FINANCIAL INSTABILITY AND THE EVOLUTION OF FOREIGN EXCHANGE EXPOSURE OF EUROPEAN FIRMS[1]

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Abstract

In rugged times, financial managers need a superior grasp of the dynamics of foreign-exchange exposure. Although its time-variability has long been recognized, most recent empirical measures of exposure continue to be estimated with methods that assume it constant over time. In this work, we offer a first approximation to the dynamics of exposure by using, alternatively, rolling-window regression and a Kalman-filter specification to estimate time-varying exposures on the daily returns of 1,031 European firms from January 2000 through May 2009, a period marked by two large upswing- downswing cycles in the European stock markets. This paper summarizes the main results graphically and begins its examination.

Keywords: *exposure; time-varying exposure; exchange rates; foreign-exchange risk*

JEL codes: *G11, G14, G15*

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[1] The authors gratefully acknowledge research funding from the Anisfield School of Business, Ramapo College of New Jersey. Special thanks to Dr. Lewis Chakrin for his continuous encouragement. This paper is the first of a pilot study testing a methodology that we intend to apply to a much broader set of firms and countries, with the ultimately goal of examining the sources of foreign exchange exposure in a dynamic context.

1. Introduction

Pervasive in the international monetary environment following the 1973 Jamaica Agreement, exchange rate volatility has soared in periods of overall financial instability. In this turbulent financial climate, it is a particularly pressing need to identify the sources, and trace out the evolution over time, of the *exposure* of firms' returns to unanticipated changes in exchange-rate returns.

Although it is well established in the financial literature that foreign-exchange exposure varies over time, and various approaches to estimating time-varying coefficients are used widely in empirical studies in the field, a number of recent works continue to estimate exposure as a time-fixed coefficient.[2]

Clearly, over time, firms learn and adjust their behavior to changes in the economic environment. Time-varying estimation algorithms permit us to view exposure *partly* as reflecting the informed financial choices of firms, as they may be shaped up by their goal of value maximization and their preferences for risk, subject to their various constraints. And *partly* as reflecting multiple shocks in their economic environment, some explicitly regarded and others captured in the catch-all "random disturbance" term.

In this paper, we use data on the *daily* returns of 1,031 European firms from January 3, 2000 through May 1, 2009 to estimate the *time-varying* exposure of firms to the US dollar, the British pound, the Swiss franc, the Japanese yen, and the Chinese renminbi ("yuan"). We utilize two alternative estimation procedures within the conventional extended-CAPM framework, namely rolling-window ordinary-least squares regression (RW) and Kalman filter estimation (KF). The period of time covered includes the end of the stock market boom of the 1990s, the slump of 2001, the real-estate boom of the mid 2000s, and the recent global financial crisis.

In this paper, we offer a graphical description of the variation of firm exposure over time and a preliminary discussion on the patterns of temporal variation. We postpone a more detailed examination of the evidence, as well as a formal econometric analysis of the role that country of origin, market sector, initial market capitalization, and foreign sales (as a share of total sales) exercise on exposure, for a future version of this paper.

[2] See Allayanis (1997). Dominguez and Tesar (2006) conjecture that, over time, firms adjust their exposure in response to shocks in the foreign exchange environment, but time variation is not built into their estimation framework.

Our analysis confirms the results reported by the canonical literature on the topic about the persistent exposure of a significant percentage of firms.[3] Our results so far suggest that the main sources of cross-sectional variation of exposure are idiosyncratic or firm-specific events, rather than broader systemic factors affecting easily identifiable groups of firms.[4]

On the other hand, the patterns of temporal variation of exposure – if a visual inspection of the graphical evidence is to be relied on – appear to be associated, partly at least, with broader conditions in the markets overall. Although not exclusively, the most dramatic breaks in exposure appear in periods of overall financial instability. At this stage of our work, drawing attention to the striking patterns of temporal variation of firm exposure is the main contribution of our work.

The remainder of the paper is organized as follows: Chapter 2 describes the data set and the estimation methodologies used. Chapter 3 presents the results followed by a preliminary analysis. Chapter 4 concludes.

2. Data and Estimation Approaches

2.1 Data Sets

The main data set used in this paper includes a sample of the daily returns of 1,031 European firms from January 3, 2000 to May 1, 2009 for a total of 2,435 days. The data included information by firm about the country of origin (Germany, France, and Italy); Dow-Junes market sector classification (11 sectors); January 1, 2000 market capitalization, and annual (2000) foreign sales as a percentage of total sales. The data on market capitalization and annual foreign sales shares has missing values. These data sets were downloaded from the Thomson One Banker databases.

To control for the market in the estimation of firm exposure, we use the daily returns on the Wilshire 5000 Index, also drawn from Thomson One Banker databases. The data on daily exchange rates between the euro and, respectively, the U.S. dollar, the British pound, the Swiss franc, the Japanese yen, and the Chinese yuan were drawn from the European Central Bank and the Federal Reserve web sites.

[3] However, unlike others (e.g. Dominguez and Tesar, 2006, who use pre-2000 data from a more diverse, not neighboring, pool of countries using different currencies), we find much thinner evidence of the explanatory power of country of origin, market sector, size, and trade involvement on the cross-sectional variation (say, for a given day) of exposure. A fuller discussion of these results will be included in future versions of this paper.

[4] Due to time constraints, we are not able to report these results in this paper. They are, however, available upon request in their raw Stata output form.

2.2 Estimation Methods

We assume that, for a given firm, the following asset-pricing process governs the generation of the data on firms' returns:

$$r_t = \alpha_0 + \beta_0 m_t + X_t \beta_t + \varepsilon_t \qquad (3)$$

where r_t denotes the log difference in the (dividend-and-split-adjusted) stock prices of a given firm between the close of day (t-1) and the close of day t, for $t = 1, \ldots, \tau$; α_0 is the constant term; β_0 is the firm's market returns "beta"; m_t is the vector of market returns; X_t is the $\tau \times j$ matrix of unanticipated day-t returns on the currencies (log difference) *vis-à-vis* the euro; β_t is the $j \times 1$ vector of "forex beta" (exposure) coefficients, where the number of currencies included $j = 1, \ldots n$; and ε_t is a well-behaved random disturbance. Note that the "forex beta" coefficients are postulated as *time-varying*.

The innovation or unanticipated component of each vector of exchange-rate return x_{it} contained in X_t is determined by assuming that exchange rates evolve according to a martingale process of the type:

$$s_{it} = s_{it-1} + x_{it} \qquad (2)$$

where s_{it} is the logarithm of the i/euro exchange rate level on t and, again, x_i is the unexpected or innovation component with $E_{t-1}(x_{it} | s_{it-1}) = 0$.[5]

Ideally, both the return on the firm's equity and the return on the exchange rates are treated as covariate and their pattern of covariation is viewed as determined jointly, although with different effects on each asset price, by changes in monetary policy and, more generally, shocks in the overall economic environment.[6] Lacking macroeconomic daily data, and with an eye on simplifying the computations, we let the random disturbance catch all of these macro-environmental influences, under the admittedly arbitrary assumption that its expectation conditional upon the market returns and unanticipated exchange rate changes is zero.

Following the literature, foreign-exchange *exposure* is defined as "a statistically significant (*ex post*) relationship between excess returns at the firm- or industry-level and foreign exchange returns."[7] In this paper, however, instead of using the slope coefficients (the "betas"), we use the t or z statistics associated with those coefficients (i.e. the betas weighted

[5] For detailed reference to this and other approaches to capturing the unanticipated component in the exchange-rate "return," see Martin and Mauer (2005) and Koutmos and Martin (2003).
[6] See Allayannis and Ofek, 2001; Bartov and Bodnar, 1994; Jorion, 1990; and Adler and Dumas, 1984.
[7] Dominguez and Tesar (2006), p. 189.

by their respective standard errors). Using the t or z statistics as the measure of exposure, the degree of statistical significance is embedded directly.

In one approach, firm exposure to a given currency is estimated as the t statistic associated to the given currency in an ordinary least squares RW regression of equation (1) above. The RW regressions use as their sample the last 200-day of observations to estimate time-varying coefficients and their standard errors.[8]

Alternatively, exposure is estimated as the z statistic (slope coefficient weighted by its standard error) associated to each given currency in a KF recursive estimation. To estimate the z statistics, the KF approach uses a linear state-space representation of the trajectory of firm returns in accordance with the following system of equations:

$$r_t = X_t \beta_t + \varepsilon_t \tag{3}$$

$$\beta_t = T_t \beta_{t-1} + \upsilon_t \tag{4}$$

$$\Omega_t = \text{var}\begin{bmatrix} \varepsilon_t \\ \upsilon_t \end{bmatrix} = \begin{bmatrix} H_t & G_t \\ G'_t & Q_t \end{bmatrix} \tag{5}$$

where the coefficient vector β_t includes here the constant term coefficient (α_0), the market-return "beta" (β_0), and the "forex betas" (β_i for $i = 1, \ldots, 5$) from equation (1); ε_t and υ_t are zero-mean normal (Gaussian) disturbances; the X_t matrix is made up by a vector of ones (constant term), the vector of market returns (r_{mt}), and the vectors of unanticipated exchange-rate returns (x_{it}) determined by equation (2) above; and Ω_t denotes the contemporaneous variance structure of the process with H_t and Q_t the variance matrices of the disturbances and G_t the matrix of disturbance covariances. All vectors and matrices are assumed to be conformable. When, as is the case in our study, the population variance structure of the process cannot be stipulated, it is assumed that the variance-covariance matrices are all well-behaved to allow for the algorithm to estimate them.

In the context of KF estimation, the first equation is called the "signal" equation; the β_t vector is called the (in this case, unobserved) "state" variable vector, and its trajectory over time is assumed to be given by the first-order vector autorregression above (equation (4)), where T_t is the "state" or "transition" matrix that recursively transforms (updates) the vector β_t.[9]

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[8] No more discussion of the OLS regressor is necessary because its mathematics are well known.
[9] Detailed descriptions of the Kalman filter estimation algorithm can be found in Harvey (1989, chs. 3-4), Hamilton (1994, ch. 13), and Koopman, Shephard, and Doornik (1999).

In a nutshell, the main difference between the two alternative estimation procedures is that, in the RW regression, the sample that determines the coefficients and standard errors is limited to the last 200 observations whereas, in the KF estimation, the sample comprises the entire set of 2,435 days, although the updating of the “slope” coefficients follows a VAR(1) process. In the KF procedure, the (time-varying) states (exposure coefficients) are determined with only a “memory” of the last state; however, the entire set of states must be fully consistent with the set of 2,435 daily observations in accordance with equation (3) above. As we shall see below, this difference generates all sorts of divergence patterns in the empirical measure of firm exposure.

3. Time Variation of Exposure

Table 1 below shows the percentage of firms exposed, overall and by direction of exposure (algebraic sign of the coefficients), as determined by the RW and KF estimation procedures, respectively. Note that a firm is *positively* exposed to currency *i* when an increase in the value of currency *i* in terms of the home currency (euro, in this case) increases. And, conversely, a firm is *negatively* exposed to currency *i* when an increase in the value of i in euro terms decreases.

Table 1 RW- and KF-Estimated Exposure (Percentage of All Firms)

Currency	***RW (-)***	***RW (+)***	***RW Total***	***KF (-)***	***KF (+)***	***KF Total***
Dollar	3.63%	2.74%	6.37%	3.51%	3.28%	6.79%
Pound	2.66%	3.12%	5.77%	5.20%	4.22%	9.42%
Franc	5.87%	2.98%	8.86%	16.51%	5.49%	21.99%
Yen	3.90%	3.85%	7.76%	5.06%	4.61%	9.67%
Yuan	2.67%	3.43%	6.10%	3.20%	3.25%	6.45%

Source: Authors’ estimations

The existence of a significant group of firms exposed has been amply documented in the literature. In our results, the high exposure of European firms to the Swiss franc stands out: 5.9% under RW and 16.5% under KF. Pending further study, we rationalize this result as evidence that some European firms may view the monetary policy of the Swiss National Bank, *vis-à-vis* that of the European Central Bank or the Federal Reserve, as a stabilizing factor.

Figures 1-5 below show the percentage of firms exposed (positively or negatively) to the dollar, pound, franc, yen, and yuan, respectively, at the 5 percent level of significance, as determined by the RW and KF estimates. The vertical lines indicate, from left to right, the spring-2000 peak, the spring-2003 trough, the summer-2007 peak, and the spring-2009 trough, respectively, of the Dow Jones Euro Stoxx 50 Index.

Figure 1 Percentage of European Firms Exposed to the US Dollar

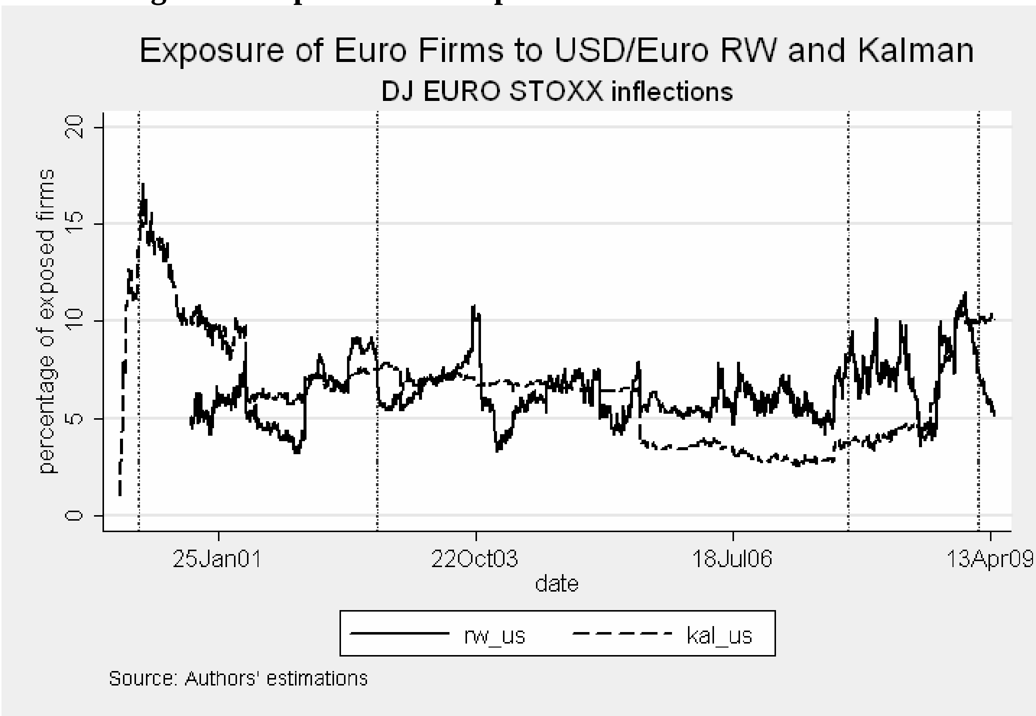


Figure 2 Percentage of European Firms Exposed to the British Pound

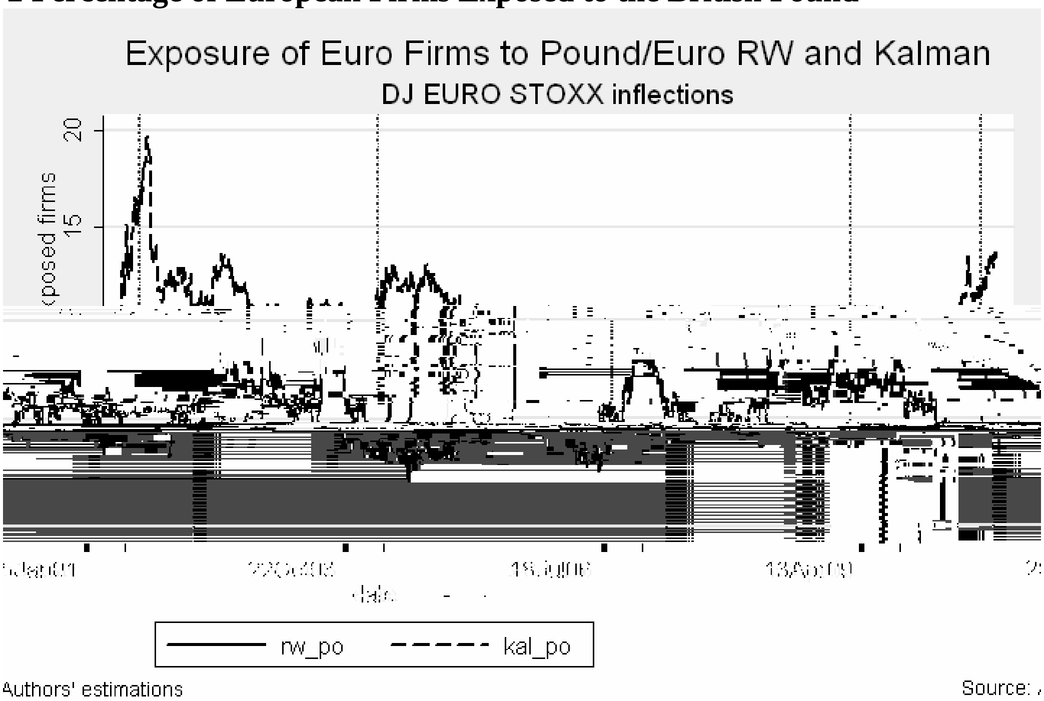


Figure 3 Percentage of European Firms Exposed to the Swiss Franc

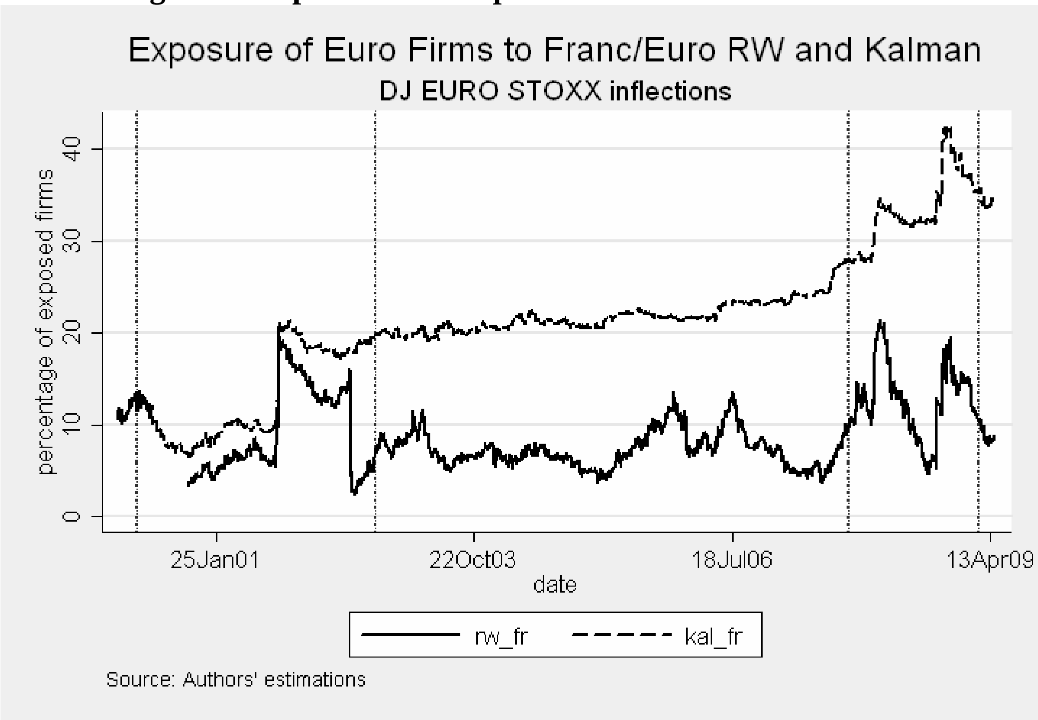


Figure 4 Percentage of European Firms Exposed to the Japanese Yen

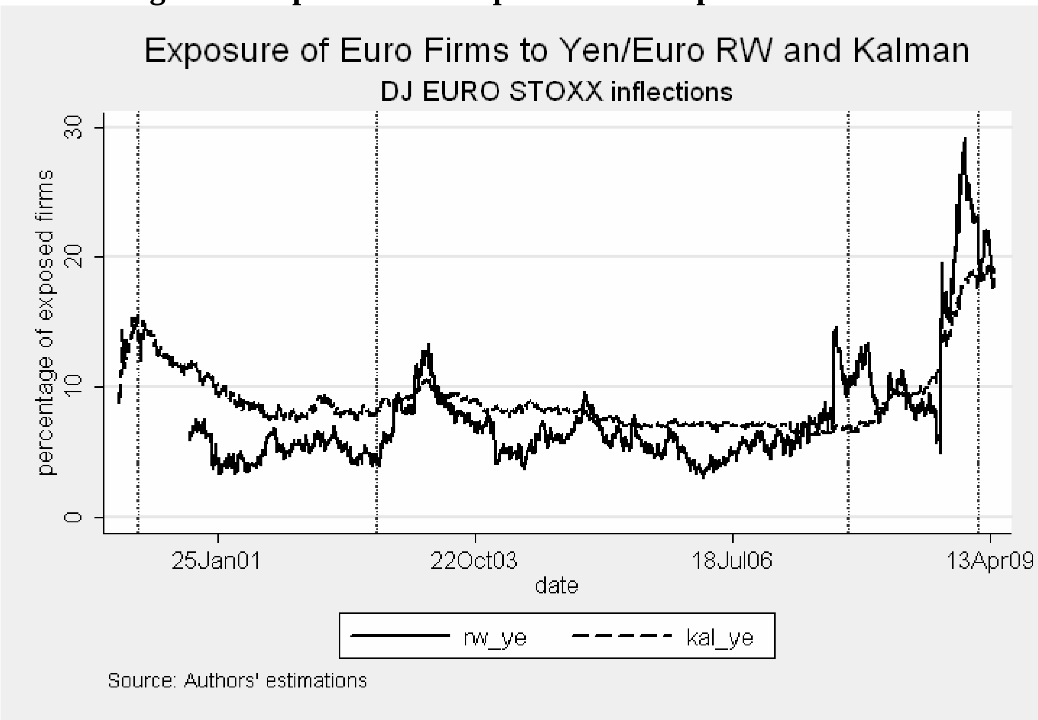
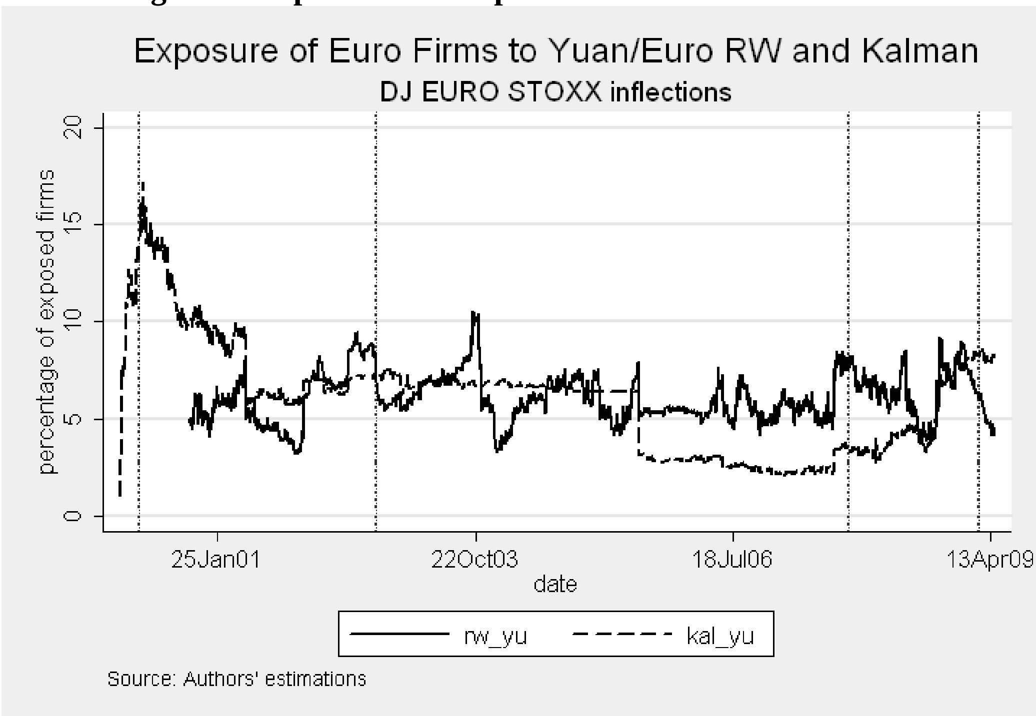


Figure 5 Percentage of European Firms Exposed to the Chinese Yuan



Pending a more formal analysis of these time series, it seems apparent to the eye (partly excepting the dollar and the yuan) that, during the upswing in the European stock market, the volatility of the series diminished. The widest swings occurred during the periods of stock market decline.

A more fundamental question is, of course, the extent to which the dramatic breaks on the trajectories of the share of exposed firms documented in these graphs is informative in the sense of reflecting overall shifts in the distribution of the exposures, as opposed to being mere artifacts of the arbitrary threshold of "statistical significance": z or $t > 1.96$. In other words, do these breaks exist because on those particular days a number of firms cluster on the borderline so that even tiny idiosyncratic events push them to the other side of the line in a cascading fashion, or do they reflect shifts in the mass of the entire distribution of exposures? Figures 6-10 are intended to address these questions by showing the trajectories of the mean, median, 10^{th} and 90^{th} percentiles of the distribution of the absolute values of the RW exposures. Figures 11-15 do the same for the absolute values of the KF exposures.

Figure 6 RW |Dollar Exposure| (Mean, Median, 10th and 90th Percentiles)

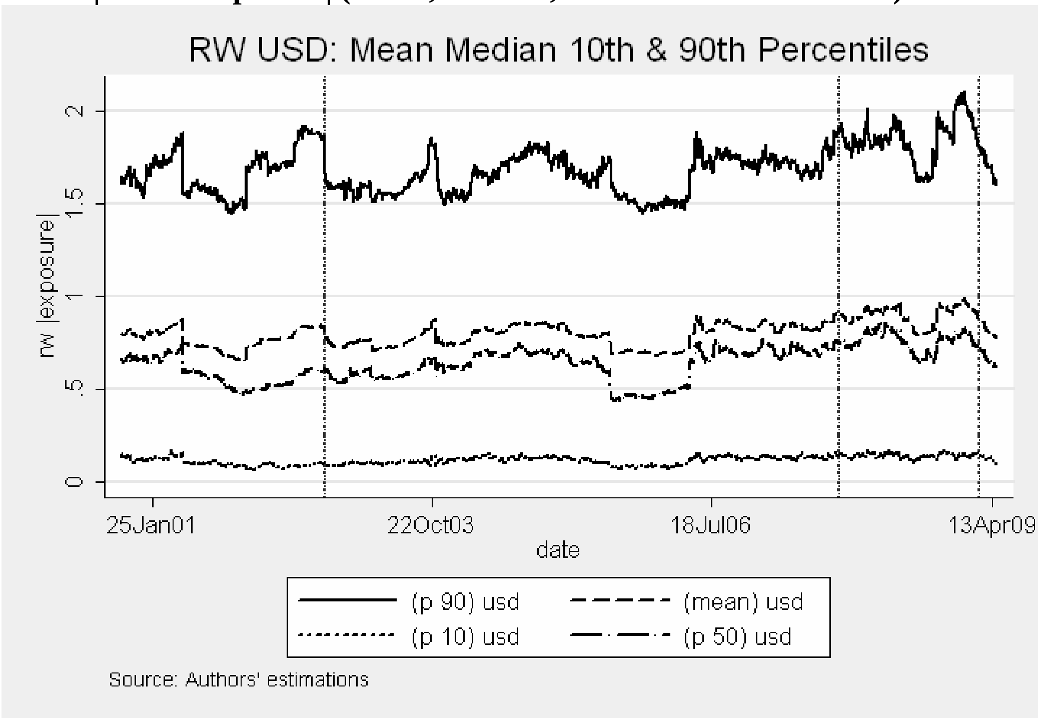


Figure 7 RW |Pound Exposure| (Mean, Median, 10th and 90th Percentiles)

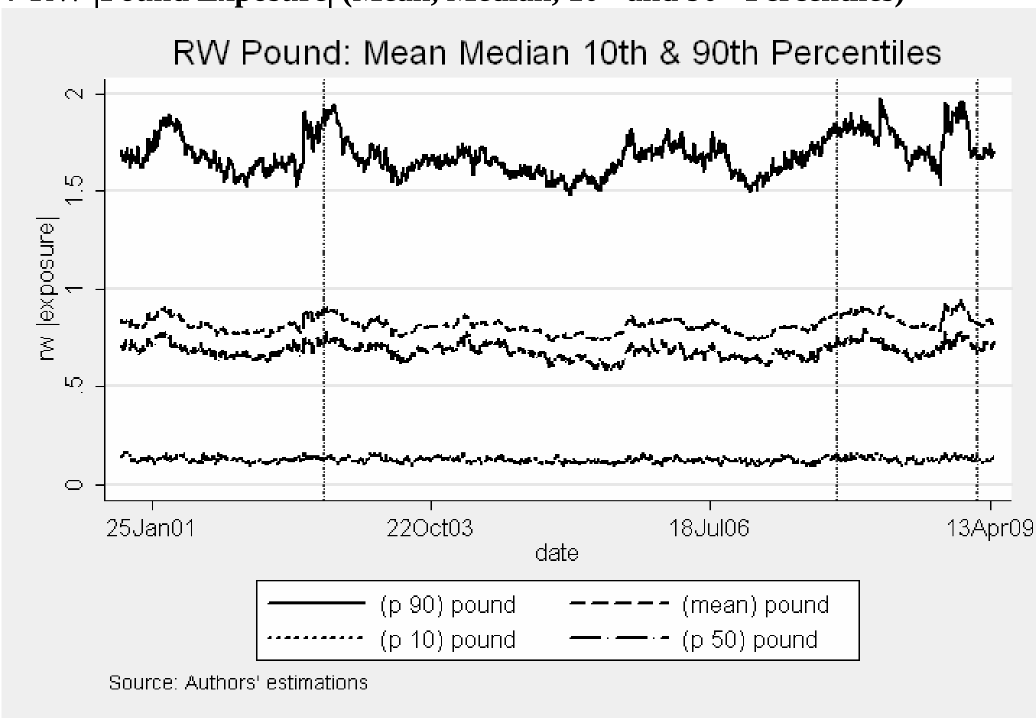


Figure 8 RW |Franc Exposure| (Mean, Median, 10th and 90th Percentiles)

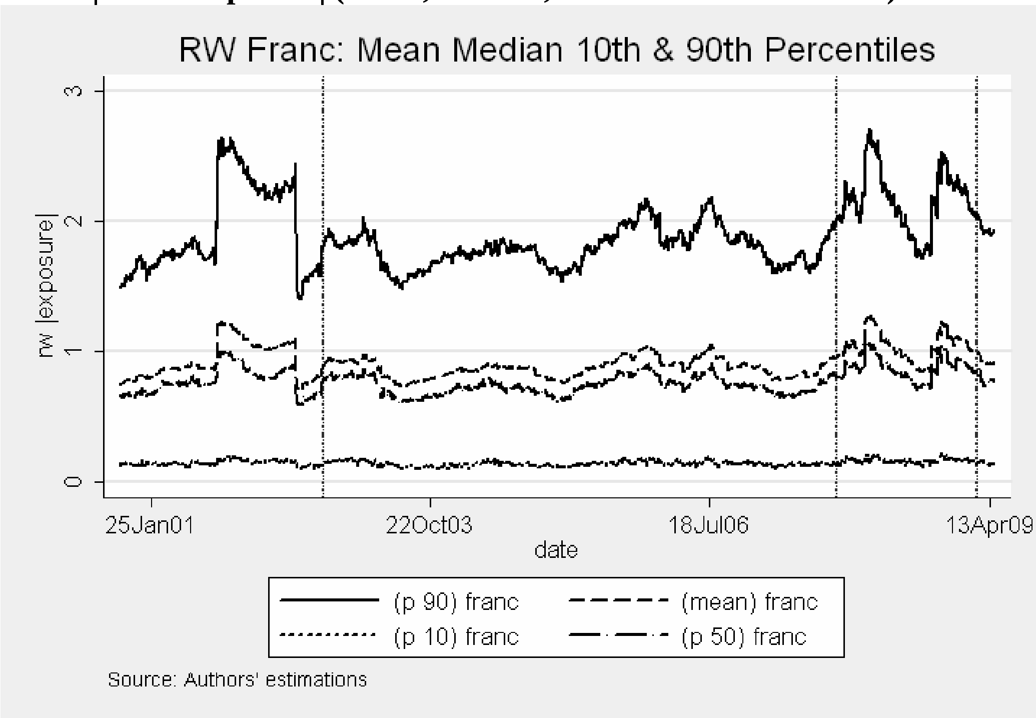


Figure 9 RW |Yen Exposure| (Mean, Median, 10th and 90th Percentiles)

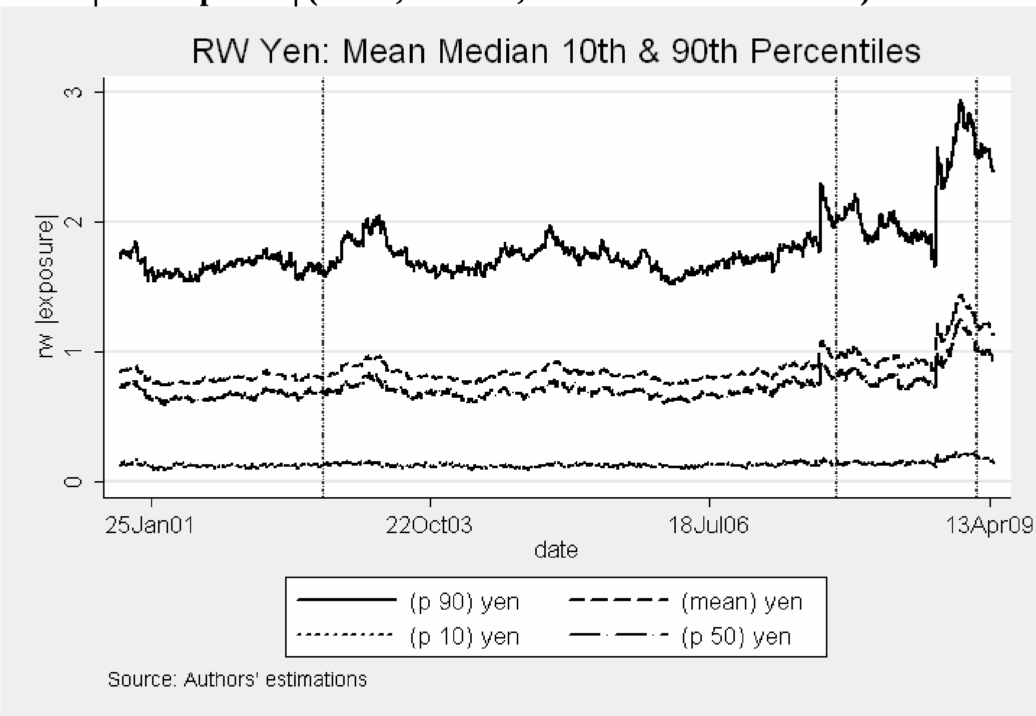


Figure 10 RW |Yuan Exposure| (Mean, Median, 10th and 90th Percentiles)

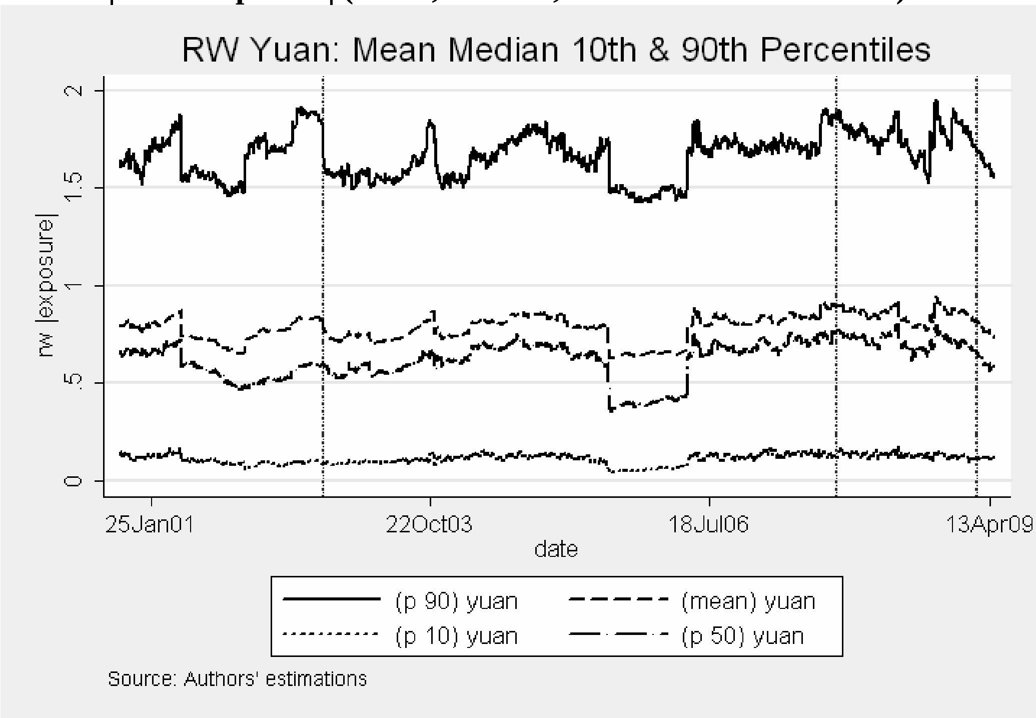


Figure 11 KF |Dollar Exposure| (Mean, Median, 10th and 90th Percentiles)

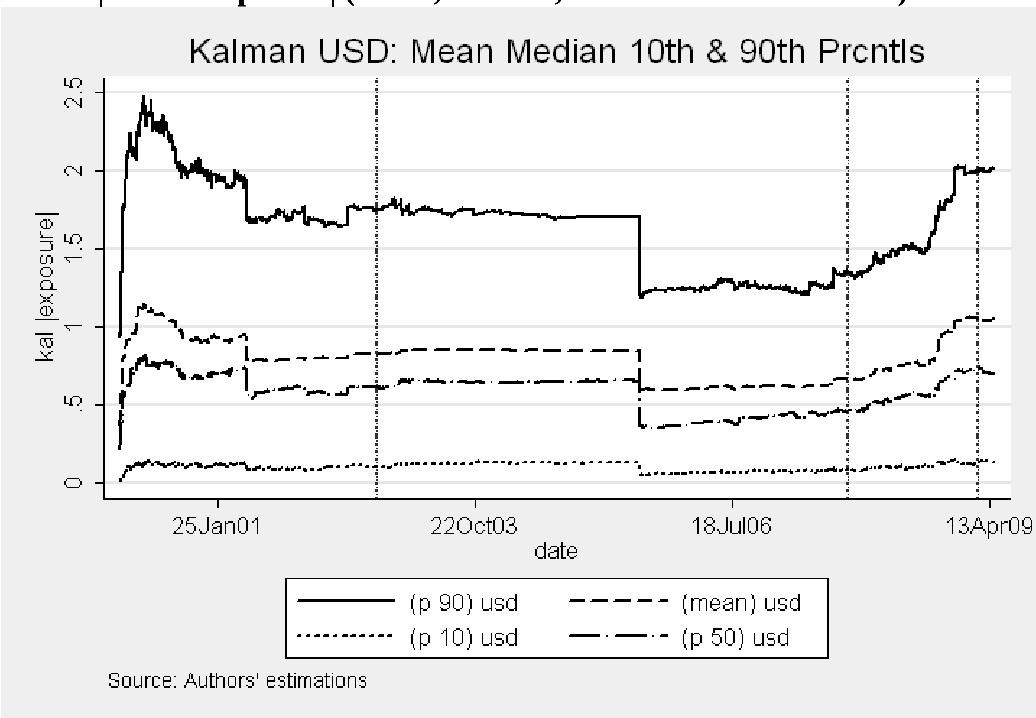


Figure 12 KF |Pound Exposure| (Mean, Median, 10th and 90th Percentiles)

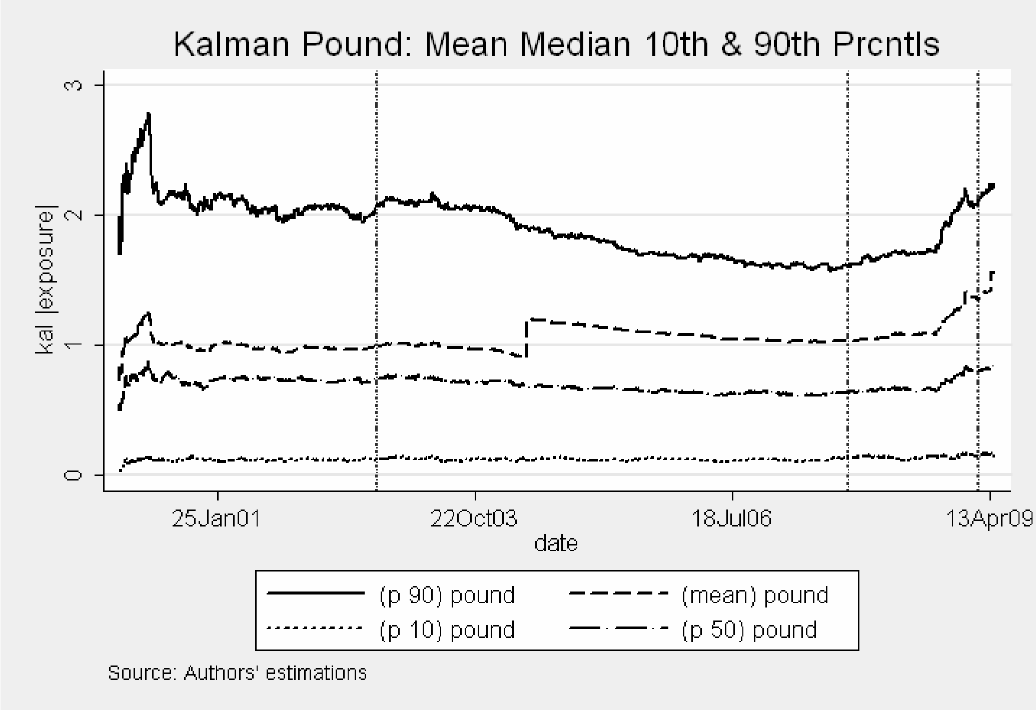


Figure 12 KF |Franc Exposure| (Mean, Median, 10th and 90th Percentiles)

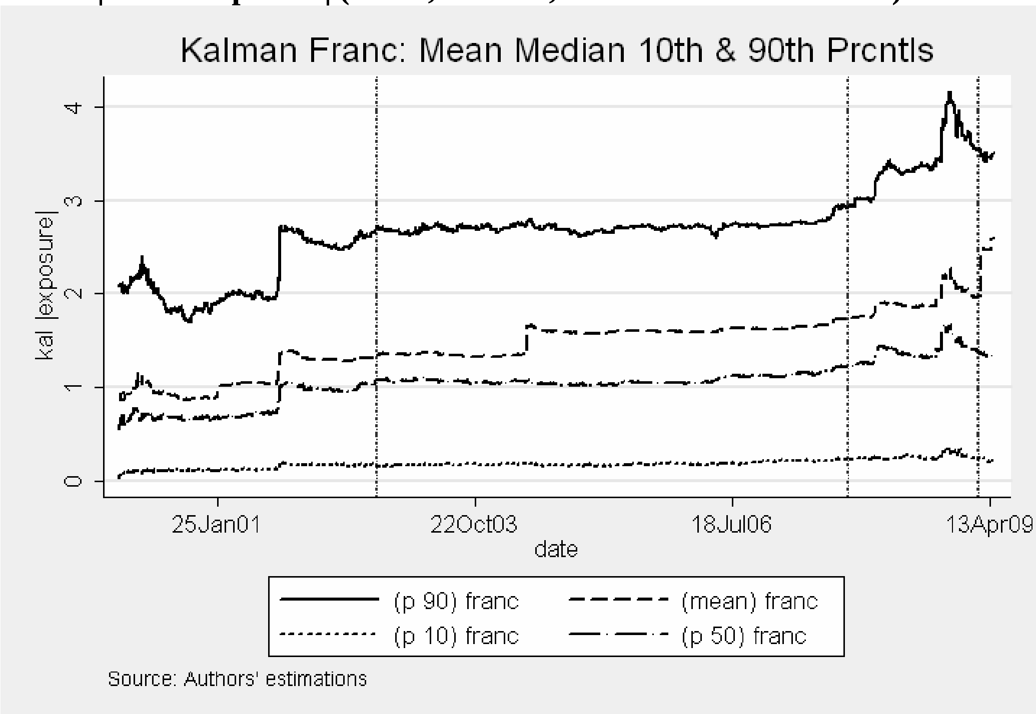


Figure 13 KF |Yen Exposure| (Mean, Median, 10th and 90th Percentiles)

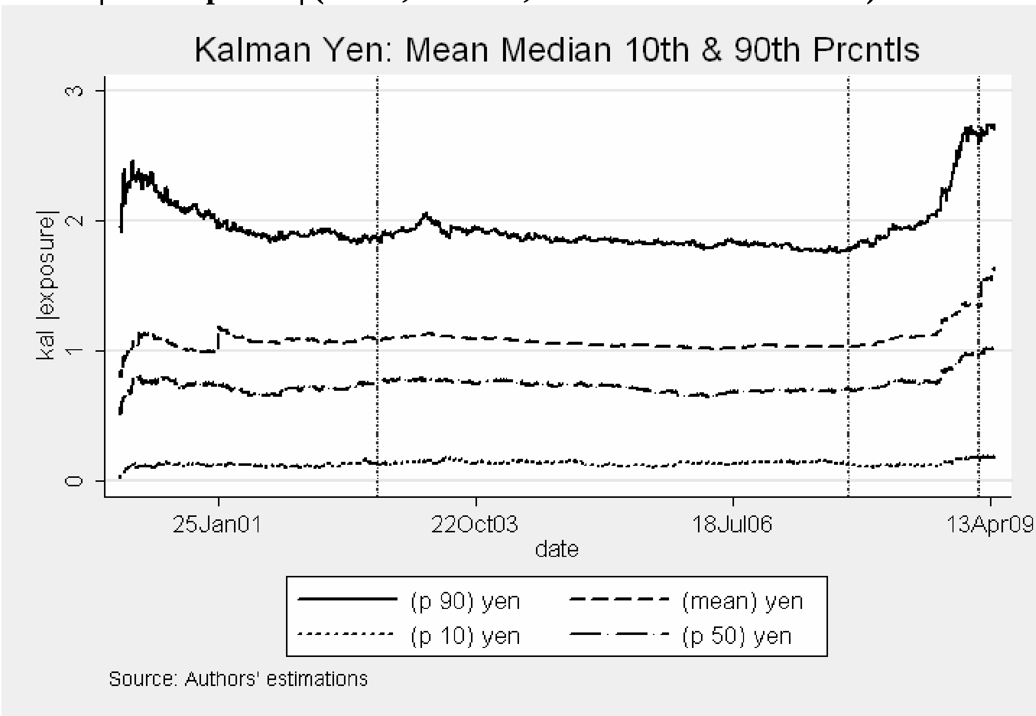
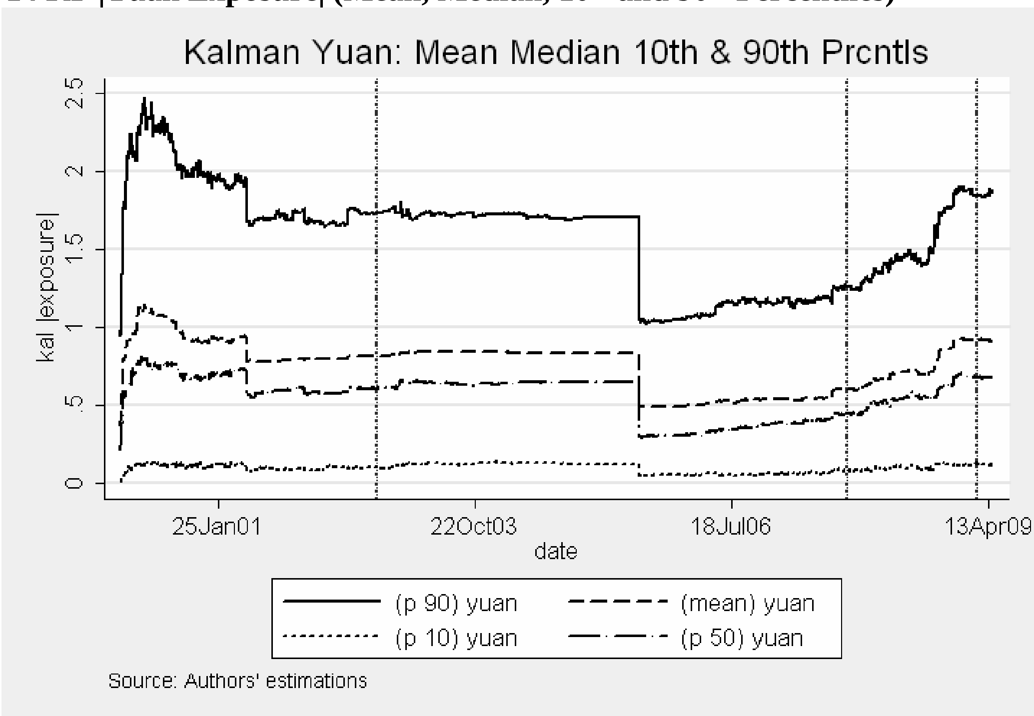


Figure 14 KF |Yuan Exposure| (Mean, Median, 10th and 90th Percentiles)



As expected, the entire distribution of firm exposures is more stable than the shares of firms "significantly" exposed. Having said that, a quick visual inspection of the graphs suggests that, overall, the breaks in the trajectory of the share of exposed firms reflect shifts in the entire density of exposures. Secondly, the right tails of the distributions are more volatile than their centers and much more volatile than the left tails. The difference between the mean and the median indicate that the distributions are skewed with most of the “action” occurring on the right tails.

A plausible narrative suggested by these graphs is that all sorts of idiosyncratic or system-wide events continuously buffet the value of individual firms. As a result, for given targeted returns, some of them suddenly find themselves in high-exposure territory. Athough, also continuously, the firms strive to reign on these misalignments by hedging and, more generally, adjusting their behavior to bring themselves back into line or back into their risk-preference “comfort zones,” in periods of time of market-wide turbulence, their efforts may get overwhelmed, which may account for the persistence of high exposures in those particular periods of time.

To what extent the RW and KF estimations of exposures diverge? Figures (15-19) contrast the trajectories of the RW and KF centers (means) of the distributions.

Figure 15 |Dollar Exposure| (RW and KF Means)

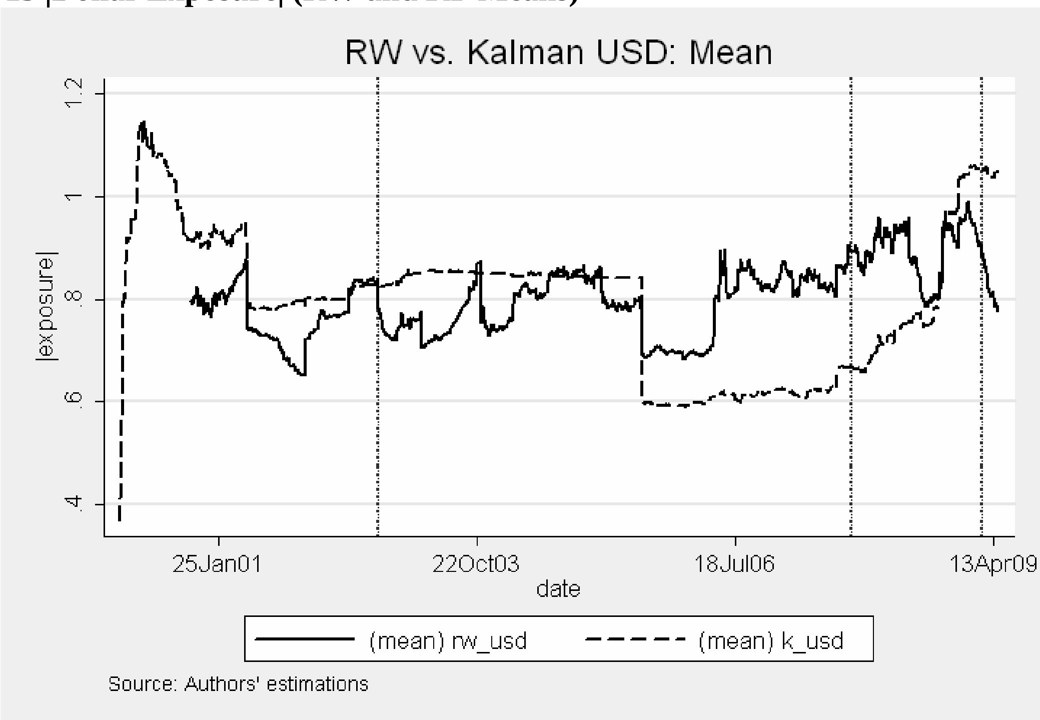


Figure 16 |Pound Exposure| (RW and KF Means)

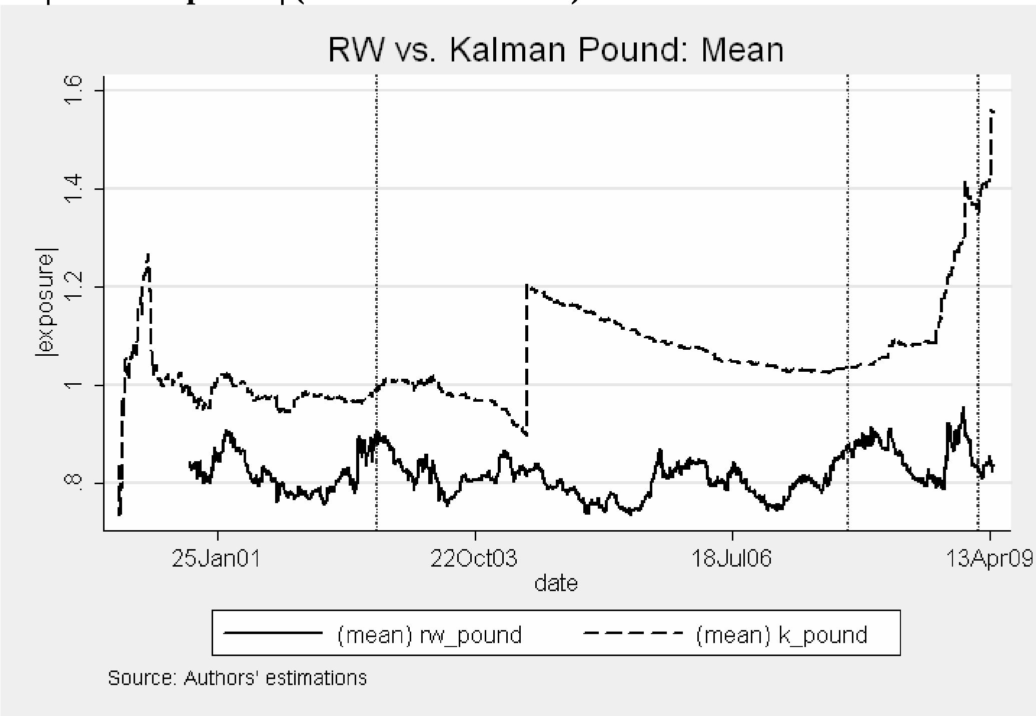


Figure 17 |Franc Exposure| (RW and KF Means)

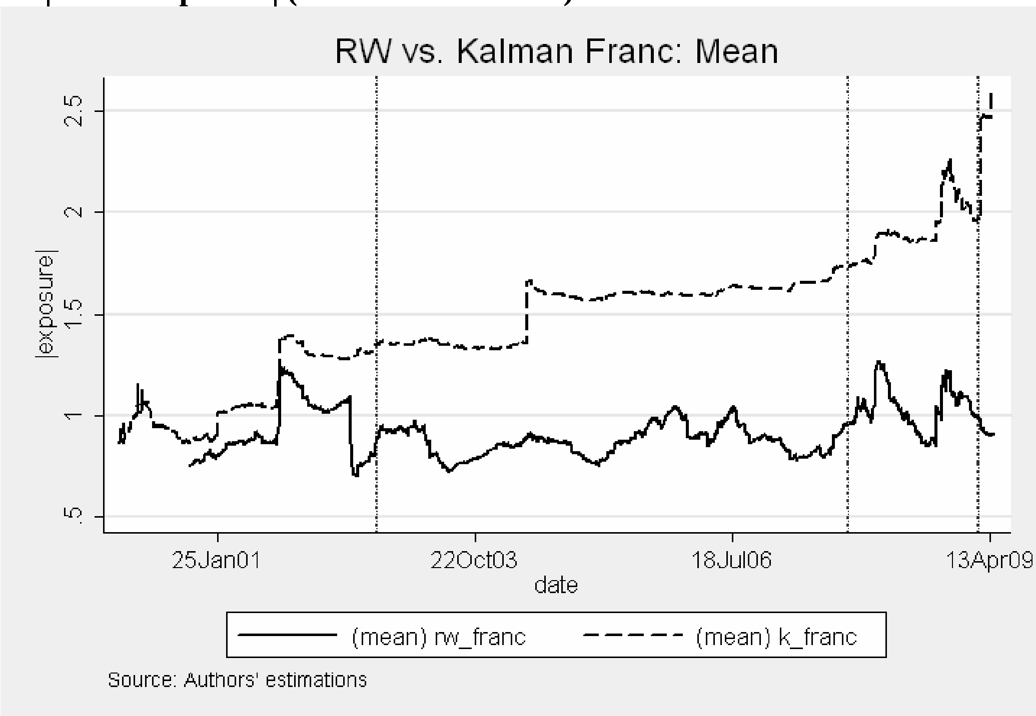


Figure 18 |Yen Exposure| (RW and KF Means)

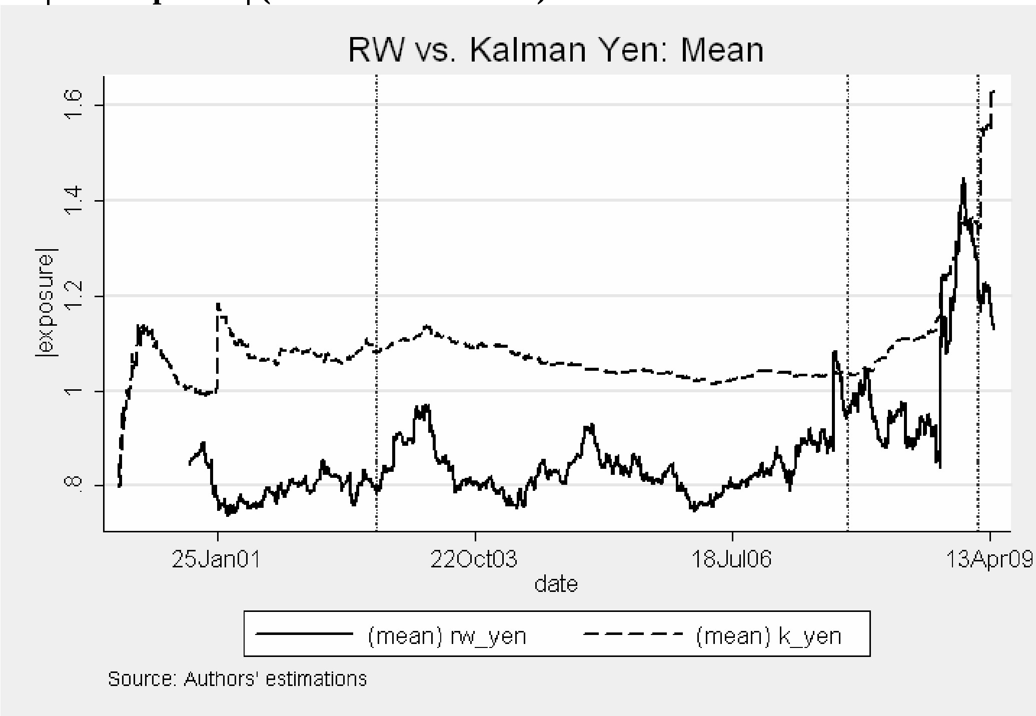
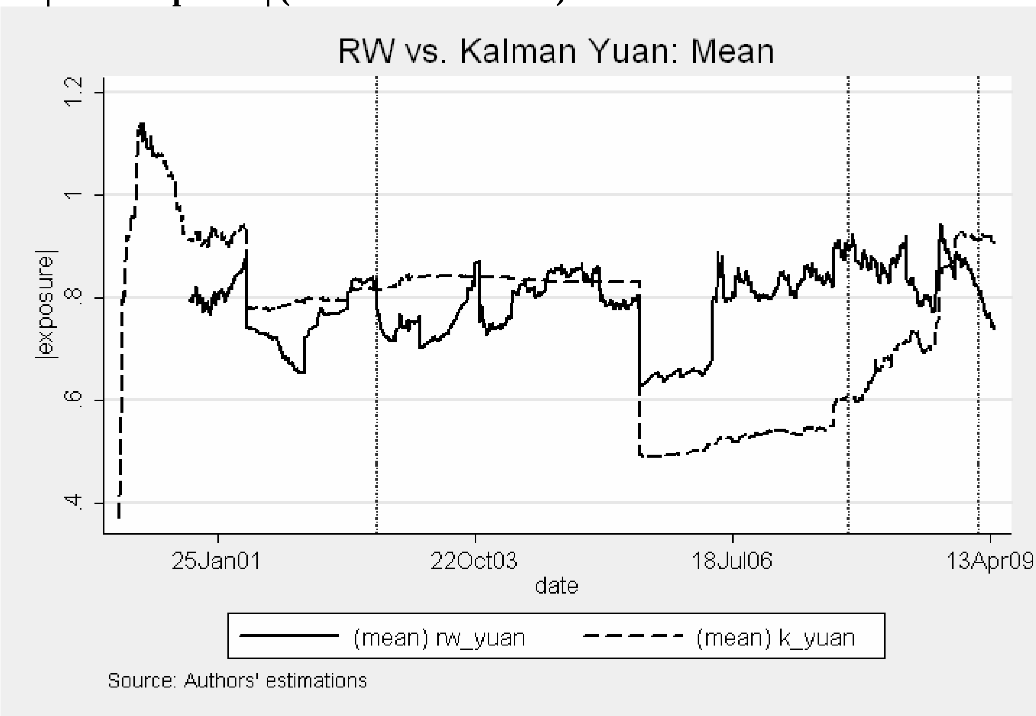


Figure 19 |Yuan Exposure| (RW and KF Means)



4. Conclusion

Using daily-return data for 1,031 European firms from January 3, 2000 to May 1, 2009 in an extended-CAPM framework, we estimated the (standard-error weighted) time-varying coefficients of *exposure* of firms to unanticipated variation in the returns on the US dollar, the

British pound, the Swiss franc, the Japanese yen, and the Chinese yuan, with two alternative methods: Rolling-Window OLS regression and Kalman Filter estimation.

The time series generated this way offer a unique view of the patterns of time variation of the full distribution of firms' exposure to foreign exchange volatility. This paper offers a first and preliminary approximation to the study of the time variation of foreign exchange exposure. Additional work is required to identify possible trends and breaks, and (cross-sectional) sources of variation in a dynamic context.

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