illustrate the pure cross-sectional dispersion of the variables. Table 5 present the correlations of the various measures of financial constraints and Tobin's q. The key point from this table is that most of the variables have a low degree of correlation.[6] Exceptions are the two size measures - number of employees and market size - as well as the correlations of the two size measures with the debt to total capital ratio.

Table 6 around here

Table 6 shows the empirical findings for the various measures of financial constraints. As a general principle underlying the analysis, firms have been divided into three groups according to their position in the cross-sectional distribution of each variable, which has been calculated on a daily basis.[7] The left-hand-side columns use the bottom third of the distribution of each respective variable for a firm to have a low measure, the middle third (i.e. between 33% and 67%) to have a medium level, and the top third to have a high level of the variable. The right-hand-side columns of Table 6 make a similar categorization, but using instead the 10% and 90% levels as cut-offs. All results have undergone robustness checks, such as excluding outliers from the estimation. The results proved, however, highly robust to such changes.

First, the results provide evidence that the *size* of firms is an important factor for the determination of the monetary policy transmission in equity markets. Small firms, based

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[6] The low correlations between different measures of financial constraints imply that a firm that is relatively constrained according to one measure need not be constrained according to another measure, a possible outcome since financial constraints can take different forms and degrees.

[7] Some of the firm characteristics are evolving considerably through time. Accordingly, it is important to categorise firms on a daily basis in order to disentangle the effects of monetary policy on a given day on the distribution of firms from the asymmetries of monetary policy over time.

either on the number of employees or the market value of firms, are estimated to react more to monetary policy shocks than medium-sized and large firms. This is very much in line with the finding in the literature, as discussed above, that small firms tend to be more affected by such shocks. Nevertheless, it is interesting that we can confirm this result also for a set of firms that are overall quite large.

Second, the results show that firms with low *cashflows* are affected significantly stronger by US monetary policy shocks. For the 10%-90% categorization, stock returns of firms with low cashflows respond almost twice as much to monetary policy (i.e. –8.8% in response to a 100 bp shock) as compared to firms with high cashflows (i.e. –4.7% to the same shock).

Third, firms that have a good *Moody's investment rating* and firms that have a good *Moody's bank loan rating*[8] are more immune to monetary policy shocks than those with a poor rating. Firms with a poor investment rating or with a low bank loan rating react nearly twice as much to monetary policy (–6.5% or –6.1%, respectively) than firms with high ratings (–3.8% or –3.9%, respectively).

Fourth, the effects for the *debt to capital ratio* are found to be non-linear: firms with either high or low values of these ratios respond more to monetary policy than firms that have intermediate levels. Overall, the largest effect of monetary policy is recorded for firms with a *low* level of debt, whereas firms with high levels of debt react similar to the average firm.[9] This finding is interesting because it may come somewhat unexpected. Indeed, this finding conveys a very interesting message. We interpret it as indicating that firms that have a high level of debt are *not* more constrained financially than others. On the contrary, the results suggest that firms hold low levels of debt *because* they *are* currently financially constrained and thus may find it relatively more difficult to borrow more. A similar result has been found, e.g., in Peersman and Smets (2002) and Dedola and Lippi (2000).

Fifth, firms with a high *price earnings ratio* are affected more strongly by monetary policy, indicating that the re-assessment of their earnings expectations is particularly sensitive to changes in interest rates.

Finally, economic theory is ambiguous about the relationship between monetary policy, equity markets and Tobin's q, as a proxy of investment opportunities and an important corollary of the analyzed financial constraint proxies. On the one hand, a high q indicates

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[8] Of course, both measures are highly correlated as firms with good investment ratings also tend to have good bank loan ratings.

that ample investment opportunities are present for a firm, which may imply, *ceteris paribus*, that this firm has higher financial constraints by requiring more external funds to finance this investment. The higher degree of constraints may therefore also imply a higher sensitivity of this firm to monetary policy shocks. On the other hand, a firm with a relatively high value of its assets (a larger q) may find it easier and may receive more favorable conditions to raise external funds to finance investment. This in turn would imply that firms with a large q have lower financial constraints and hence they may be less sensitive to monetary policy shocks.

Following Kaplan and Zingales (1997) and Lamont, Polk and Saa-Requejo (2001), we use firms' market to book ratios as proxies for Tobin's q. It is clearly difficult if not impossible to measure q accurately,[10] but using the market to book ratio is fairly common in the literature and should provide a reasonably close approximation.

Table 6 reveals that the strongest response of equity returns to monetary policy shocks is experienced by firms with a high q. This difference is sizeable, but significant only for the 33%-67% categorization.

Overall, the results show that much of the asymmetric response of firms to monetary policy shocks, as shown in Figure 1, is explained by differences across firms in their degree to which they are financially constrained and to which they have different investment opportunities, as proxied by Tobin's q.

5. Propensity Score Matching

A potential shortcoming of the results presented in the previous section is that the industry affiliation of a firm is highly correlated with its financial characteristics, as documented in table 7. As argued in section 1, firm-specific effects that are related to financial constraints affect a firm's future earnings stream because they change the *supply* of goods by this firm. On the other hand, once these effects have been accounted for, all remaining differentiation of stock responses to monetary policy should signal the effect of changes in interest rates on the *demand* of the goods of a firm, and this way on its expected future earnings stream. We have argued that it is especially the industry-specific effects that are likely to be

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[9] This effect is found to be statistically significant also when comparing the effects of low levels versus high levels of debt, the test for which is not shown in Table 6.

[10] See Erickson and Whited (2000) for a detailed analysis of the potential importance of measurement errors in Tobin's q. The focus of the paper by Erickson and Whited is, however, primarily on the relationship between Tobin's q and investment.

demand-driven. However, in order to disentangle these effects, we need to take any correlation between industry affiliation and the financial characteristics into account.
Given the large number of financial variables and sectors we need to include, it is not feasible to simultaneously estimate all factors in one model.[11]

Table 7 around here

To solve for this problem, we employ Propensity Score Matching methods that have long been used in biology and other fields (Rosenbaum and Rubin 1983) but have only recently been utilized in economics, mostly in labor economics.[12] The usual terminology is that of "treatment effects", the term coming from experimental economics where some individuals undergo a certain experiment or treatment (T=1) whereas others remain in a control group (T=0). The treatment effect β_2 over the entire population is defined as

$$\beta_2\big|_{T=1} \quad = \quad E\left(\beta_{i,2}\middle|T=1\right) \quad = \quad E\left(r_i^{T=1}\middle|T=1\right) - E\left(r_i^{T=0}\middle|T=1\right) \qquad (6)$$

In other words, the treatment effect is defined as the difference in the expected outcome of the variable of interest (r_i) of an individual, if this one individual could be observed once in the treatment group and once in the control group. In our case, this implies that the pure industry-specific demand effect of monetary policy β_2 is the difference of the response of one firm's equity returns if it could be observed once as being in sector *T=1* and also once as being in sector *T=0*.
Of course it is not possible to measure the treatment effect *directly* since an individual can only be observed as being either in the treatment group or in the control group - i.e. only in one industrial sector - but never both. The usual way of obtaining the treatment effect is by estimating the expected treatment effect β_2^e as

$$\beta_2^e\big|_{T=1} \quad = \quad E\left(r_i^{T=1}\middle|T=1\right) - E\left(r_j^{T=0}\middle|T=0\right) \qquad (7)$$

[11] Accounting for the higher degree of collinearity within sectors for the financial constraint variables would require to include in the econometric model interaction terms for each of the 9 sectors with each of the 8 financial constraint variables in each of the 3 categorisations (low, medium, high) shown in Table 6. Hence the model would have to include at least 9x8x3 = 216 interaction terms, plus additional interaction terms to account for collinearity across some of the financial constraint variables shown in Table 5.

and assuming that

$$\beta_2\big|_{T=1} \;=\; \beta_2^e\big|_{T=1} \;\Rightarrow\; E\left(r_i^{T=0}\middle|T=1\right)=E\left(r_j^{T=0}\middle|T=0\right) \tag{8}$$

which implies that what is usually approximated as the treatment effect is the difference in the expected reaction of the variable of interest between one individual *i*, who is in the treatment group, and another individual *j*, who is in the control group.

Rubin (1977) shows that a necessary and sufficient condition for the treatment effect β_2 to be identified is that the outcome r_i for an individual *i* be independent from what group it actually belongs to conditional on a vector of covariates X_i,

$$r_{i,t}^{T=1},\, r_{i,t}^{T=0} \;\perp\!\!\!\perp\; T_i\big|X_i \quad , \quad \forall i \tag{9}$$

i.e. the outcome r_i differs across individuals only as far as they have different individual characteristics X_i. This condition is generally referred to as the "*conditional independence assumption*" (or CIA) because it entails the assumption that all relevant differences between the two outcomes r_i are fully captured by the observable and included covariates X_i.[13]

Clearly, β_2^e is a biased estimator of the true treatment effect β_2 if this assumption is violated, i.e. individuals in different groups differ along a relevant vector of covariates *X* and thus are not comparable. A common way of solving for this bias via *randomisation*, i.e. by picking individuals for the control group randomly from a large population of other individuals with the same covariates *X*.

In a non-experimental setting, as is the case for our analysis, randomisation is not an option. The alternative is the propensity score matching method, whose basic idea is that precise causal inference can be made if two observations are identical in all aspects that jointly affect treatment status and the variable of interest but differ in their treatment status. In our case, this means that we can determine the pure demand effect of monetary policy β_2 if we can compare the reaction of firms that are identical in *X* with the exception that they belong to different sectors *T*. This means that we could estimate β_2 by analyzing only those firms from our sample that are identical in their relevant individual characteristics X_i - i.e. financial constraints and Tobin's q - but belong to different sectors.

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[12] Two influential papers in the field of labour economics are by Heckman, Ichimura and Todd (1997), and by Dehejia and Wahba (2002), who use the method to assess the performance of job training programs in the United States.

5.1 Algorithm of Propensity Score Matching

However, the large *dimensionality* of our vector X makes this strategy infeasible as there are no individual firms that are exactly alike in all five financial constraint variables and Tobin's q analyzed above. The first step of the propensity score matching algorithm is therefore to reduce the dimensionality to a single dimension. This is done parametrically by estimating a parsimonious logit model

$$p(X_i) \quad = \quad \Pr(T_i = 1 | X_i) \quad = \quad \frac{e^{\mu f(X_i)}}{1 + e^{\mu f(X_i)}} \qquad (10)$$

yielding the propensity score *p*, which is the probability of an individual firm being in sector *T=1*, as compared to *T=0*, and the function $f(X_i)$ comprising the set of covariates in linear and higher-order form to obtain a parsimonious specification of the logit model.

In order to ensure that firms in different sectors with a similar propensity score are really comparable with respect to their covariates, it is then tested whether their means of the covariates are the same (a necessary condition for the "balancing property" to hold). In order to do this, the firms are grouped into strata, depending on their propensity score, where we define strata of 2.5%, i.e. 0.000-0.025, 0.025-0.050,…, 0.975-1.000, and we then conduct the tests for each stratum. Around 90% of the tests of equality of means are accepted.[14]

After the calculation of the propensity scores, the third step requires now the "matching" of the different observations. The idea is that to obtain the true treatment effect β_2, we need to compare individuals that have the same propensity scores, and differ only in their sector affiliation. The matching algorithm finds for each individual those other individuals that are identical, or at least very similar, but belong to a different sector T. For this purpose, we chose the "radius method" in which each individual *i* is matched with all those individuals *j* of one other sector whose propensity score lies within a radius or tolerance level δ from the individual's own propensity score *p*:

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[13] See e.g. Imbens (1999), who discusses the assumption also in a multivariate setting.

[14] Note that only a parsimonious logit specification yields the desired equality of means within strata. Testing different specifications showed that for our modelling a relatively simple specification is best. Our chosen logit specification includes the financial constraint and Tobin's q variables in linear form as well as the debt-to-capital ratio interacted with market value and interacted with the cashflow-to-income ratio.

$$\left|p(X_j) - p(X_i)\right| \leq \delta \qquad (11)$$

Thus the matching is conducted *with* replacement, i.e. each individual may have more than one match *m* from the other sector.[15] The matching is done for all individuals *i* in sector *T=0* and all individuals *j* in sector *T=1*. If an individual does not have any match within the tolerance level δ, it is dropped from the data.

The central objective of the matching algorithm is to create a distribution of the weighted propensity score *p* of firms *i* in sector *T=0* that is identical to the distribution for firms *j* in sector *T=1*. For this purpose, the matching procedure in (11) is used to create weights ϕ_i for each individual *i*:

$$\phi_i = 1 + \sum_j \frac{m_{ij}}{\sum_i m_{ij}} \quad \forall j \quad s.t. \quad \left|p(X_j) - p(X_i)\right| \leq \delta \qquad (12)$$

The intuition behind this weighting scheme is that the weight of each individual *i* is determined not only by the number of matches m_{ij} it has in sector *T=1*, but also by the relative importance of these matches, i.e. by how many matches the matched individuals *j* have themselves - the denominator in equation (12). Conducting the weighting for all individuals *i* and *j* therefore yields that

$$\sum_i \phi_i = \sum_j \phi_j \qquad i \in T = 0\,,\; j \in T = 1 \qquad (13)$$

i.e. the integrals of the two distributions with weighted individuals are identical. Moreover, the weighting also ensures that (13) is not only valid for the integrals, but that it holds approximately for every stratum of the distributions within the area of common support.

[15] There are different matching methods that may be used in this context. Alternatives are those that are based on matching without replacement, such as the *nearest-match method*, in which each individual *i* is matched only once with the individual *j* that is most similar. The main reason for choosing the radius method for our purpose is the disadvantage that the nearest-match method could match individuals that are quite different, hence violating the conditional independence assumption and introducing a potential bias in the estimate of the treatment effect β_2. By contrast, the radius method generates far more matches for individuals, with the potential drawback of increasing the variance of the estimator. The choice between the nearest-match method and the radius-method therefore raises a potential *bias-variance trade-off*. See Rosenbaum (1995) for a detailed discussion also of alternative matching methods.

Hence the matching algorithm is completed and has generated two identically weighted propensity score functions. This now allows obtaining an unbiased treatment effect β_2.

The final step of the propensity score matching is to extend this procedure for two sectors to a multinomial setting with nine sectors. Our extension of the binomial case to the multinomial case follows the method proposed by Lechner (2002). Imbens (1999) shows that the binomial case can be extended to the multi-treatment case so that the conditional independence assumption still holds for all sectors T

$$r_i^{T=1}, r_i^{T=2}, \ldots r_i^{T=9} \quad \perp\!\!\!\perp \quad T_i | X_i \quad , \quad \forall i \quad \forall T \tag{14}$$

To implement the algorithm, the first requirement is to repeat the above procedure for all 36 sector pairs in the data. Moreover, we need to ensure that each individual i has at least one match with *every* other sector. An individual is therefore dropped from the sample if it does not have at least one match with every other sector. Since this individual, in turn, is the match for other individuals as well, the above procedure is repeated iteratively until only those individuals are left in the sample that fulfil the matching condition with each of the other sectors.

The main challenge now is to find a transformation which makes the weighted propensity score functions comparable not only between each sector pair, but across *all* sector pairs. To do this, a scaled weight ω_i is calculated for each individual so as to obtain the same weight for each individual in all binomial sector comparisons:

$$\omega_i = \frac{\phi_i}{\left(\sum_{j=1}^{N} \phi_j\right) \Big/ N} \qquad \begin{array}{l} \forall j = 1, \ldots, N \quad s.t. \quad \left| p(X_j) - p(X_i) \right| \leq \delta \\ j \in T = 1 \end{array} \tag{15}$$

This implies that we use sector *T=1* as the base sector. All observations of sector *T=1* enter with weight one, all observations of the other sectors enter with a weight that ensures that the weighted distribution is identical to the one of sector *T=1*, and as such also identical to all sectors.

This procedure allows us to obtain an unbiased treatment effect β_2 across all sectors. We use the weights ω_i obtained from the propensity score matching as probability weights in weighted least squares regressions of equation (3) so as to be able to determine the effects of financial constraints controlling for sectoral differences, and for sector-effects controlling for heterogeneity across firm characteristics.

5.2 Empirical results

Using this new weighted sample, we repeat the same empirical exercise as for Table 2 to extract sector-specific effects of monetary policy that are cleaned from any financial constraint (and thus supply) effects, and for Table 6 to find the effects of financial constraints and Tobin's q that are free of sectoral demand effects. Using the methodology described above, with a radius of δ=0.01, yields about 55% of the observations that can be matched and thus remain in the sample.

Table 8 shows the estimates for the pure sector-specific effects of monetary policy shocks, i.e. when controlling for financial constraints and Tobin's q. Comparing the results with those of Table 2 reveals that the ranking of the sectors according to their reaction to monetary policy shocks has remained unchanged. Sectors that are the most sensitive ones are the cyclical sectors of communications, technology and cyclical consumer goods. The less affected sectors are the least cyclical ones of utilities, energy and non-cyclical consumer goods.

However, controlling for financial constraints reduces the dispersion of coefficients, which is mainly due to the smaller effects for the technology and communications sectors (although this is somewhat compensated by the larger effects found for energy and utilities). The significance of the results, in particular the differences to the average effect, shown in the second set of columns, is roughly unchanged, despite the smaller sample size. Overall, therefore, we conclude that there are strong sector-specific effects of monetary policy, with some sectors reacting two times stronger to monetary policy shocks than the average.

Table 9 shows the findings for the financial constraint variables and for Tobin's q based on the weighted sample. The results are qualitatively similar to those of the unadjusted sample of Table 6. Most importantly, firms with low cashflows and with a high Tobin's q are significantly more sensitive to monetary policy than other firms. Smaller firms are reacting significantly more to monetary policy than larger firms. The results for the debt to capital ratio are also confirmed in that firms with low debt ratios are more sensitive than firms with medium or large debt ratios. Price-earnings ratios do not seem to play a significant role for determining how firms react to monetary policy any longer when using the weighted sample.

The important change between the results based on the unweighted sample versus the weighted sample is that the *differences* of the effects of monetary policy of the financial constraints and q variables are substantially smaller under the weighted sample. In other words, firms' differences in their reaction to monetary policy shocks are frequently substantially smaller when controlling for sectoral variations in financial constraints and Tobin's q.

To gauge information about the relative importance of the sectoral or industry-specific effects versus the firm-specific effects, based on the financial constraints and Tobin's q, we re-estimate the model of equation (3) above, but now include all industry-specific and firm-specific variables and their interaction terms with monetary policy shocks.[16] We then check the overall R-squared, as well as the respective contributions from the set of industry-specific variables and the set of firm-specific variables. Overall, industry-specific effects are relatively more important in explaining the variance of equity prices than firm-specific effects. For FOMC days with monetary policy surprises, we find that industry-specific effects explain 12% of the variance of equity returns, whereas firm-specific factors account only for about 7% of the variation.

We conducted several robustness tests, including the use of different radius for the propensity score matching. Moreover, one potential disadvantage of the propensity score matching method is that some individual firms that are outliers get a very large weight, thus leading to an unnecessary increase in the variance. To avoid this drawback, we also deleted such outliers from the procedure. The results, however, proved largely robust for correcting for such outliers.

In sum, the findings confirm that both sectoral effects, on the one hand, and financial constraints and Tobin's q, on the other hand, are indeed important factors for understanding why some firms react more strongly to monetary policy than others. The greater resilience, the larger dispersion as well as the bigger explanatory power of sectoral effects suggest that it is in particular industry-specific factors that are of central importance in explaining the large heterogeneity of firms' reaction to US monetary policy shocks.

[16] At this stage, due to the orthogonality conditions of the weighted sample, it is no longer necessary to include interaction terms of sector affiliation and financial constraint variables as described in footnote 11, which makes one-step estimation feasible.

6. Conclusions

The paper has analyzed the reaction of equity markets to US monetary policy in the period 1994 till 2003. In particular, the paper has focused on the relative contributions of the credit channel and the interest rate channel of monetary policy transmission. The empirical methodology employs monetary policy surprises defined as the unexpected component of FOMC announcements on the days of policy decisions. Similar to Bernanke and Kuttner (2003), this empirical measure avoids the pitfalls of endogeneity and lack of identification, as outlined by Rigobon and Sack (2002, 2003), by instead developing and employing a truly exogenous measure of monetary policy shocks.

As to the results of the paper, we have found evidence that monetary policy affects equity markets in a strongly asymmetric fashion. The effect of monetary policy on equity markets is stronger when changes in the fed funds target rate occur and come as a surprise to market participants, when the direction of monetary policy changes, and when there is a high degree of previous market volatility.

Furthermore, monetary policy affects individual stocks in a strongly heterogeneous fashion. Industrial sectors that are cyclical and capital-intensive react frequently two to three times stronger to US monetary policy than non-cyclical industries. Looking at various measures of financial constraints we show that firms that are financially constrained respond significantly more to monetary policy than less constrained ones. A somewhat unexpected finding is that the largest effect of monetary policy is experienced by firms with a *low* level of debt, whereas firms with high levels of debt react similar to the average firm. We interpret this result as indicating that firms that have a high level of debt are *not* more constrained financially than others, but instead that firms hold low levels of debt *because* they *are* currently financially constrained and thus may not be able to borrow more. Furthermore, we find that firms with a high Tobin's q are affected more.

Finally, when accounting for the correlations between industry-affiliation and financial constraints and Tobin's q by using a sample based on propensity score matching, it turns out that the significant heterogeneity of the effects of monetary policy on individual stocks prevails. Financial constraints, Tobin's q and industry affiliation play a role, but it is in particular the latter that are of central importance in explaining the large heterogeneity of firms' reaction to US monetary policy shocks.

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Table 1: Response of S&P500 to monetary policy surprises

		Parameter estimates			Parameter estimates		Test for difference
		beta1	***t-stat***		**beta2**	***t-stat***	**p-value**[1]
(1)	General effect	-0.055 ***	*-2.890*				
(2)	No change in monetary policy	-0.010	*-0.520*	Change in monetary policy	-0.060 ***	*-2.990*	0.067 *
(3)	Change expected	-0.014	*-0.850*	No change expected	-0.089 ***	*-5.470*	0.002 ***
(4)	No directional change in mon. policy	-0.038 *	*-1.670*	Directional change in monetary policy	-0.098 ***	*-51.580*	0.009 ***
(5)	Low volatility (<10 percentile)	0.022	*1.350*	High volatility (>10 percentile)	-0.074 ***	*-4.540*	0.000 ***
(6)	Low volatility (<50 percentile)	-0.011	*-0.870*	High volatility (>50 percentile)	-0.090 ***	*-5.320*	0.000 ***
(7)	Low volatility (<80 percentile)	-0.012	*-0.940*	High volatility (>80 percentile)	-0.092 ***	*-5.370*	0.000 ***
(8)	Positive surprise	0.000	*-0.020*	Negative surprise	-0.082 ***	*-5.250*	0.002 ***
(9)	Surprise component	-0.064 ***	*-3.520*	Expected component	0.012	*1.260*	

Note:
[1] Tests the null hypothesis that beta1 and beta2 are equal.

Table 2: Sectoral effects of monetary policy

Sector	Overall effect			Difference to average			R^2
	β		*std error*	β_2		*std error*	
Technology	-0.158	***	*0.023*	-0.114	***	*0.017*	0.157
Communications	-0.117	***	*0.022*	-0.061	***	*0.017*	0.037
Consumer, Cyclical	-0.086	***	*0.019*	-0.030	***	*0.011*	0.087
Industrial	-0.069	***	*0.015*	-0.010		*0.006*	0.068
Financial	-0.053	***	*0.014*	0.008		*0.007*	0.063
Basic Materials	-0.048	***	*0.015*	0.014		*0.010*	0.052
Consumer, Non-cyclical	-0.004		*0.009*	0.069	***	*0.010*	0.000
Energy	0.008		*0.016*	0.072	***	*0.015*	0.001
Utilities	0.017		*0.015*	0.086	***	*0.016*	0.007

Note: The response of the S&P500 stocks to monetary policy surprises is estimated as $r_{i,t} = \alpha + \beta s_t + \varepsilon_{i,t}$, where $i \in sector_k$ for β in the upper panel, and $r_{i,t} = \alpha + \beta_1 s_t + \beta_2 s_t x_i + \tau x_i + \varepsilon_{i,t}$, where $i \in S\&P500$, and x_i denotes a dummy variable which takes the value of 1 for stocks of sector k, and 0 otherwise. Sample: 78 FOMC meeting dates, January 1994-February 2003.

Table 3: Effects of monetary policy by industry group

Group	Overall effect			Difference to average			R^2
	β		*std error*	β_2		*std error*	
Semiconductors	-0.210	***	*0.031*	-0.161	***	*0.025*	0.237
Internet	-0.171	***	*0.040*	-0.109	***	*0.032*	0.140
Computers	-0.142	***	*0.020*	-0.086	***	*0.014*	0.154
Telecommunications	-0.129	***	*0.027*	-0.071	***	*0.023*	0.029
Electronics	-0.127	***	*0.021*	-0.068	***	*0.014*	0.156
Software	-0.125	***	*0.025*	-0.070	***	*0.017*	0.102
Diversified Fiancial Services	-0.110	***	*0.021*	-0.055	***	*0.013*	0.140
Auto Manufacturers	-0.109	***	*0.025*	-0.048	***	*0.015*	0.140
Electrical Comp&Equip	-0.104	***	*0.020*	-0.050	***	*0.015*	0.123
Leisure Time	-0.100	***	*0.038*	-0.040		*0.029*	0.056
Auto Parts&Equipment	-0.099	***	*0.024*	-0.038	**	*0.016*	0.151
Retail	-0.093	***	*0.018*	-0.036	***	*0.011*	0.112
Home Builders	-0.087	***	*0.025*	-0.031		*0.020*	0.113
Media	-0.086	***	*0.017*	-0.025	***	*0.009*	0.127
Home Furnishings	-0.084	***	*0.021*	-0.022		*0.014*	0.130
Advertising	-0.081	***	*0.021*	-0.022		*0.016*	0.139
Airlines	-0.081		*0.054*	-0.015		*0.045*	0.024
Lodging	-0.080	**	*0.035*	-0.015		*0.027*	0.055
Trucking&Leasing	-0.072	***	*0.023*	-0.013		*0.017*	0.115
Biotechnology	-0.069	***	*0.022*	-0.009		*0.018*	0.057
Machinery-Diversified	-0.069	***	*0.018*	-0.006		*0.013*	0.093
Machinery-Constr&Mining	-0.068	***	*0.021*	-0.007		*0.017*	0.120
Packaging&Containers	-0.068	***	*0.019*	-0.010		*0.015*	0.084
Office/Business Equipment	-0.064	**	*0.029*	-0.007		*0.027*	0.042
Forest Products&Paper	-0.063	***	*0.020*	-0.001		*0.015*	0.078
Miscellaneous Manufactur	-0.062	***	*0.016*	-0.001		*0.007*	0.085
Hand/Machine Tools	-0.056	***	*0.018*	0.001		*0.013*	0.074
Apparel	-0.055	***	*0.017*	0.006		*0.013*	0.053
Commercial Services	-0.054	***	*0.012*	0.005		*0.008*	0.045
Building Materials	-0.053	***	*0.017*	0.008		*0.012*	0.076
Toys/Games/Hobbies	-0.051	**	*0.024*	0.008		*0.020*	0.042
Transportation	-0.051	***	*0.018*	0.009		*0.015*	0.056
Banks	-0.051	***	*0.014*	0.009		*0.010*	0.083
Iron/Steel	-0.051	**	*0.020*	0.016		*0.017*	0.048
Distribution/Wholesale	-0.050	***	*0.015*	0.007		*0.012*	0.085
Textiles	-0.050	*	*0.027*	0.008		*0.022*	0.043
Mining	-0.049	***	*0.017*	0.013		*0.015*	0.041
Chemicals	-0.041	***	*0.015*	0.020	**	*0.010*	0.045
Entertainment	-0.038		*0.031*	0.026		*0.025*	0.020
Real Estate Investment Trusts	-0.029	***	*0.009*	0.036	***	*0.012*	0.060
Aerospace/Defense	-0.028	**	*0.014*	0.033	***	*0.012*	0.009
Housewares	-0.026		*0.019*	0.033	*	*0.018*	0.023
Household Products/Wares	-0.025	**	*0.013*	0.037	***	*0.012*	0.017
Engineering&Construction	-0.024		*0.046*	0.044		*0.043*	0.002
Savings&Loans	-0.021		*0.020*	0.039	*	*0.023*	0.014
Environmental	-0.017		*0.029*	0.051	**	*0.026*	0.005
Insurance	-0.017		*0.014*	0.045	***	*0.007*	0.009
Oil&Gas Services	-0.011		*0.026*	0.048	**	*0.024*	0.002
Healthcare-Products	-0.009		*0.012*	0.053	***	*0.010*	0.002
Pipelines	0.000		*0.025*	0.064	**	*0.025*	0.000
Gas	0.004		*0.012*	0.069	***	*0.013*	0.001
Healthcare-Services	0.009		*0.014*	0.072	***	*0.014*	0.002
Pharmaceuticals	0.010		*0.014*	0.071	***	*0.014*	0.002
Oil&Gas	0.014		*0.016*	0.077	***	*0.015*	0.005
Food	0.015		*0.011*	0.079	***	*0.013*	0.007
Electric	0.018		*0.015*	0.087	***	*0.016*	0.008
Agriculture	0.021		*0.013*	0.084	***	*0.013*	0.013
Cosmetics/Personal Care	0.024	*	*0.013*	0.084	***	*0.014*	0.021
Beverages	0.028	**	*0.013*	0.093	***	*0.016*	0.016
Metal Fabricate/Hardware	0.035		*0.051*	0.103	**	*0.041*	0.018

Note: see table 2

Table 4: Summary statistics of Tobin's q and financial constraint variables

Full period: 1 January 1994 - 14 February 2003

	mean	standard deviation	minimum	maximum
Tobin's q	5.85	37.34	0.04	3396.17
Cashflow to income ratio	2.31	24.26	-98.00	1873.90
Price-earnings ratio	31.28	54.95	0.76	1000.00
Debt to total capital ratio	41.06	23.31	0.00	99.92
Market value	31331.79	78254.30	21.73	1189643.00
Number of employees	36563.22	68090.99	203.00	910000.00

Table 5: Cross-correlations of Tobin's q and financial constraint variables

	Tobin's q	Cashflow to income ratio	Price-earnings ratio	Debt to total capital ratio	Market value	Number of employees
Tobin's q	1					
Cashflow to income ratio	-0.0016	1				
Price-earnings ratio	0.0237	-0.0027	1			
Debt to total capital ratio	0.0362	0.0052	-0.1416	1		
Market value	0.0158	-0.0042	-0.0482	0.3716	1	
Number of employees	-0.0035	-0.0058	-0.1049	0.1834	0.5212	1

Table 6: Tobin's q, financial constraints and the effects of monetary policy

		33% - 67% categorisation[1]			10% - 90% categorisation[1]		
		$\beta_1+\beta_{z,2}$	*std error*	difference[2] p-value	$\beta_1+\beta_{z,2}$	*std error*	difference[2] p-value
Tobin's q	low	-0.044 ***	*0.008*	0.050 *	-0.055 ***	*0.009*	0.902
	medium	-0.052 ***	*0.009*	--	-0.056 ***	*0.009*	--
	high	-0.076 ***	*0.012*	0.000 ***	-0.078 ***	*0.015*	0.028 **
Cashflow to net income ratio:	low	-0.078 ***	*0.014*	0.000 ***	-0.088 ***	*0.016*	0.000 ***
	medium	-0.056 ***	*0.012*	--	-0.060 ***	*0.013*	--
	high	-0.050 ***	*0.013*	0.300	-0.047 ***	*0.015*	0.194
Price-earnings ratio	low	-0.053 ***	*0.012*	0.941	-0.066 ***	*0.015*	0.063 *
	medium	-0.053 ***	*0.012*	--	-0.054 ***	*0.012*	--
	high	-0.074 ***	*0.015*	0.003 ***	-0.092 ***	*0.019*	0.002 ***
Size: Market value	low	-0.072 ***	*0.015*	0.003 ***	-0.064 ***	*0.016*	0.546
	medium	-0.055 ***	*0.012*	--	-0.059 ***	*0.012*	--
	high	-0.055 ***	*0.012*	0.917	-0.065 ***	*0.015*	0.424
Size: Number of employees	low	-0.071 ***	*0.014*	0.011 **	-0.097 ***	*0.018*	0.000 ***
	medium	-0.054 ***	*0.012*	--	-0.056 ***	*0.012*	--
	high	-0.057 ***	*0.013*	0.601	-0.059 ***	*0.015*	0.712
Debt to total capital ratio	low	-0.080 ***	*0.015*	0.000 ***	-0.131 ***	*0.020*	0.000 ***
	medium	-0.049 ***	*0.012*	--	-0.047 ***	*0.012*	--
	high	-0.054 ***	*0.012*	0.267	-0.084 ***	*0.016*	0.000 ***
Moody's investment rating	low	-0.065 ***	*0.013*	0.000 ***			
	high	-0.038 ***	*0.010*	--			
Moody's bank loan rating	low	-0.061 ***	*0.013*	0.000 ***			
	high	-0.039 ***	*0.013*	--			

Notes:

[1] The categorisation is made according to the following specification: each firm's respective variable is defined to be "low" if it is in the bottom 33% or in the bottom 10% of the variable's distribution, "high" if it is in the top 33% or 10%, and "medium" otherwise. Categorisation for both Moody ratings is "high" if rating is in the A range, and "low" otherwise.

[2] Shows p-value of test of the null hypothesis that coefficient of low level and high level of financial constraints, respectively, is different from medium level. Test for Moody's ratings is for equality of coefficients of low rating versus high rating.

The estimated model is an extension of equation (3): $r_{i,t} = \alpha + \beta_1 s_t + \sum_{z=1,2} \beta_{z,2} s_t x_{z,i,t} + \sum_{z=1,2} \tau_z x_{z,i,t} + \varepsilon_{i,t}$, where x_1 (x_2) denotes a dummy variable that defines whether a firm belongs to the low (high) categorization.

Table 7: Comparing demand and supply effects

	Tobin's Q		Cashflow to income ratio		Price-earnings ratio	
Sectors:	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Basic Materials	3.47	3.58	2.77	20.54	33.51	64.02
Communications	7.01	12.64	3.75	53.38	57.50	101.86
Consumer, Cyclical	4.65	8.71	1.55	9.98	25.55	41.92
Consumer, Non-cyclical	10.83	78.84	1.85	16.20	28.89	32.87
Energy	2.52	1.00	3.36	12.90	41.76	69.96
Financial	3.08	3.49	2.16	20.83	20.15	35.41
Industrial	4.26	6.70	2.75	31.93	24.30	31.37
Technology	9.04	18.41	2.12	20.33	50.12	75.10
Utilities	1.82	0.93	2.26	8.27	13.57	5.82

	Debt to total capital ratio		Market value		Number of employees	
Sectors:	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Basic Materials	42.08	18.34	11760	14995	26389	27334
Communications	35.23	22.68	29630	48894	33969	49293
Consumer, Cyclical	38.38	20.14	16879	39387	78305	130059
Consumer, Non-cyclical	37.15	21.62	21967	36089	34426	51907
Energy	38.68	13.69	20550	45325	16257	22579
Financial	57.29	27.20	91246	153070	23103	35106
Industrial	38.89	19.27	19727	66621	47191	62695
Technology	20.44	19.13	21665	50328	21173	41898
Utilities	56.28	10.06	16461	10918	10910	6418

Table 8: Sectoral effects of monetary policy *after* Propensity Score Matching

Sector	**Overall effect**			**Difference to average**			R^2
	b		***std error***	b_2		***std error***	
Technology	-0.109	***	*0.021*	-0.073	***	*0.016*	0.080
Communications	-0.091	***	*0.023*	-0.051	***	*0.015*	0.062
Consumer, Cyclical	-0.089	***	*0.019*	-0.045	***	*0.013*	0.086
Industrial	-0.070	***	*0.016*	-0.028	***	*0.008*	0.077
Financial	-0.047	***	*0.016*	-0.001		*0.010*	0.025
Basic Materials	-0.032	***	*0.012*	0.012		*0.009*	0.047
Consumer, Non-cyclical	-0.008		*0.009*	0.045	***	*0.009*	0.001
Energy	0.022		*0.017*	0.076	***	*0.017*	0.007
Utilities	0.046	***	*0.017*	0.096	***	*0.019*	0.032

Note: See Table 2 for explanation of the model.

Table 9: Effects of Tobin's q and financial constraints *after* Propensity Score Matching

		33% - 67% categorisation[1]			10% - 90% categorisation[1]		
		$\beta_1+\beta_{z,2}$	*std error*	difference[2] p-value	$\beta_1+\beta_{z,2}$	*std error*	difference[2] p-value
Tobin's q	low	-0.047 ***	*0.013*	0.037 **	-0.049 ***	*0.015*	0.260
	medium	-0.032 ***	*0.012*	--	-0.039 ***	*0.012*	--
	high	-0.055 ***	*0.015*	0.002 ***	-0.090 ***	*0.021*	0.000 ***
Cashflow to net income ratio:	low	-0.059 ***	*0.014*	0.001 ***	-0.060 ***	*0.016*	0.078 *
	medium	-0.031 **	*0.013*	--	-0.042 ***	*0.013*	--
	high	-0.044 ***	*0.013*	0.023 **	-0.050 ***	*0.015*	0.235
Price-earnings ratio	low	-0.039 ***	*0.012*	0.552	-0.039 ***	*0.013*	0.664
	medium	-0.043 ***	*0.013*	--	-0.043 ***	*0.013*	--
	high	-0.051 ***	*0.015*	0.300	-0.060 ***	*0.018*	0.166
Size: Market value	low	-0.059 ***	*0.014*	0.001 ***	-0.052 ***	*0.015*	0.325
	medium	-0.038 ***	*0.013*	--	-0.043 ***	*0.013*	--
	high	-0.037 ***	*0.013*	0.848	-0.051 ***	*0.017*	0.416
Size: Number of employees	low	-0.033 **	*0.013*	0.026 **	-0.020	*0.016*	0.017 **
	medium	-0.048 ***	*0.012*	--	-0.046 ***	*0.012*	--
	high	-0.049 ***	*0.013*	0.908	-0.053 ***	*0.015*	0.304
Debt to total capital ratio	low	-0.064 ***	*0.015*	0.000 ***	-0.074 ***	*0.018*	0.004 ***
	medium	-0.040 ***	*0.012*	--	-0.042 ***	*0.013*	--
	high	-0.030 **	*0.012*	0.102	-0.036 **	*0.016*	0.690

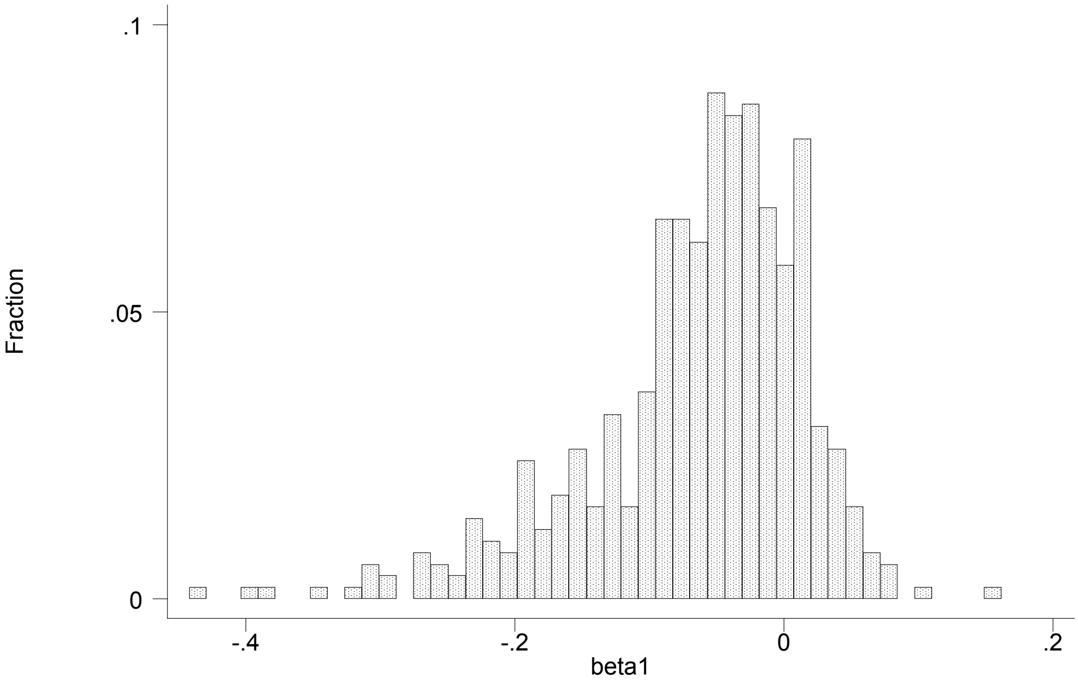
Notes:

[1] The categorisation is made according to the following specification: each firm's respective variable is defined to be "low" if it is in the bottom 33% or in the bottom 10% of the variable's distribution, "high" if it is in the top 33% or 10%, and "medium" otherwise.

[2] Shows p-value of test of the null hypothesis that coefficient of low level and high level of financial constraints, respectively, is different from medium level.

See Table 6 for an explanation of the model. However, the model estimated uses the weighted sample, with the weights obtained from the propensity score matching method.

Figure 1: Distribution of monetary policy effects across S&P500 stocks



Appendix

Table A1: Test of unbiasedness of expectations of monetary policy announcements

α	t-stat	β	t-stat	R^2	Wald test	p-value
-0.013	-1.01	1.039	17.19	0.795	0.73	[0.483]

Following Gravelle and Moessner (2001), Table A1 shows the results for the test whether the expectations of monetary policy announcements are unbiased, based on the following equation:

$$A_{k,t} = \alpha + \beta E_{k,t} + \varepsilon_{k,t} \tag{A.1}$$

The unbiasedness test is a Wald test of the joint hypothesis H_0: $\alpha=0$ and $\beta=1$. This hypothesis cannot be rejected at the 90% level.

Table A2: Test of efficiency of expectations of monetary policy announcements

R^2	Wald test	p-value
0.078	0.92	[0.486]

The expectations are efficient if forecast errors of monetary policy decisions ($A_{k,t}$ - $E_{k,t}$) cannot be predicted systematically on the basis of past announcements:

$$A_{k,t} - E_{k,t} = \zeta + \sum_{p=1}^{P} \psi_p A_{k,t-p} + \varepsilon_{k,t} \tag{A.2}$$

with the lag length usually chosen as P=6. The hypothesis to be tested is $\psi_1 = \psi_2 = \ldots = \psi_P = 0$. The Wald tests show that this hypothesis cannot be rejected for the expectation series.

Table A3: Response of S&P500 to monetary policy surprises (defined as monetary policy announcements minus the median of Reuters survey expectations)

		Parameter estimates			Parameter estimates		Test for difference
		beta1	*t-stat*		beta2	*t-stat*	p-value[1]
(1)	General effect	-0.058 ***	*-3.760*				
(2)	No change in monetary policy	0.006 ***	*2.910*	Change in monetary policy	-0.062 ***	*-4.080*	0.000 ***
(3)	Change expected	-0.011	*-0.550*	No change expected	-0.084 ***	*-7.450*	0.001 ***
(4)	No directional change in mon. policy	-0.051 ***	*-2.910*	Directional change in monetary policy	-0.098 ***	*-48.930*	0.007 ***
(5)	Low volatility (<10 percentile)	0.022 *	*1.650*	High volatility (>10 percentile)	-0.075 ***	*-6.300*	0.000 ***
(6)	Low volatility (<50 percentile)	0.000	*0.040*	High volatility (>50 percentile)	-0.090 ***	*-8.840*	0.000 ***
(7)	Low volatility (<80 percentile)	-0.030	*-1.430*	High volatility (>80 percentile)	-0.098 ***	*-7.560*	0.006 ***
(8)	Positive surprise	-0.014	*-0.600*	Negative surprise	-0.077 ***	*-5.810*	0.017 **
(9)	Surprise component	-0.064 ***	*-4.720*	Expected component	0.015 *	*1.830*	

Note:
[1] Tests the null hypothesis that beta1 and beta2 are equal.

Table A4: Response of S&P500 to Kuttner (2001) monetary policy surprises

		Parameter estimates			Parameter estimates		Test for difference
		beta1	*t-stat*		beta2	*t-stat*	p-value[1]
(1)	General effect	-0.077 ***	*-4.390*				
(2)	No change in monetary policy	0.006	*0.380*	Change in monetary policy	-0.096 ***	*-6.190*	0.000 ***
(3)	Change expected	-0.053 **	*-2.490*	No change expected	-0.114 ***	*-7.260*	0.019 **
(4)	No directional change in mon. policy	-0.083 ***	*-4.400*	Directional change in monetary policy	-0.128 ***	*-26.150*	0.020 **
(5)	Low volatility (<10 percentile)	0.003	*0.100*	High volatility (>10 percentile)	-0.092 ***	*-6.110*	0.005 ***
(6)	Low volatility (<50 percentile)	-0.016	*-0.910*	High volatility (>50 percentile)	-0.106 ***	*-7.520*	0.000 ***
(7)	Low volatility (<80 percentile)	-0.049 **	*-2.290*	High volatility (>80 percentile)	-0.122 ***	*-8.000*	0.005 ***
(8)	Positive surprise	-0.008	*-0.220*	Negative surprise	-0.092 ***	*-5.910*	0.025 **
(9)	Surprise component	-0.113 ***	*-8.010*	Expected component	0.025 ***	*3.180*	

Note:
[1] Tests the null hypothesis that beta1 and beta2 are equal.

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