The response of multinationals' foreign exchange rate exposure to macroeconomic news*

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Abstract

We use intraday data to estimate the daily foreign exchange exposure of US multinationals. We show that macroeconomic news releases information that affects the foreign exchange exposure of multinationals' value. It leads to a substantial shift in the joint distribution of stock and exchange rate returns on the day of the announcement. This shift has both a transitory and persistent component. Specifically, higher-than-expected nonfarm payroll and federal funds target interest rates lead to a persistent decrease of the foreign exchange rate exposure.

Keywords: Foreign exchange exposure, high-frequency data, macroeconomic news.

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1 Introduction

Changes in foreign exchange rates affect the cash flows and the value of internationally active firms. The exposure of firms to foreign exchange rates varies over time and is not directly observable, and therefore is challenging to estimate (see, Jorion, 1990, Boudt et al., 2015). Previous empirical work has dealt with time variation by splitting the sample (e.g., Jorion, 1990, Williamson, 2001), or using rolling windows (e.g., Glaum et al., 2000) or taking a parametric approach (e.g., Boudt et al., 2015). The availability of intraday data and recent advances in econometric techniques, permits us to estimate the time variation in the foreign exchange rate exposure more precisely.

The present paper extends the existing literature by using intraday exchange rate and stock price data to estimate the time-varying foreign exchange exposure of 182 S&P 500 US multinationals over the period 2008–2014 sample more precisely and in a more timely manner. On average, these firms have a positive exposure, meaning that their stock prices benefit from a US dollar depreciation.

We identify several macroeconomic announcements that systematically affect foreign exchange rate exposure. In particular, nonfarm payroll (NFP) and Federal Open Market Committee (FOMC) target announcements are important sources of information. Foreign exchange rate exposures decrease persistently following positive nonfarm payroll and FOMC target announcements. This is consistent with the information provided by a higher-than-expected nonfarm payroll or FOMC target announcement: both signal a strengthening domestic economy, and therefore an increase in the relative importance of the domestic and import activities of the firm, and hence a decrease in the exposure. In contrast to the persistent effects of NFP and FOMC announcements, price index announcements, such as export price and producer price index surprises, have a significant transitory impact on exposure. A positive price index surprise, temporarily decreases the foreign exchange rate exposures. Sectors exhibit some differences in the responses, though most conclusions hold generally.

The existence of both persistent and transitory news effects on exposure suggests to us that announcements provide information on two unobservable and time-varying variables: the state of the economy and the sensitivity of the firm's stock price to changes in the exchange rate. The information pertaining to the state of the economy should have a transitory effect on the exchange rate and stock returns while the information on the sensitivity of the stock price to the exchange rate should persistently affect the foreign exchange rate exposure of the firm.

A fairly large literature studies the effects of macroeconomic and policy announcements on asset prices, including stock returns and foreign exchange rates. Andersen et al. (2003, 2007) find that macroeconomic news is quickly incorporated into both stock prices and foreign exchange rates. Lahaye et al. (2011) extend that line of research to associate cojumps in stock prices, interest rates and foreign exchange rates with macroeconomic news releases. Mun (2012) finds similar results in the joint response of foreign exchange rates and stock markets to macro announcements. (Bauer and Neely, 2014, Dewachter et al., 2014, Neely, 2015) research central bank communications and policy effects on stock price and foreign exchange movements.

There is also a substantial literature that characterizes foreign exchange rate exposure dynamics. While the theoretical literature rationalizes foreign exchange exposure for multinational firms (see, e.g., Shapiro, 1975), it has been difficult to empirically identify significant foreign exchange rate exposures.[1] Some authors have modeled exchange rate exposure dynamics as a function of industry and firm structure (see, e.g., Allayannis and Ihrig, 2001, Bodnar et al., 2002, Dominguez and Tesar, 2006, Doukas et al., 2003, Gao, 2000, Williamson, 2001). Jorion (1990) finds that the exchange rate exposure depends on the economic development. He and Ng (1998) relate exposure to the relative importance of foreign activities and the firm's hedging behaviour. Francis et al. (2008) and Chaieb and Mazzotta (2013) find that firm and industry characteristics explain cross-sectional differences but not the exposure dynamics. Instead, they find that the time variation in the exposure in contrast is related to shifts in macroeconomic conditions. Chaieb and Mazzotta (2013) show that exposure of multinational firms increases in times of domestic recessions. Boudt et al. (2015) show that the firm's exposure depends on the moneyness of the option to export.

Our paper connects these two literatures on announcement effects on asset prices and foreign exchange exposure by linking foreign exchange rate exposure dynamics to news on macroeconomic conditions. We estimate the impact of macro announcements on the firm's foreign exchange rate risk rather than the impact of news on aggregated stock markets and foreign exchange rates separately. In fact, the joint reactions, are the very reason for an immediate, short-lived change in the exposure. For example, if macroeconomic news depreciates the currency and increases the firm's value, we would expect that to show up as a transitory increase in the exposure over the day of the announcement.

[1] Bartram and Bodnar (2007) provide an extensive literature review on the foreign exchange rate puzzle.

The remainder of the paper proceeds as follows. Section 2 provides an overview of the literature and develops the hypotheses. Section 3 discusses the data and methodology. Section 4 presents the estimated foreign exchange rate exposures. Section 5 characterizes the foreign exchange rate exposure dynamics. Section 6 further analyzes the foreign exchange rate exposures of sectors, firms reporting high and low foreign sales, the incremental foreign exchange rate exposure and the impact of the choice of the estimator. Section 7 concludes.

2 Definitions and hypothesis development

2.1 Definitions

One can define a firm's foreign exchange rate exposure as either the *total* exposure or the *incremental* exposure to exchange rate changes (see, e.g., Bodnar and Wong, 2003). Adler and Dumas (1984) define a firm's *total* foreign exchange rate exposure as the elasticity of that firm's value to changes in the exchange rate. More precisely, let $V_{i,t}$ be the value of firm i at time t and S_t the spot exchange rate expressed in units of domestic currency per unit of foreign currency. Then, the foreign exchange rate exposure of firm i at time t, $\delta_{i,t}$, is given by the total derivative of the firm's value (in log) with respect to the exchange rate (in log):

$$\delta_{i,t} = \frac{d \log V_{i,t}}{d \log S_t}. \tag{1}$$

Alternatively, one could use partial differentials in order to control for other effects on firm value such as changes in the aggregate market valuation (Jorion, 1990). This leads to the definition of the *incremental* exposure, i.e., the firm's exposure different from the market's exposure. We discuss the *incremental* exposure in Subsection 6.3.

In our main analysis, we use the *total* exposure as it corresponds to the parameter of interest for hedging purposes (see, e.g., Liu et al., 2015, for a detailed discussion). Investors looking to hedge their portfolio using currency derivatives are interested in understanding the total effects of changes in the foreign exchange rate on their portfolio's value. Also, it is an important risk management tool for the firm's management as it gives an aggregate view on the total sensitivity of the firm's value to changes in the foreign exchange rates.

In order to understand the effect of macroeconomic news, we rewrite the total firm value as the value of the firm's divisions with a positive exposure coefficient, i.e., those in exporting or import-substituting activities (subscript x), the divisions with a zero coefficient, i.e., those in a non-tradeable division in a sheltered sector (subscript d), and the firms with a negative exposure coefficient, i.e., those that engage in activities that rely on imported inputs or have the option to import instead of buying or producing locally (subscript m):

$$V = V_x + V_m + V_d,$$

where, for simplicity in notation, we omit the subscript i for the firm and the subscript t for the time. It then follows that the firm's exposure coefficient is the weighted sum of the exposure coefficients of the divisions with a positive and negative exposure coefficients, and that the coefficient changes when the weights change or the exposure coefficients of the divisions change:

$$\begin{aligned}
\delta = \frac{d\log V}{d\log S} &= \frac{1}{V}\frac{d(V_x + V_m + V_d)}{d\log S} \\
&= \frac{V_x}{V}\frac{1}{V_x}\frac{dV_x}{d\log S} + \frac{V_m}{V}\frac{1}{V_m}\frac{dV_m}{d\log S} \\
&= w_x\frac{d\log V_x}{d\log S} + w_m\frac{d\log V_m}{d\log S} \\
&= w_x\delta_x + w_m\delta_m, \qquad (2)
\end{aligned}$$

where $w_x = V_x/V$, $w_m = V_m/V$ (the weights at the beginning of the period) and where we use that $\delta_d = dV_d/d\log S = 0$, by definition of the domestic division. A net exporting firm thus has a positive exposure and thus benefits from a foreign currency appreciation. Following the same arguments, a net importer has a negative exposure.

This decomposition formalizes the intuition that the relative weight of the export and import activities, as influenced by the level of the exchange rate, determines the value of the exchange rate exposure. When S changes, the relative weights for the next period change too. The decomposition in Equation 2 forms the basis for most of the hypotheses that we develop in the next section.

2.2 Hypothesis development

In this paper, we study the day-by-day foreign exchange rate exposures of multinational firms. Even though we estimate the foreign exchange rate exposure on a day-by-day basis, we expect that these foreign exchange rate exposures are persistent, i.e., autocorrelated. Changes in the firms competitive position influence the firm's production and selling strategy. However, entering a foreign market or expanding the production capacity requires often time and irreversible investments, while changes in the exchange rate might quickly reverse. We therefore expect that the adjustment of a firms import/export strategy is sluggish and that the firm's exchange rate exposure therefore exhibits short term persistency. This leads us to the following hypothesis:

Hypothesis 1: *The time-varying foreign exchange rate exposure of an internationally active firm is characterized by a positive serial correlation.*

The central question in this paper is how the release of macroeconomic news affects the foreign exchange exposure. We distinguish between a short-lived transitory effect and a persistent effect. A transitory shift in exposure arises because on announcement day the joint distribution of $(r_{i,t}, s_t)$ is not likely to be the same as on average days. The phenomenon is familiar in its univariate form in the case of, say, earnings announcements: the standard deviation is higher, *ex ante* and as well as *ex post*, than on regular days. Similarly, on days when a macro news item is divulged that meaningfully affects both the stock's price and the exchange rate, these joint movements tend to be larger, in absolute terms, than on uneventful days. If the news pushes the exchange rate and the stock's value in the same direction, the result may be an above-average δ, and *vice versa*. The next day, however, we are back to the regular regime. Note, however, that a higher standard deviation is not sufficient: from $\delta_i = \rho_{is}\sigma_i/\sigma_s$, if both sigmas rise by the same factor and the correlation is constant, δ_i is unaffected. For a higher exposure we need a higher correlation, and/or a bigger increase in sigma for the stock's return than for the exchange rate. So the existence of a temporary effect is an empirical question; there is no strong prior.

Persistent shifts in exposure are more interesting. They reflect the combined effect of changes in the relative weights of the generic divisions — export (subscript x), domestic (subscript d), and imports (subscript m) —and in these divisions' individual exposures. Suppose, for instance, that

there is negative news about the U.S. economy, which makes the dollar fall. The poor prospects for domestic sales reduces the value of the domestic division, while the falling dollar improves the prospects about the cash flows from exports and hurts those from imports. The joint effect is that the weight attached to the (positive) δ_x increases while the weights for the low or negative δ_d and δ_m fall, resulting in a higher average delta.

One could object that the assumption of constant divisional exposures δ_x, δ_d and δ_m, as implicitly made in the above paragraph, is unconvincing. In a regular call option model, for instance, the call's beta falls when the underlying stock rises, because the rise in its delta[2] is more than undone by the rise in the call's price. On reflection, this objection is not convincing: while exposure δ_x may fall as S rises, any such effect ought to be weaker than the rise in the weight w_x. To show this, consider a firm with an export and a domestic activity. (The presence of an import second would reinforce the argument, but is not even needed). Real option pricing theory would predict that when S drops further and further, the export part keeps losing value, as follows: (i) the value of the firm as a whole smoothly converges to V_d, and (ii) the export division's delta smoothly approaches that of the domestic division too, zero. It follows that the elasticity of V drops to zero:[3]

$$\lim_{S\to 0} \frac{\mathrm{d}(V_d + V_x)}{\mathrm{d}S} \frac{S}{V_d + V_x} = 0 \times \frac{0}{V_d} = 0. \tag{3}$$

At the other end, when S is extremely high, the prospects of abandoning exports in the foreseeable future are too low to have a big impact on valuation. So in the limit the value of an extremely in-the-money exporting division would converge to the present value (PV) of a perpetual foreign-currency stream (the maximal sales revenue, worth $S \times PV^*$) minus the PV of a perpetual stream of the corresponding domestic-currency production costs, worth PV, without any option to ever abandon

[2] In this paragraph, by delta (as opposed to δ) we mean the option delta, $\partial C/\partial S$.

[3] For compactness, we use standard calculus; the derivation in stochastic calculus is available on request. Note that our point is about the δ for the entire firm, not for V_x.

exports again.[4], Then

$$\begin{aligned}\lim_{S\to\infty}\delta_x &= \lim_{S\to\infty}\frac{\mathrm{d}(PV^*S-PV+V_d)}{\mathrm{d}S}\frac{S}{PV^*S-PV+V_d},\\ &= \lim_{S\to\infty}\frac{PV^*S}{PV^*S-PV+V_d}\\ &= 1. \end{aligned} \tag{4}$$

In short, the overall δ smoothly moves from 0 (when $S\to 0$) to unity (when $S\to\infty$);[5] we do not need to know how much of that comes from weights (w_x, w_d, w_m) from changing δs, nor indeed whether the divisional δs rise or fall.

Based on these arguments, we state following hypotheses:

Hypothesis 2a: *Macroeconomic news provides investors with information about the value of the firm and the exchange rate that leads to an immediate, but transitory effect on the foreign exchange rate exposure.*

Hypothesis 2b: *Macroeconomic news provides investors with information about the sensitivity of the firms value to changes in the exchange rate that persistently affects the foreign exchange rate exposure.*

We distinguish between different types of macroeconomic announcements which can affect the foreign exchange rate exposure of a firm, namely: real activity, inflation, trade and Federal Open Market Committee (FOMC) announcements on the federal funds target rate and 10-year yield shocks. Neely and Dey (2010) review the literature on the effects of macroeconomic announcements on foreign exchange rates. Andersen et al. (2003, 2007) and Lahaye et al. (2011) study the intraday announcement effects on both stock prices and foreign exchange rates. Mun (2012) discusses the joint effects of macroeconomic announcements on stock prices and foreign exchange rates.

[4] We use a simplified version of the model of Sercu and Van Hulle (1992), which features a mothballing stage between active exporting and abandoning exports.

[5] This is for the firm as a whole. Levered stock would have higher exposure.

3 Data and methodology

This section introduces the methodology used to estimate the daily foreign exchange rate exposure coefficient using high-frequency data. We then describe the sample of firms, foreign exchange rate data, and the macroeconomic announcements. Third, we present the equation that relates the macroeconomic news announcements to the dynamics in the daily foreign exchange rate exposures.

3.1 Estimating the time-varying foreign exchange rate exposure

The foreign exchange exposure coefficient $\delta_{i,t}$, as defined in (1), is of course not directly observable. When one assumes the exposure coefficient to be static, it is common to follow Adler and Dumas (1984) and estimate $\delta_{i,t}$ as the ordinary least squares (OLS) estimate of the slope coefficient of the regression of the log returns of stock i on the log returns of the foreign exchange rate. The resulting estimate can then be interpreted as the minimum variance hedging ratio (Johnson, 1960, Stein, 1961, Dumas, 1978).[6]

In order to account for the time variation in $\delta_{i,t}$, previous studies either split their sample or use rolling estimation windows (see, e.g., Jorion, 1990, Bartram and Bodnar, 2012). This unrealistically assumes that parameters are constant over relatively long time periods. In this paper, we use intraday price data to obtain timely and precise estimates of the exchange rate exposure. Figure 1 illustrates the intraday data. $r_{i,t}$ denotes the open-to-close log return on day t, and $r_{i,t,k}$ is the log return of stock i during the k^{th} intraday period on day t, and $k = 1,\ldots,K$. From the additivity of log returns, it follows that $r_{i,t} = \sum_{k=1}^{K} r_{i,t,k}$. $s_{t,k}$ denotes the log return on the exchange rate or index of exchange rates over the same time interval as $r_{i,t,k}$.

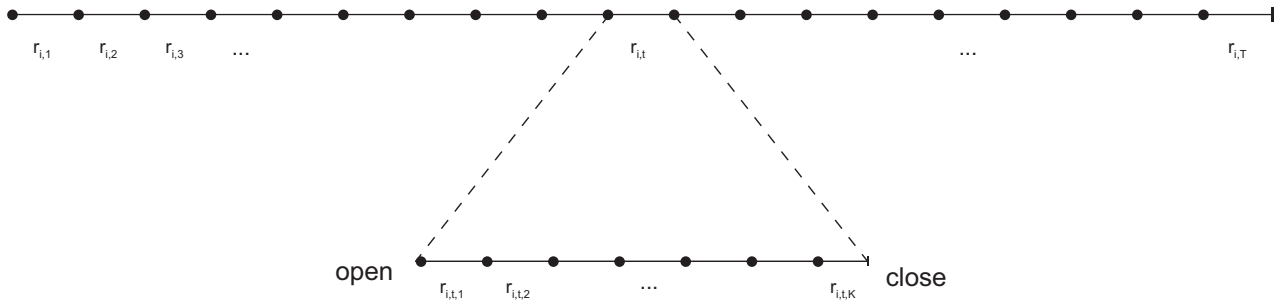
For each day t, we regress the intraday stock returns of firm i on the intraday exchange rate returns:

$$r_{i,t,k} = \alpha_{i,t} + \delta_{i,t} s_{t,k} + \varepsilon_{i,t,k}\,, \tag{5}$$

for intraday periods $k = 1,\ldots,K$, and where $\varepsilon_{i,t,k}$ denotes the error term. To mitigate problems from microstructure noise or non-synchronous trading, we sample the stock price data and prices of the

[6] Often, the Adler-Dumas model is extended with a market index. We discuss the foreign exchange rate exposures estimated using this model in Section 6.

Figure 1: The calculation of intraday stock returns.



exchange rate index every ten minutes between 9:30 a.m. EST and 4:00 p.m. EST. One trading day thus consists thus of 39 ten-minute return observations. Section 3 details the data.

The literature on realized regressions and realized beta estimation (see, e.g., Barndorff-Nielsen and Shephard, 2004, Andersen et al., 2006, Patton and Verardo, 2012) has also used high frequency data to estimate of the stock's beta coefficient in the market model. This literature has tremendously improved methods to estimate jumps in the presence of microstructure noise and non-synchronous trading (see, e.g., Todorov and Bollerslev, 2010, Boudt et al., 2017, and the references therein). In contrast with the realized beta literature, we do not impose the mean return to be zero, but follow the traditional setup of Adler and Dumas (1984) and regress the K equally spaced intraday stock on the foreign exchange rate returns using OLS. This method should be robust against local trends in the 10-minute price data used (Barndorff-Nielsen et al., 2009) and the OLS approach exactly decomposes the exposure coefficient into a common exposure and firm-specific exposure, as shown by the Frisch and Waugh (1933)- Lovell (1963) theorem, which we discuss in Subsection 6.4. In the robustness section, we also consider the alternative of using a jump- and outlier-robust estimator.

3.2 Data

Our raw sample is comprised of 676 US firms that were included in the S&P 500 index at one point between May 2008 and December 2014 (1,672 trading days). We exclude financial firms from the sample and restrict our sample to internationally active firms by requiring that the firms' foreign sales relative to total sales exceed 10% for each year over our sample period (see Jorion, 1990, Allayannis and Ofek, 2001, among others). After applying these criteria, we obtain a sample of 182 firms; Table 1 describes these 182 firms. The average annual foreign sales ratio is 50%, substantially exceeding the

Table 1: Firm specific characteristics for annual foreign-sales-to-total-sales ratio and market capitalization of the 182 US firms between 2008-2014. This table shows, for each year between 2008-2014, the average, first, second and third quartile of the annual foreign sales relative to total sales ratio and of the annual market capitalization, together with the average total weight the 182 firms represent in the S&P 500 index (in %).

	Foreign sales (%)				Market cap (in $bio)				Weight in S&P 500
	Mean	Median	25%	75%	Mean	Median	25%	75%	Mean (%)
2008	47.08	46.59	31.01	60.88	31.93	34.34	26.27	35.77	57.20
2009	47.16	47.00	30.94	60.94	27.59	27.45	25.03	30.37	58.78
2010	48.57	47.00	30.78	63.43	32.88	32.85	31.50	34.26	57.33
2011	50.01	49.29	34.50	49.30	37.07	37.39	36.01	38.34	53.90
2012	50.33	49.49	34.48	49.49	39.43	39.52	38.65	40.24	55.89
2013	49.22	47.79	31.91	47.79	44.15	44.13	42.18	45.50	53.31
2014	49.17	48.29	32.48	48.29	49.05	49.15	48.25	49.97	52.92

required 10%. These firms represent over 55% of the S&P 500, on average, between 2008 and 2014. Thomson Reuters Datastream provides the accounting data, including total and foreign sales, which are available on an annual basis. CRSP provides data on the stocks' market capitalizations. The Trades and Quotes (TAQ) database provides high-frequency stock price data.

Olsen and Associates provide the exchange rate series. The exchange rate return is the return on an trade-weighted index defined as units of USD per unit of a basket of foreign currencies. An increase (decrease) in the index refers to a depreciation (appreciation) of the USD relative to the basket of foreign currencies. The Federal Reserve provides annually revised currency weights, which Table 11 in Appendix A.1 reports. Figure 2 plots the prices of the trade-weighted index over the sample period. The dollar both appreciates and depreciates over the sample.

The International Money Market Services (MMS) provides data on the expected (surveyed) and realized macroeconomic indicators, which we select on the basis of previous studies and which Table 2 summarizes.[7] Table 3 provides an overview of the sequence of these scheduled macroeconomic news releases within a quarter. In our sample, nonfarm payroll news is released first in a month, followed by the trade balance, the export price index, the consumer price index and the producer price index announcements. The sequence of the price index releases is not fixed. The price index announcements refer to the most recently completed month while the trade balance figures are more lagged and refer to the month before the most recently completed. GDP announcements are released at least one month after the end of the quarter in three revisions that each estimate the same quantity, the GDP of the previous quarter, with progressively larger information sets. The first an-

[7] Definitions of the macroeconomic indicators are included in the Appendix A.2.

Figure 2: Trade-weighted exchange rate index over period May 2008 to December 2014. The rates are expressed in US dollars per unit of foreign currencies.

nouncement is the advanced GDP announcement, reported with a one-month lag, followed by two revisions: GDP preliminary and GDP final, with a two- and three-month lag, respectively. We pool the three GDP announcements and consider them as one for parsimony's sake. The FOMC meets every six weeks. FOMC announcements are forward looking announcements that provide news on the monetary policy implemented by the Federal Reserve Bank. We distinguish between target federal funds rate announcements and unconventional policy announcements that influence the ten-year yield. When the FOMC target rate approached the zero lower bound at the end of 2008, the Federal Reserve began to implement unconventional policies (Wright, 2012) such as quantitative easing and forward guidance to influence long-term yields (Kiley, 2014). Researchers, such as Bauer and Neely (2014), have concluded that changes in the ten-year yield measure the unconventional monetary policy surprises.

As in Balduzzi et al. (2001), we standardize the announcements by subtracting the MMS survey expectation and dividing that quantity by it's own sample standard deviation. This makes the announcement coefficients in the regression more easily comparable. The surprise $Surp_{j,t}$ for funda-

Table 2: Macroeconomic announcements. The table provides an overview of the scheduled macroeconomic announcements included in the analysis over the period 2008-2014. Frequency: the frequency at which news on the fundamental is announced with Q: quarterly, M: monthly and 6 weeks: every 6 weeks. Time: announcement time in Eastern Standard Time (EST). First release: first release date of announcement in our sample. Observations: total number of observations. Mean: average surprise. # pos.: number of positive surprises. #neg: number of negative surprises.

Announcements	Variable name	Frequency	Time (EST)	First release	Observations	Mean	# pos.	# neg.
Real activity announcements								
Real GDP Advance	GDP Adv	Q	8 : 30	07-31-2008	26	0.08	11	12
Real GDP Preliminary	GDP Prel	Q	8 : 30	05-29-2008	27	−0.08	10	13
Real GDP Final	GDP Fin	Q	8 : 30	09-26-2008	27	−0.24	8	14
Employees on nonfarm payrolls	NFP	M	8 : 30	06-06-2008	79	−0.14	34	44
Inflation announcements								
Consumer price index	CPI	M	8 : 30	05-14-2008	80	−0.10	21	34
Producer price index	PPI	M	8 : 30	05-20-2008	80	0.03	35	37
Export price index	EXPPI	M	8 : 30	05-13-2008	80	−0.08	41	35
Trade announcements								
Trade Balance	TRADE	M	8 : 30	05-09-2008	80	0.08	42	38
Federal Open Market Committee (FOMC)								
Federal funds target	FOMC TARGET	6W	14 : 15	06-25-2008	52	0.20	48	4
Federal funds 10-y yield	FOMC 10y	6W	14 : 15	06-25-2008	52	0.06	25	27

mental j $(j = 1, ..., J)$ at day t is:

$$Surp_{j,t} = \frac{A_{j,t} - E_{j,t}}{\hat{\sigma}_j}, \tag{6}$$

where $A_{j,t}$ is the announced value of fundamental j at day t, $E_{j,t}$ is the survey expectation, and $\hat{\sigma}_j$ is the sample standard deviation of the surprise component for fundamental j.

3.3 Modelling the macroeconomic effects on the foreign exchange rate exposure

To test the hypotheses on the effects of macroeconomic news on exchange rate exposure dynamics, we must define the functional relationship linking the macroeconomic news to that exposure. In our main analysis, we test our hypotheses using the cross-sectional average exposure coefficient as the dependent variable:

$$\bar{\delta}_t = \frac{1}{N} \sum_{i=1}^{N} \hat{\delta}_{t,i}, \tag{7}$$

with N the number of firms in our sample. We will show in Section 4 that the average exposure usefully summarizes the substantial common inter-temporal covariation in the cross-section of expo-

Table 3: The sequence of the macroeconomic announcements within a quarter. The table provides an overview of the sequence of the macroeconomic announcements within a quarter. M1, M2, M3 represent the first, second and third month of a quarter. Gross domestic product (GDP) announcements are released quarterly in three stages: GDP advanced, GDP preliminary and GDP final, one month, two months and three months after the end of the quarter, respectively. Nonfarm payroll (NFP), consumer price index (CPI), producer price index (PPI), export price index (EXPPI) and trade balance (TRADE) are monthly announcements. The FOMC meets every six weeks. The integers in the table show the number of announcements of the particular type that occurred on the day (top rows) in the given month (left column).

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
GDP	**M1**																										2	4	3	5	1	1
	M2							1															1	1	1	3	3	4	4	7	1	1
	M3					1															2		3	2	1	4	7	2	2	2	2	
NFP	**M1**	1	2	3	3	2	3	3	3	2	2												1									
	M2	2	2	3	4	3	4	5	2																							
	M3	1	1	2	4	5	5	4	2	2																						
CPI	**M1**													1	3	7	9			3			1								1	
	M2													1	1	4	2	5	1	4	6	2										
	M3													1	2	4	5	7	7													
PPI	**M1**											1	3	2	3	8			3		3		1							1		
	M2											1	1		3	2	5	1	5	4	3	1										
	M3												2	4	7	4	4	5														
EXPPI	**M1**									1	3	5	3	4	8									1								
	M2									1	4			7	7	3		2	2													
	M3										2	3	6	7	3	3	2															
TRADE	**M1**			2		1		2		2	1	3	4	8	1										1							
	M2		1		1		3		3	1	7	5	2	2	1																	
	M3				3	1		4	1	4	7	4		2																		
FOMC	**M1**																1								1	2	1	2	4	2	6	
	M2	3	1	1	1	1				1	1		1																1			
	M3				1								1	3	1	1	4	2	5	1	2	2	1	3		1						

sure coefficients. We will also consider several exposure measures based on industry and intensity of foreign sales.[8]

The model linking the surprises in the macroeconomic announcements ($Surp_{j,t}$) to the average foreign exchange rate exposure coefficient ($\bar{\delta}_t$) needs to be flexible enough to capture both the short-term effect of the news due to the revaluation of stock price and exchange rates, as well as the persistent change in the exposure coefficient. Importantly, it also needs to accommodate the possibility of a stationary autoregressive component in the exposure coefficient. The following model satisfies those objectives:

$$\bar{\delta}_t = c + c_t + \rho(\bar{\delta}_{t-1} - c - c_{t-1}) + \varphi' X_t + \sum_{j=1}^{J} \theta_j Surp_{j,t} + \varepsilon_t, \tag{8}$$

$$\text{with } c_t = c_{t-1} + \sum_{j=1}^{J} \lambda_j Surp_{j,t} \text{ and } c_0 = 0.$$

[8] We do not consider the individual exposure as the dependent variable, because of the pitfalls in terms of biased estimation when estimating by panel fixed effects estimation the parameters of an autoregressive panel regressions (see,e.g., Nickell, 1981).

The error term is assumed to be stationary with zero mean. The λ (θ) coefficients on the surprises capture the persistent (transitory) effect of the surprises on the average foreign exchange exposure. Except for the auxiliary equation expressing the persistent changes of the macroeconomic news on the exposure coefficient, this is a standard regression specification, where X_t denotes a set of control variables. We consider two types of control variables. The first group of controls is related to the foreign exchange rate: (i) the sign of the change in the foreign exchange rate (see, e.g., Bartram, 2004, Bartram and Bodnar, 2012, Carter et al., 2003, Chaieb and Mazzotta, 2013, Koutmos and Martin, 2007), (ii) the magnitude of the change in the foreign exchange rate (see, e.g., Muller and Verschoor, 2006) and (iii) the moneyness of the option to export (Boudt et al., 2015). The second group of controls in X is related to one-off events. One-off events could influence the foreign exchange rate exposure, but could also coincide with a macroeconomic announcement. Including dummies for one-off events allows us to distinguish the systematic impact of surprises in macroeconomic announcements from the extraordinary impact of one-off events. Appendix A.3 details the definitions of the controls.

We estimate the model by non-linear least squares and account for the heteroscedasticity and autocorrelation in the residuals by using HAC standard errors (Andrews, 1991, Andrews and Monahan, 1992). Our sample contains 1,672 daily observations, 8 indicators, and 486 announcements on 393 announcement days.

4 Estimated foreign exchange rate exposures

This section presents the results on the estimated foreign exchange rate exposures. Panel A of Table 4 shows the cross-sectional average of the estimated foreign exchange rate exposures has a positive mean. On average, if the foreign currency index appreciates by 1%, the firm's stock price tends to increase by 1.09%. This means that the firms have, on average, a net long economic position in the foreign exchange rate and therefore benefit from a strengthening foreign currency. 44% (35%) of the daily estimated exposures are significant at the 10% (5%) level. Most of the significant exposures are positive (38% and 32% at the 10% and 5% level, respectively). The average correlation between the firms' exposures is 0.52.

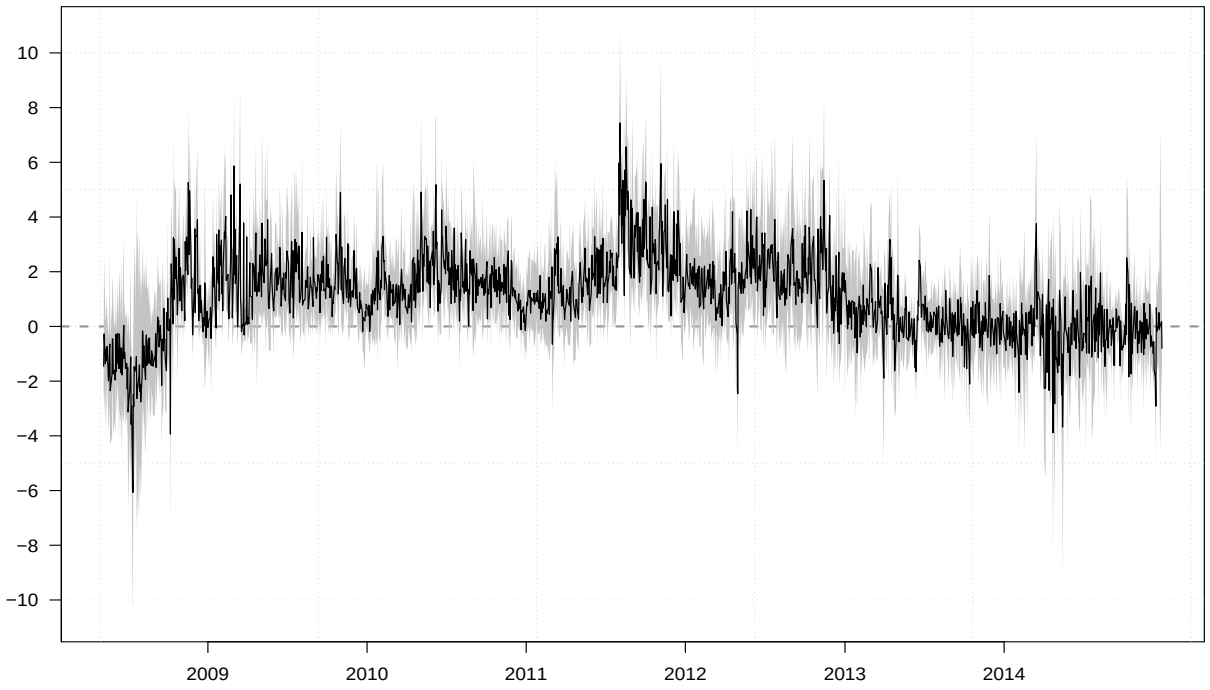
Table 4: Summary of the estimated foreign exchange rate exposures of 182 US multinational firms. The table reports the estimation results for the average foreign sales ratio over the firm and over time, the total (Panel A) and incremental (Panel B) foreign exchange rate exposures. Results are reported for all firms in the sample (All) and for seven GICS sectors. The table shows the average exposure (over the firms and over time) and the % of significantly positive and negative coefficients at the 5% and the 10% level (over the firms and over time).

	All firms	Energy	Materials	Industrials	Cons. goods	Cons. staples	Health care	IT
% of sample	100	9.34	8.79	18.68	17.03	11.54	11.54	21.43
% of S&P 500	100	10.00	6.67	13.33	19.44	8.52	12.60	16.85
Foreign sales	48.79	47.99	52.03	42.15	41.70	49.88	48.11	58.60
Panel A: Total exposure								
Average	1.09	1.77	1.29	1.20	1.10	0.54	0.69	1.13
% + sign. at 5%	31.72	41.51	36.30	35.51	30.11	23.37	25.64	31.66
% + sign. at 10%	38.32	48.33	43.05	42.07	36.61	29.90	31.94	38.40
% - sign. at 5%	4.12	1.98	3.51	4.38	4.62	4.41	4.34	4.44
% - sign. at 10%	5.94	3.06	5.10	6.16	6.56	6.52	6.48	6.31
Panel B: Incremental exposure								
Average	0.11	0.50	0.24	0.12	0.05	−0.01	−0.03	0.05
% + sign. at 5%	7.53	11.72	8.78	7.86	6.44	6.20	6.29	7.18
% + sign. at 10%	11.42	17.27	13.51	11.75	10.00	9.76	9.77	10.70
% - sign. at 5%	5.76	3.40	4.64	5.35	6.03	6.68	6.75	6.34
% - sign. at 10%	8.96	5.44	7.23	8.53	9.31	10.18	10.56	9.78

This high level of correlation indicates substantial commonality between the firms' foreign exchange rate exposures. The first principal component of the matrix of foreign exchange exposures explains 54% of the variation in the estimated standardized foreign exchange rate exposure. The second component explains less than 4% of the variance. Additionally, the first principal component has a correlation of over 99% with the simple average of the estimated foreign exchange rate exposures. We focus on the cross-sectional average exposure in the empirical analysis because it seems to represent the common variation in the exposures. In the robustness analysis, we also present results for the firms categorized by sector and by the proportion of foreign sales.

Figure 3 shows the cross-sectional average exposure over time. Note that the exposure exhibits substantial time-variation and is actually negative at the beginning of the sample. It increases from 2009 onwards up to 2011 to levels of two or more, after which it turns to about zero. Mid-2011 the exposure starts to decrease again and is on average negative at the end of the sample period. This appears to be related to the pattern of depreciation and appreciation cycles shown in Figure 2.That is, the exposure falls, and turns negative when the USD is strong, in line with what one expects from the relative attractiveness of the export and import activities, as we discuss in Subsection 2.1.

Figure 3: Time variation in the average total foreign exchange rate exposure of 182 multinational US firms. The plot shows the daily cross-sectional average of the estimated incremental foreign exchange rate exposure (in black) over the period May 2008–2014. The shaded region is the range between the 10% and 90% quantiles of the daily cross-sectional foreign exchange rate exposures.



In fact, the pattern in Figure 3 matches the movements in the average foreign sales ratio as shown in Column 1 of Table 1. The foreign sales ratio is a measure of a firm's foreign involvement.[9] Among others Jorion (1990), He and Ng (1998) and Dominguez and Tesar (2006) find a positive relation between the foreign sales ratio and foreign exchange rate exposure. The average foreign sales ratio increases from 2008 up to 2012. After 2012, the foreign sales ratio drops, but is still 2% above the average ratio in 2008. In the next section, we explore the drivers of the foreign exchange rate exposure dynamics.

5 Foreign exchange rate exposure dynamics

The previous section showed that the cross-sectional average of foreign exchange exposure is usually positive but varies over time. This section investigates the determinants of the exchange rate exposure

[9]The foreign sales are defined as the sales by foreign affiliates, not the export sales of the firm.

dynamics, particularly the impact of macro announcements on the foreign exchange rate exposure. We find that the foreign exchange rate exposure is persistent and that nonfarm payroll, price index and target interest rate announcements substantially affect exchange rate exposures.

The second row of Table 5 reports that the exposure's AR(1) coefficient is positive and significant, which is in line with the first hypothesis.

To test the impact of macroeconomic announcements, we distinguish between an immediate, although short-lived, learning effect and a persistent effect. Columns 1 and 3 of Table 5 investigate the estimated transitory effects of macroeconomic surprises. The inflation announcements, namely consumer price, producer price and export price index, have a significant transient impact on the foreign exchange rate exposure on the announcement day. A one standard deviation increase in the export price index tends to briefly decrease the exposure by 0.229. Mun (2012) argues that inflation surprises reduce subsequent stock prices because they reduce expected future economic growth, and imply more stringent monetary policy and an increase of interest rates. These arguments are in line with the findings of Andersen et al. (2007). On the other hand, higher-than-expected inflation could depreciate the dollar through purchasing power parity (Neely and Dey, 2010). The joint occurrence of these moves lead to a lower exchange rate exposure on announcement days.

Columns 2 and 3 of Table 5 investigate the persistent impact of the macroeconomic surprises on the average exchange rate exposure. Nonfarm payroll, consumer price index and FOMC target announcements have a significant persistent effect. Lahaye et al. (2011) defined nonfarm payroll and FOMC announcements as the most important macroeconomic announcements. Nonfarm payroll announcements provide information on both future expected growth and interest rates (Boyd et al., 2005). A positive surprise on the nonfarm payroll employment persistently reduces foreign exchange exposure because it indicates that the US economy is stronger than expected and domestic sales and import of goods will be relatively more important.

Positive FOMC target announcements persistently reduce the exposure. As with the nonfarm payroll announcements, an higher-than-expected interest rate indicates a stronger-than-expected US economy. This increases the relative importance of domestic sales and import activities, and therefore lowers exchange rate exposure.

The adjusted R^2 is 57.41%. Figure 4 compares the fitted exposures of the test equation specified

Table 5: The foreign exchange rate exposure dynamics. The dependent variable is the average daily exposure. The data set consist of 1,672 daily observations and 486 announcements. Details on the announcements included in the regression are provided in Table 2. Details on the control variables included are provided in Table 13. *, **, and *** denote significance at the 10%, 5%, and 1% level with HAC standard errors (between brackets).

	(1). Transitory		(2). Persistent		(3). Trans. + Pers.	
	Est.	SE	Est.	SE	Est.	SE
(Intercept)	0.333^{***}	(0.054)	-0.599^{***}	(0.233)	-0.618	(0.445)
AR(1)	0.686^{***}	(0.021)	0.420^{***}	(0.029)	0.417^{***}	(0.036)
GDP Pers			-0.009	(0.043)	-0.008	(0.068)
GDP Trans	-0.052	(0.272)			0.125	(0.275)
NFP Pers			-0.297^{***}	(0.032)	-0.297^{***}	(0.062)
NFP Trans	-0.133	(0.151)			0.118	(0.127)
CPI Pers			0.067^{**}	(0.027)	0.067^{***}	(0.049)
CPI Trans	-0.075	(0.134)			-0.197^{*}	(0.120)
PPI Pers			0.101^{**}	(0.042)	0.112	(0.078)
PPI Trans	-0.192	(0.170)			-0.334^{*}	(0.191)
EXPPI Pers			-0.009	(0.026)	-0.002	(0.049)
EXPPI Trans	-0.213^{*}	(0.113)			-0.229^{**}	(0.110)
TRADE Pers			0.022	(0.036)	0.038	(0.073)
TRADE Trans	-0.077	(0.101)			-0.142^{*}	(0.084)
FOMC TARGET Pers			-0.221^{***}	(0.022)	-0.227^{***}	(0.041)
FOMC TARGET Trans	-0.082	(0.173)			0.113	(0.191)
FOMC 10Y Pers			-0.130^{**}	(0.059)	-0.146	(0.095)
FOMC 10Y Trans	0.100	(0.172)			0.163	(0.186)
Controls	Yes		Yes		Yes	
Adj. R^2(%)	47.81		56.87		57.41	

in Equation 8, with the average realized foreign exchange rate exposures. The fitted values capture a large part of the variation in the realized exposures.

Figure 5 shows two representative impulse-response functions for surprises: one on the export price index, the other on the number of nonfarm payroll employees. An export price index announcement reduces the foreign exchange rate exposure, though the impact lasts for the day of the announcement. On the other hand, a one standard deviation positive nonfarm payroll surprise persistently decreases the foreign exchange rate exposure.

Table 6 reports the dates of the ten macroeconomic announcements with the largest absolute impact on the foreign exchange rate exposure. These announcements are concentrated in the first part of our sample (2008 to 2011), during the period of greatest financial market volatility. The fourth column reports the impact of the macroeconomic surprises on the foreign exchange rate. The nonfarm payroll announcement of Dec. 5, 2008 persistently raised the exchange rate exposure by 1.04. This is a substantial impact; the average foreign exchange rate exposure is 1.09 over the entire sample.

Figure 4: Realized and fitted foreign exchange rate exposures over the period 2008–2014. The plot shows the realized foreign exchange rate exposures (gray) and the fitted values (black) of the regression specified in Equation 8.

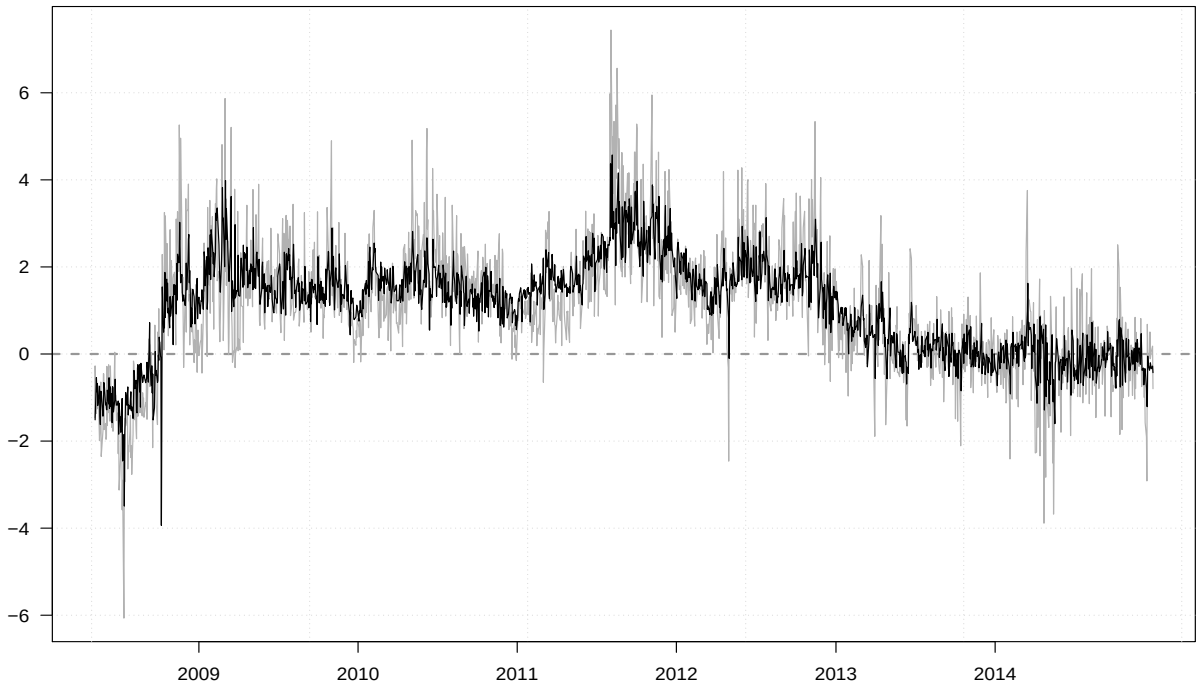


Figure 5: The impact of a positive one standard deviation export price index (left) and nonfarm payroll (right) surprise on the average exchange rate exposure in an event window around the announcement. Day 0 is the day of the announcement.

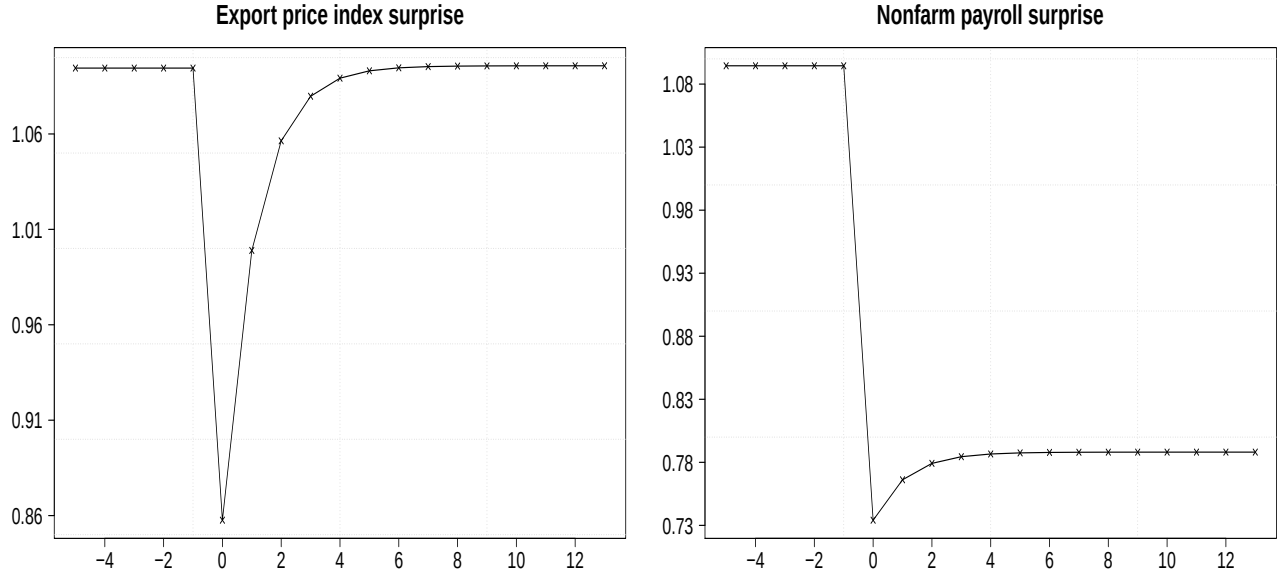


Table 6: The ten macroeconomic announcements with the largest absolute impact on the average foreign exchange rate exposure. P and T indicate whether the effect is persistent or transitory, respectively. Impact: the impact of the announcement on the estimated foreign exchange rate exposure which equals $\lambda_j \times Surp_j$ for a persistent effect and $\theta_j \times Surp_j$ for a transitory effect (see Equation 8).

Announcement	Type	Date	Impact	Event
NFP	P	12-05-2008	1.04 =-0.30x-3.84	The economy shed 533,000 jobs in November, according to a government report Friday - bringing the year's total job losses to 1.9 million. November had the largest monthly job loss total since December 1974. (CNN, 12-05-2008)
	Intuition: Consistent with Hypothesis 2b, when investors perceive a decrease in the number of jobs signals a weaker US economy, lower local demand and hence an increased relative importance of export-oriented activities with a positive exposure.			
FOMC target	P	10-08-2008	1.01 =-0.23x-4.48	Joint announcement of the Bank of Canada, the Bank of England, the European Central Bank (ECB), the Federal Reserve, Sveriges Riksbank and the Swiss National Bank announcing reductions in policy interest rates (Federal Reserve, 10-08-2008)
	Intuition: Consistent with Hypothesis 2b, a decrease in the interest rates signals a weaker US economy to investors, which lowers domestic demand, hence an increased relative importance of export-oriented activities with a positive exposure and therefore a persistent increase in the exposure.			
PPI	T	11-18-2008	0.93 =-0.33x-2.77	US producer prices declined by a record 2.8 per cent in October. The Labor Department said the producer price index recorded its third consecutive monthly reduction. (Reuters, 11-18-2008)
	Intuition: Cosistent with Hypothesis 2a, an unexpected decline in producer price index leads to an immediate revaluation of the stock prices and foreign exchange rate. A lower-than-expected producer price index leads to an appreciation of the USD and decrease in the stock returns consistent with the law of one price, and therefore an immediate increase in the exposure.			
PPI	T	04-14-2009	0.93 =-0.33x-2.77	Producer prices drop, biggest 12-month fall since 1950 (Reuters, 04-14-2009)
PPI	T	12-15-2009	-0.84 =-0.33x2.52	US producer prices jumped a surprising 1.8 percent last month and industrial output rose firmly, sparking inflation jitters in financial markets. (Reuters, 12-15-2009)
FOMC target	P	12-16-2008	0.81 =-0.23x-3.60	Federal Reserve cuts target interest rate below 1% for the first time. (Federal Reserve, 12-16-2008)
EXPPI	T	11-10-2011	0.80 =-0.23x-3.54	US Exports Hit $180.4 Billion in September, An All-time High (Reuters, 11-10-2011)
PPI	T	09-15-2009	-0.76 =-0.33x2.27	Producer prices jump 1.7% (Reuters, 09-15-2009)
PPI	T	03-16-2011	-0.76 =-0.33x2.27	Producer price index increased 1.6%. (Bureau of Labor Statistics, 03-18-2011)
EXPPI	T	09-11-2008	0.70 =-0.23x-3.10	Prices for US exports unexpectedly declined, down 1.7% for their first drop since October 2006. (Reuters, 09-11-2008)

6 Further analysis

This section reports additional analyses of foreign exchange rate exposure. First, rather than aggregating all firms in our sample, we now study the foreign exchange rate exposure aggregated by sector and categorized by the foreign sales ratio. Second, we control for market exposure when estimating each firm's foreign exchange rate exposure. Third, we redo the analysis with robust estimators and

20-min return observations.

6.1 Sector exposures

This subsection studies exposure by sector. Although one might expect that differing industry structures should produce differences in foreign exchange rate exposures (Marston, 2001), it is ultimately an empirical question how macro announcements affect exposure across the sectors.

Table 1 reports substantial variation in the average estimated exposures for seven GICS sectors.[10] The average exposure for the consumer staples and health care sectors is less than 0.70, while the average exposure of the energy sector exceeds 1.70. The health care sector includes both significant import activities for the pharmaceutical industry and export for the medical equipment industry, which could partly offset each other, explaining the lower exposure (Chaieb and Mazzotta, 2013).

Table 7 reports the exposure dynamics by sector. The main results for the average cross-sectional exposure also hold for the sector exposures. Nonfarm payroll and FOMC target announcements have a persistent impact on foreign exchange rate exposure. A higher-than-expected export price index temporarily decreases the exposure of all sectors, except for the Energy sector. The impact of other announcements differs across the sectors.

6.2 Exposures conditional on the level of foreign sales

Prior research shows that a firm's foreign exchange rate exposure is positively related to its foreign sales (see, e.g., Williamson, 2001). In this section, we analyze whether the foreign exchange rate exposure of firms with a high foreign sales ratio exhibits different dynamics compared with firms with a lower foreign sales ratio. Therefore, we categorize the multinational firms into two groups, the firms systematically (i.e., for each year) reporting the 25% lowest and 25% highest foreign sales.

The average exposure of a high-foreign-sales firm is 1.14, while the average exposure of a low-foreign-sales firms is 0.91. Overall, low- and high-foreign-sales firms behave similarly. Despite the similarities across both groups, the low foreign sales firms respond to two different announcements: the consumer price and trade balance surprises have a transitory impact.

[10] The GICS sector classification consists of eleven sectors. We use seven of these sectors in our analysis. Sectors consisting of only a limited number of firms and the financial sectors are removed.

Table 7: The foreign exchange rate exposure dynamics per GICS sector. The dependent variable is the average daily exposure of the firm's in the sector. The data set consist of 1,672 daily observations and 486 announcements. Details on the announcements included in the regression are provided in Table 2. Details on the control variables included are provided in Table 13. *, **, and *** denote significance at the 10%, 5%, and 1% level with HAC standard errors (between brackets).

	Energy		Materials		Industrials		Cons. goods		Cons. staples		Health care		IT	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
(Intercept)	1.42^{**}	(0.51)	-0.41	(0.47)	-0.82	(0.57)	-1.31	(0.69)	-0.48	(0.32)	-0.46	(0.31)	-1.10^{**}	(0.52)
AR(1)	0.28^{***}	(0.03)	0.33^{***}	(0.03)	0.43^{***}	(0.05)	0.40^{***}	(0.04)	0.37^{***}	(0.04)	0.32^{***}	(0.05)	0.35^{***}	(0.04)
GDP Pers	-0.02	(0.09)	0.02	(0.07)	0.01	(0.08)	0.02	(0.09)	-0.02	(0.05)	-0.06	(0.06)	-0.01	(0.08)
GDP Trans	0.19	(0.34)	0.14	(0.28)	0.14	(0.32)	0.04	(0.34)	0.09	(0.19)	0.09	(0.20)	0.18	(0.30)
NFP Pers	-0.20^{***}	(0.06)	-0.30^{***}	(0.06)	-0.35^{***}	(0.08)	-0.38^{***}	(0.09)	-0.19^{***}	(0.04)	-0.20^{***}	(0.05)	-0.33^{***}	(0.07)
NFP Trans	-0.04	(0.16)	0.11	(0.12)	0.14	(0.14)	0.15	(0.15)	0.07	(0.10)	0.04	(0.12)	0.16	(0.13)
CPI Pers	0.15^{**}	(0.06)	0.11^{**}	(0.05)	0.08	(0.06)	0.06	(0.07)	0.01	(0.03)	0.01	(0.04)	0.07	(0.05)
CPI Trans	-0.07	(0.20)	-0.33^{**}	(0.12)	-0.22	(0.16)	-0.27	(0.18)	-0.18^{*}	(0.09)	-0.21^{*}	(0.11)	-0.18	(0.19)
PPI Pers	0.08	(0.08)	0.08	(0.07)	0.11	(0.09)	0.12	(0.10)	0.05	(0.05)	0.11^{*}	(0.06)	0.17^{*}	(0.09)
PPI Trans	-0.40	(0.26)	-0.36^{*}	(0.20)	-0.32	(0.20)	-0.36^{*}	(0.20)	-0.17	(0.14)	-0.32^{*}	(0.17)	-0.41^{**}	(0.20)
EXPPI Pers	0.08	(0.05)	0.03	(0.05)	-0.01	(0.06)	-0.04	(0.06)	0.00	(0.03)	0.01	(0.04)	-0.02	(0.05)
EXPPI Trans	-0.22	(0.17)	-0.22^{*}	(0.12)	-0.24^{**}	(0.11)	-0.25^{*}	(0.13)	-0.13^{*}	(0.07)	-0.26^{*}	(0.10)	-0.24^{*}	(0.13)
TRADE Pers	-0.04	(0.07)	0.08	(0.07)	0.04	(0.09)	0.06	(0.09)	0.03	(0.05)	-0.01	(0.05)	0.06	(0.08)
TRADE Trans	-0.13	(0.15)	-0.20^{*}	(0.11)	-0.15	(0.09)	-0.14	(0.09)	-0.14^{***}	(0.06)	-0.09	(0.07)	-0.17^{*}	(0.09)
FOMC TARGET Pers	-0.16^{***}	(0.05)	-0.21^{***}	(0.04)	-0.26^{***}	(0.05)	-0.28^{***}	(0.06)	-0.14^{***}	(0.03)	-0.18^{***}	(0.03)	-0.26^{***}	(0.05)
FOMC TARGET Trans	-0.10	(0.28)	0.02	(0.23)	0.09	(0.20)	0.03	(0.20)	0.25	(0.19)	0.15	(0.20)	0.16	(0.22)
FOMC 10Y Pers	-0.12	(0.08)	-0.14	(0.10)	-0.15	(0.11)	-0.17	(0.12)	-0.15^{***}	(0.07)	-0.10	(0.08)	-0.13	(0.11)
FOCM 10Y Trans	0.26	(0.24)	0.19	(0.18)	0.20	(0.21)	0.23	(0.23)	0.19	(0.16)	0.19	(0.19)	-0.06	(0.20)
Controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Adj. R^2(%)	38.22		50.60		55.16		56.46		44.70		44.19		53.85	

6.3 Incremental foreign exchange rate exposure

The *total* foreign exchange rate exposure can be estimated by regressing the intraday stock returns on the intraday foreign exchange returns. Prior work often adds a market return to this regression to control for effects which are common with the changes in the foreign exchange rate and affect the valuation of all firms in the market.

In terms of economic relevance, one argument in favour of *total* exposure is that this one is the coefficient that firms need when they hedge their currency exposure. But that argument can be countered by noting that, if the firm would also add a stock-index futures to its hedging toolkit, the relevant coefficients would be those of the multiple regression, with s and r_m as the regressors. A more pertinent argument follows from the analysis of citetLiuSercuVandebroek2015. They consider the familiar solution for a two-regressor slope coefficient:

$$\gamma_i = \frac{\delta_i - \beta_i \delta_m}{1 - R^2_{s,m}}, \tag{9}$$

where $R^2_{s,m}$ is the R^2 of the market's total-exposure regression and β_i the slope of firm i's market-

Table 8: The foreign exchange rate exposure dynamics for firms categorized based on the proportion of foreign sales relative to total sales. The low (high) foreign sales category consists of the 25% firms systematically reporting the lowest (largest) percentage of foreign sales over the sample (2008-2014). The dependent variable is the average daily exposure. The data set consist of 1,672 daily observations and 486 announcements. Details on the announcements included in the regression are provided in Table 2. Details on the control variables included are provided in Table 13. *, **, and *** denote significance at the 10%, 5%, and 1% level with HAC standard errors (between brackets).

	(1). Low Foreign Sales		(2). High Foreign Sales	
	Est.	SE	Est.	SE
(Intercept)	-0.822	(0.500)	-0.775^{*}	(0.456)
AR(1)	0.426^{***}	(0.039)	0.372^{***}	(0.037)
GDP Pers	-0.011	(0.068)	0.002	(0.070)
GDP Tran	0.093	(0.264)	0.142	(0.266)
NFP Pers	-0.290^{***}	0.067	-0.300^{***}	(0.062)
NFP Trans	0.124	(0.128)	0.134	(0.127)
CPI Pers	0.540	(0.052)	0.061	(0.051)
CPI Trans	-0.290^{**}	(0.133)	-0.168	(0.137)
PPI Pers	0.094	(0.080)	0.131	(0.080)
PPI Trans	-0.313^{**}	(0.175)	-0.372^{*}	(0.210)
EXPPI Pers	-0.020	(0.049)	-0.000	(0.050)
EXPPI Trans	-0.196^{**}	(0.103)	-0.247^{**}	(0.120)
TRADE Pers	0.040	(0.073)	0.051	(0.077)
TRADE Trans	-0.149^{**}	(0.067)	-0.079	(0.088)
FOMC TARGET Pers	-0.223^{***}	(0.045)	-0.238^{***}	(0.042)
FOMC TARGET Trans	0.113	(0.180)	0.176	(0.200)
FOMC 10Y Pers	-0.133	(0.098)	-0.125	(0.097)
FOMC 10Y Trans	0.180	(0.187)	0.104	(0.176)
Controls	Yes		Yes	
Adj. R^2(%)	56.38		54.47	
# of firms	31		31	
Average foreign sales ratio	22.13		77.29	

model regression. In a conventional regression, the interpretation of subtracting $\beta_{ji}\delta_m$ is that the *incremental* exposure γ_i removes from the *total* exposure δ_i the part that comes from the market, taking into account the extent to which r_i is sensitive to the market. But the market return is not an exogenous extra regressor; rather, it is the value-weighted average of the returns on the individual stocks that show up on the left-hand side:

$$\delta_m = \sum_{i=1}^{N} w_i \delta_i, \tag{10}$$

with w_i denoting i's value weight. So removing from the total exposure the part that 'comes from the market' here boils down to removing the average exposure. This is not a good idea when the purpose is to see how exposure is affected by news announcements. As Liu et al. (2015) note, it follows from Equation 9 that the average *incremental* exposure is zero by construction, meaning that this estimator

will generate about 50/50 positive/negative γ coefficients for the individual stocks:

$$\begin{aligned}\sum_{i=1}^{N} w_i \gamma_i &= \frac{[\sum_{i=1}^{N} w_i \delta_i] - [\sum_{i=1}^{N} w_i \beta_{0,i}]\delta_m}{1 - R^2_{s,m}}, \\ &= \frac{\gamma_{1,m} - 1 \times \gamma_{1,m}}{1 - R^2_{s,m}} = 0. \end{aligned} \tag{11}$$

Our sample of firms is not the entire market, and it is definitely not a random sample as we specifically go for internationally active firms (see Section 3), which are likely to be more exposed than the left-out companies. Still, as we shall see, the average exposure of our internationally active firms drops by 90% as soon as we take out the market-wide average exposure. Not surprisingly, then, the remaining exposure seems to be unrelated to news. The conclusion, however is not that exposures are not very news-sensitive. Rather, the conclusion is that news-sensitivity is quite similar across firms, so that the average is picking up most of the signals. We would have missed this totally if we had immediately worked with *incremental* exposures.

To estimate the incremental foreign exchange rate exposure, we regress the intraday stock returns on the intraday foreign exchange rate returns and the intraday market return:

$$r_{i,t,k} = \alpha_{i,t} + \beta_{i,t} r^m_{t,k} + \gamma_{i,t} s_{t,k} + \varepsilon_{i,t,k}, \tag{12}$$

in which $r_{i,t,k}$ is the log return of stock i during the k^{th} intraday period of day t, $r^m_{t,k}$ is the corresponding market return over the k^{th} intraday interval, $s_{t,k}$ is the domestic currency log return on the trade-weighted exchange rate index over the k^{th} intraday period and $\varepsilon_{i,t,k}$ denotes the error term. The market return included is the return on the S&P 500 index. We use the highly liquid SPY exchange-traded fund, tracking the S&P 500 index, to calculate the high-frequency market returns (see Patton and Verardo, 2012, among others).

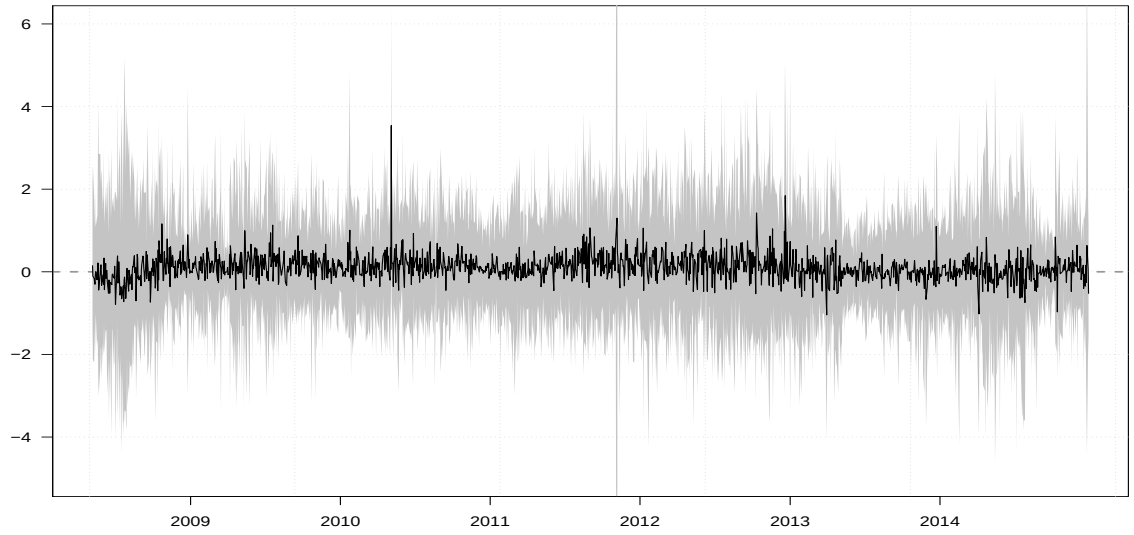
Panel B of Table 4 shows the incremental exposure which is, on average, positive (0.11), meaning that, on average, these firm's benefit from a currency depreciation, and 20% (13%) of the estimates are significant at the 10% (5%) level. The incremental exposures are substantially lower than the total exposure in Table 4.

Panel A of Figure 6 plots the daily incremental exposure. The average incremental exposure is

low in 2008, increases up to 2012, and drops afterwards. The average incremental exposure exhibits some spikes, e.g., on the day of the Flash Crash in May 2010 the average incremental exposure jumps to 3.54. Panel B plots the market's foreign exchange rate exposure. The market's average exposure equals to 0.94. Note also that the time variation in the market's exposure is similar to the average total exposure in Figure 3.

Figure 6: Time variation in the incremental foreign exchange rate exposure and the market's foreign exchange rate exposure. Panel A shows the daily cross-sectional average of the estimated incremental foreign exchange rate exposure (in black) over the period May 2008–2014. The shaded region is the range between the 10% and 90% quantiles of the daily cross-sectional incremental foreign exchange rate exposures. Panel B shows the estimated market's exposure over the period May 2008–2014.

(A) Average incremental exposure $\bar{\gamma}_t$



(B) Market exposure $\delta_{m,t}$

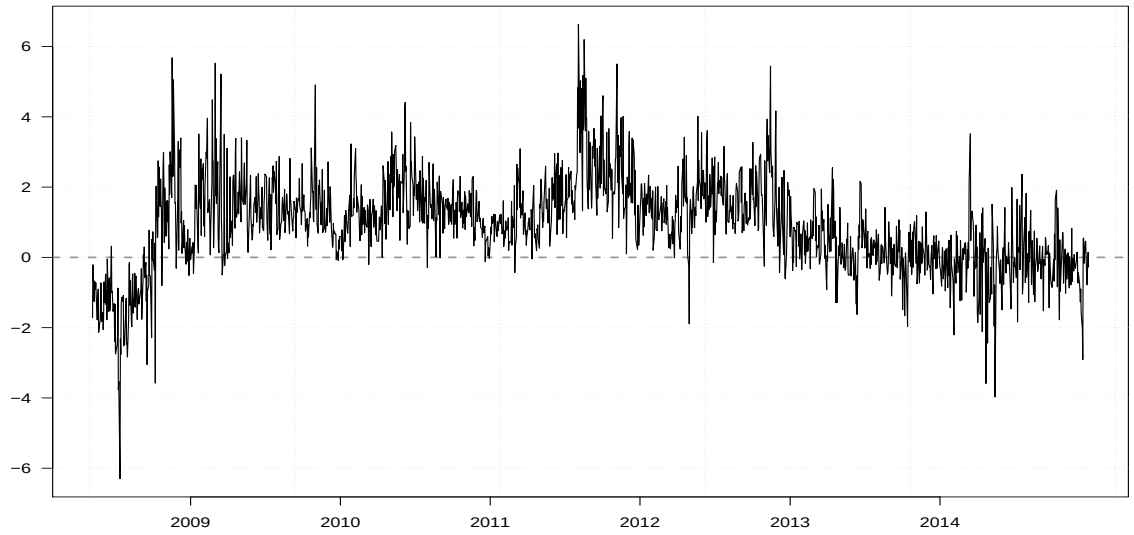


Table 9: The incremental and market foreign exchange rate exposure dynamics. The dependent variable is the cross-sectional average daily incremental exposure (Panel A) and market exposure (Panel B). The data set consist of 1,672 daily observations and 486 announcements. Details on the announcements included in the regression are provided in Table 2. Details on the control variables included are provided in Table 13. *, **, and *** denote significance at the 10%, 5%, and 1% level with HAC standard errors (between brackets).

	Incremental exposure		Market exposure	
	Est.	SE	Est.	SE
(Intercept)	-0.134^{***}	(0.033)	-0.606	(0.437)
AR(1)	-0.009	(0.024)	0.417^{***}	(0.037)
GDP Pers	0.010	(0.008)	-0.013	(0.061)
GDP Trans	0.022	(0.037)	0.113	(0.253)
NFP Pers	-0.027^{***}	(0.004)	-0.268^{***}	(0.056)
NFP Trans	-0.016	(0.028)	0.104	(0.120)
CPI Pers	0.008^{*}	(0.004)	0.050	(0.044)
CPI Trans	-0.003	(0.033)	-0.201^{*}	(0.104)
PPI Pers	0.024^{***}	(0.008)	0.106	(0.070)
PPI Trans	-0.036	(0.033)	-0.312	(0.194)
EXPPI Pers	-0.009^{**}	(0.004)	-0.002	(0.044)
EXPPI Trans	-0.008	(0.028)	-0.212^{**}	(0.098)
TRADE Pers	0.008	(0.005)	0.049	(0.067)
TRADE Trans	-0.017	(0.024)	-0.172^{**}	(0.085)
FOMC TARGET Pers	-0.018^{***}	(0.004)	-0.213^{***}	(0.036)
FOMC TARGET Trans	0.009	(0.059)	0.085	(0.197)
FOMC 10Y Pers	-0.008	(0.008)	-0.156^{*}	(0.088)
FOMC 10Y Trans	-0.091^{*}	(0.045)	0.224	(0.174)
Controls	Yes		Yes	
Adj. R^2(%)	10.37		56.16	

Table 9 shows regression results breaking down total exposure dynamics into incremental exposure and the market's exposure. The market's exposure is strongly autocorrelated and unsurprisingly responds to similar surprises as the total exposure. Nonfarm payroll and FOMC announcements have a persistent impact. Consumer and export price index announcements have a transitory impact on the market's exposure. The incremental exposure, in contrast, exhibits no significant autocorrelation. Four macroeconomic announcements persistently affect the incremental foreign exchange rate exposure, wile only two persistently affect market exposure. All announcements, except for the trade balance announcement, persistently influence the incremental exposure. A higher-than-expected nonfarm payroll announcement, decreases the incremental exposure. The FOMC ten-year yield surprises are the only surprises with a transitory impact on incremental exposure. A positive FOMC ten-year yield surprise has a transitory negative impact on the incremental exposure.

Table 10: The exposure dynamics using alternative estimators. The dependent variable is the cross-sectional average daily exposure estimated using outlier robust estimators (Panel A) and 20-minute return observations (Panel B). The data set consist of 1,672 daily observations and 486 announcements. Details on the announcements included in the regression are provided in Table 2. Details on the control variables included are provided in Table 13. *, **, and *** denote significance at the 10%, 5%, and 1% level with HAC standard errors (between brackets).

	Robust		20 min.	
	Est.	SE	Est.	SE
(Intercept)	-0.573	(0.444)	-0.618	0.445
AR(1)	0.374^{***}	(0.077)	0.417^{***}	0.036
GDP Pers	0.002	(0.071)	-0.008	0.068
GDP Trans	0.043	(0.211)	0.125	0.275
NFP Pers	-0.310^{***}	(0.066)	-0.297^{***}	(0.062)
NFP Trans	0.164	(0.117)	0.118	(0.127)
CPI Pers	0.080	(0.058)	0.067	(0.049)
CPI Trans	-0.193	(0.127)	-0.197^{*}	(0.120)
PPI Pers	0.102	(0.079)	0.112	(0.078)
PPI Trans	-0.349^{*}	(0.188)	-0.334^{*}	(0.191)
EXPPI Pers	-0.002	(0.048)	-0.002	(0.049)
EXPPI Trans	-0.229^{**}	(0.101)	-0.229^{*}	(0.110)
TRADE Pers	0.023	(0.071)	0.038	(0.073)
TRADE Trans	-0.127^{*}	(0.086)	-0.142	(0.084)
FOMC TARGET Pers	-0.218^{***}	(0.047)	-0.227^{***}	(0.041)
FOMC TARGET Trans	0.148	(0.169)	0.113	(0.191)
FOMC 10Y Pers	-0.141	(0.097)	-0.146	(0.095)
FOMC 10Y Trans	0.167	(0.190)	0.163	(0.186)
Adj. R^2(%)	53.12		48.17	

6.4 Robustness

This subsection tests whether the type of estimator matters. First, we estimate the results using outlier robust estimators, as in Yohai (1987), to control for possible jumps induced by macroeconomic announcements or other factors(Lahaye et al., 2011). Second, we estimate the foreign exchange rate exposures using 20-minute return observations instead of 10-minute observations. Table 10 shows that our analysis is robust to either of these changes in procedure.

7 Conclusion

This paper illustrates the impact of macroeconomic news on the foreign exchange rate exposures of US multinational firms. The use of high-frequency stock and foreign exchange rate data allows us to obtain timely estimates of the foreign exchange rate exposures. We find that macroeconomic announcements affect the foreign exchange rate exposures in a statistically and economically significant

way.

We distinguish between a short-lived learning effect and a persistent effect of macroeconomic announcements. The first is transitory because news prompts investors to revalue stock prices and exchange rates. The latter is persistent, because the information provided by the announcement changes the perceived relative importance of import and export-oriented activities, and therefore persistently affects the foreign exchange rate exposure of the firm. Price index announcements have a short-lived transitory impact; nonfarm payroll and FOMC target announcements have a persistent impact on foreign exchange rate exposure. A lower-than-expected number of employees on nonfarm payrolls signals a weaker US economy, lower domestic demand, increased relative importance of export-oriented activities and hence an increase in the exposure.

The responses of the foreign exchange rate exposures are relevant for corporate (risk) managers, who benefit from the understanding of the sensitivity of the firm's cash flows and value to changes in the foreign exchange rate. Also, investors or portfolio managers could incorporate the provided insights in the exposure dynamics in their portfolio allocation and hedging decisions.

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A Appendix

A.1 Currency weights in the trade-weighted index

Table 11: Currency weights (%) in trade-weighted index based on Federal Reserve Total Trade Weights.

	2008	2009	2010	2011	2012	2013	2014
Australia	1.9	2.1	2.1	2.3	2.2	2.0	2.0
Brazil	3.2	2.9	3.2	3.5	3.5	3.4	3.4
Canada	22.1	20.4	20.6	20.2	19.8	20.0	20.0
Euro area	27.0	27.1	25.2	25.8	25.5	25.9	25.9
Hong Kong	2.0	2.0	2.0	2.0	2.0	2.1	2.1
Japan	12.6	11.5	12.1	11.4	11.9	10.9	10.9
Korea	5.4	5.7	6.0	6.1	6.0	6.1	6.1
Mexico	14.5	15.9	17.3	17.6	18.3	18.8	18.8
Singapore	2.9	3.2	3.2	3.1	3.0	2.8	2.8
Switzerland	2.3	2.8	2.6	2.6	2.6	2.7	2.7
United Kingdom	6.2	6.4	5.6	5.5	5.3	5.3	5.3

A.2 Definition of the macroeconomic announcements

Table 12: Macroeconomic announcements. The table provides definitions of the scheduled macroeconomic announcements based on Neely and Dey (2010).

Announcements	Definition
Real activity announcements	
Real GDP Advance	Initial estimate of GDP, the value of the goods and services produced by the US, 1-month lag
Real GDP Preliminary	Adjusted estimate of GDP Advance, 2-month lag
Real GDP Final	Final estimate of GDP, 3-month lag
Employees on nonfarm payrolls	Change in number of employed people during previous months, excluding farming industry, trends in hiring payments and sectors
Inflation announcements	
Consumer price index	The normalized price paid by urban for a representative basket of goods and services
Producer price index	Price level of output from domestic producers
Export price index	Change in prices of goods sold to foreign buyers by US exporters
Trade announcements	
Exports	Exports disaggregated by country of final destination and type of good
Imports	Imports disaggregated by country of origin and type of good
Trade balance	Difference in value of exports and imports
FOMC	
Federal funds target	Target interest rate set at FOMC meeting
Federal funds ten-year yield	Ten-year yield shocks to measure unconventional monetary policy

A.3 Control variables

Table 13: Control variables. This table provides details on the control variables included in the analysis. Panel A shows the controls related to the foreign exchange rate. Panel B reports the one-off events included in the analysis. The one-off dummy $D_{q,t}(q = 1...Q)$ equals to one on days that news is released which could influence the foreign exchange rate exposure, but could coincide with a macroeconomic announcement. Including dummies for one-off events allows us to distinguish the systematic impact of surprises in macroeconomic announcements from the extraordinary impact of one-off events. Details on the Fed LSAP program can be found in Bauer and Neely (2014)

Panel A: Controls based on the foreign exchange rate

Variable	Description
M_{t-1}	Moneyness: The moneyness is defined as the distance between the exchange rate level at time t, S_t, and the level of the exchange rate at which the value of the option becomes zero, $\bar{S}_t$. We set $\bar{S}_t$ as the average value of the rolling window of 100 exchange rate values (Boudt et al., 2015)
$\Delta S_t I(\Delta S_t > 0)$ ($\Delta S_t I(\Delta S_t < 0)$)	Positive (negative) change in the exchange rate value (see, e.g., Chaieb and Mazzotta, 2013)
ΔS_t^2	The magnitude of the change in the foreign exchange rate (see, e.g., Muller and Verschoor, 2006)

Panel B: One-off events

Event	Date	Description
Coordinated interest rate cut	10-08-2008	Coordinated interest rate cut between the European Central Bank, Bank of England, Federal Reserve Bank, Bank of Canada, Swedish Riksbank and Swiss National Bank.
Joint currency intervention	03-17-2011	G-7 joint currency intervention to weaken in the wake of the Thoku earthquake in Japan
OMT announcement	07-26-2012	ECB announcement of the Outright Monetary Transactions program by Mario Draghi: "Whitin our mandate the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough"
Fed LSAP program	11-25-2008	Initial "large-scale asset purchases" (LSAP) announcement
	12-01-2008	Chairman's speech on LSAP
	12-16-2008	FOMC states that it considers to expand purchases of agency securities and initiating purchases of Treasury securities
	03-18-2009	FOMC announces purchases up to an additional $750 billion
	08-10-2010	Balance Sheet Maintained: Fed will reinvest principal payments from LSAP purchases in Treasuries
	09-21-2010	Statement projects that inflation is likely to remain subdued for some time before rising to levels the Committee considers consistent with its mandate.
	11-03-2010	Statement announces purchases of $600 billion in Treasury securities
	08-22-2012	FOMC members "judged that additional monetary accomodation would likely be warranted fairly soon."
	09-13-2012	Fed will purchase $40 billion of MBS per month as long as "the outlook for the labor market does not improve substantially ... in the context of price stability."