NORTHERN ARIZONA UNIVERSITY
The W. A. Franke College of Business

Time and Regime Dependence of Foreign Exchange Exposure

Working Paper Series—10-11 | August 2010

Ding Du
Northern Arizona University
The W. A. Franke College of Business
PO Box 15066
Flagstaff, AZ 86011.5066

Ding.Du@nau.edu

(928) 523-7274
Fax: (928) 523-7331

Pin Ng
Northern Arizona University
The W. A. Franke College of Business
PO Box 15066
Flagstaff, AZ 86011.5066

Pin.Ng@nau.edu

928-523-8726
(Fax) 928-523-7331

Xiaobing Zhao
Northern Arizona University
The W. A. Franke College of Business
PO Box 15066
Flagstaff, AZ 86011.5066

Xiaobing.Zhao@nau.edu

(928) 523-7279
(Fax) 928-523-7331

Time and Regime Dependence of Foreign Exchange Exposure

Introduction

Since the breakdown of the Bretton Wood system in 1973, purchasing power parity has been overwhelmingly rejected (see Frankel and Rose, 1995), implying that firms are exposed to foreign exchange risk. A firm's exchange rate exposure can originate from direct effects of exchange rate movements on firms' cash flows (through its influence on the demand for firms' goods/services or the cost of imported capital and other imported inputs), or their indirect effects (through foreign competition and competition for factors of production between traded and non-traded sectors). Therefore, even a firm with only domestic competitors and no foreign operations or sales can still be subject to foreign exchange exposure. Adler and Dumas (1984) claim that "U.S. corporations, including those with no foreign operations and no foreign currency assets, liabilities, or transactions, are generally exposed to foreign currency risk." (p 41)

However, empirical studies usually find that only a small proportion of U.S. firms have significant foreign exchange exposure. For instance, Jorion (1990) finds that only 5.2% of the individual firms and 20% of the portfolios have significant currency exposure (see also Khoo (1994), Bartov and Bodnar (1994), Allayannis (1997), Chow, Lee and Solt (1997), Bodnar and Wong (2003), Bartram (2004), and Bartram (2007)). This anomaly is called the "exposure puzzle" in the exchange rate literature. Bartram (2008) and Bartram, Brown, and Minton (2010) explain the exposure puzzle by arguing that firms use hedges to greatly reduce currency exposures to the observed low levels.

Two recent studies, however, suggest that methodological weakness, not hedging, may explain the insignificance of currency exposure in previous studies. One study by Francis, Hasan, and Hunter (2008) (hereafter FHH) emphasizes the time variation in foreign exchange exposure. Another study by Stacks and Wei (2005) (hereafter SW) argues that exchange exposure may be more significant when firms have high levels of short-term leverage, low liquidity and less internal funds. The argument of SW can be extended to predict the regime dependence of foreign exchange exposure. If high leverage and low liquidity mean high risk and therefore low prices/returns, foreign exchange exposure should depend on prices/returns of stocks. That is, exchange exposure should be particularly strong when prices/returns are low. There, of course, may be other mechanisms that can cause exchange exposure to be strong when prices/returns are high. The insight of SW is that researchers should look at foreign exchange exposure conditional on prices/returns of stocks.

In this paper, we extend the literature based on FHH and SW. First, we look at both the time and the regime (stratified according to the quantiles in the distribution of the returns) dependence of foreign exchange exposure. Second, unlike FHH and SW, we take a reduced-form approach instead of a structural approach. FHH use a conditional asset pricing model, which requires a model of investor expectation. SW use proxies to measure firm's sensitivity to short-term cash flow volatility. If the expectation model or the proxies are not appropriate, test results can be misleading. Furthermore, the regime dependence of foreign exchange exposure can be due to factors other than the sensitivity to short-term cash flow volatility. Therefore, it is important to examine the time and the regime dependence of foreign exchange exposure without structural assumptions or with a reduced-form approach. Third, different from FHH and SW, we examine the foreign exchange exposure of all U.S. industries, not sub groups of U.S. industries. Since even a firm with only domestic competitors and no foreign operations or sales could still be subject to foreign exchange exposure, it may not be appropriate to focus only on subsets of U.S. industries that have foreign transactions.

Empirically, we find that only 6 out of 30 or 20% of U.S. industry portfolios have significant exposure to the currencies of the industrialized economies if we do not allow the time and regime dependence in exposure. This is consistent with the findings in previous studies (i.e. Jorion (1990)) However, as soon as we take into account the time and regime dependence in exposure by using a random coefficient model and the quantile regression technique invented by Koenker and Bassett (1978), we find that 26 out of 30 or 87% of U.S. industry portfolios exhibit significant foreign exchange exposure!

Similarly, we find that only 5 out of 30 or 17% of U.S. industry portfolios have significant exposure to the currencies of the developing economies if we do not take into account the time and regime dependence in exposure. However, as soon as we allow the time and regime dependence in exposure, we find that 23 out of 30 or 77% of U.S. industry portfolios exhibit significant exposure to the currencies of the developing economies.

Our results therefore support FHH and SW, and suggest that methodological weakness, not hedging, explains the insignificance of currency exposure in previous studies. First, if hedging were important, we would not expect that the majority of the U.S. industries have significant currency exposure. Second, if hedging were decisive, the exposure to the currencies of the industrialized economies should not be as strong as that to the currencies of developing economies, because as FHH point out it is more difficult for U.S. firms to hedge the exchange rate risk of the currencies of developing economies.

The remainder of the paper is organized as follows: Section 2 discusses the data. Section 3 presents the empirical methodology and the empirical results. Section 4 concludes the paper with a brief summary.

Data

Following FHH, we focus on two trade-weighted currency indexes from the Federal Reserve Bank in St. Louis. The first one is the Federal Reserve's Major Currencies Index (*MCI*), which is a weighted average of the foreign exchange value of the dollar against currencies of major industrial countries.[1] The second one is the Other Important Trading Partners Index (*OITP*), which is a weighted average of the foreign exchange value of the U.S. dollar against currencies of major developing countries.[2] As FHH point out, there are two reasons to take the OITP index into account. First, trade with the developing economies has become increasingly important, growing from 31% of total trade in 1980 to about 42% in 1999 and 48% in 2006. Second, studying the exposure to the OITP index can shed light on whether hedging can explain the low exposure found in previous studies. As FHH point out, it is difficult for U.S. firms to hedge the exchange rate risk of the currencies of developing countries. Therefore, if hedging could explain the exposure puzzle, we would expect that the exposure to the OITP index should be stronger than that to the MCI index.

In line with the relevant studies (i.e. FHH and SW), we use 30 industry portfolios as our exposure testing assets. SW point out that industry portfolios may be better testing assets when a trade-weighted currency index is used since a firm is not exposed to all currencies in the basket in the same magnitude as the composition of the basket. Moreover, it is well known that using portfolios instead of individual stocks in empirical asset pricing can result in more precise parameter estimates (i.e. Fama and MacBeth, 1973, and Chen, Roll, and Ross, 1986). The industry portfolio returns as well as other stock market data are from the Kenneth French's website.[3]

To help understand the currency exposure, we follow SW and compile the international trade data for the U.S. manufacturing industries. We first retrieve monthly commodity imports and exports data at the four-digit SIC level from the U.S. International Trade Commission. The imports data are U.S. general imports based upon general custom values, and the exports are the total exports data based upon FAS values. Since we focus on two trade-weighted currency indexes in this paper, we extract the total imports/exports to/from each group of countries (i.e. MCI countries or OITP countries) for each four-digit SIC commodity group for the period from 1989 to 2001 (the trade data based on the SIC codes are only available for this period).

Then, we match the imports and exports data with the stock returns data based on the SIC codes. Finally, we compute the trade balance for each industry as the difference between total exports and general imports. It is important to note that the trade data may only be viewed as a rough estimate, because the match is based on the SIC codes not the actual firm-level imports and exports data. For instance, household furniture and appliances are classified as Consumer Goods. But such consumer goods

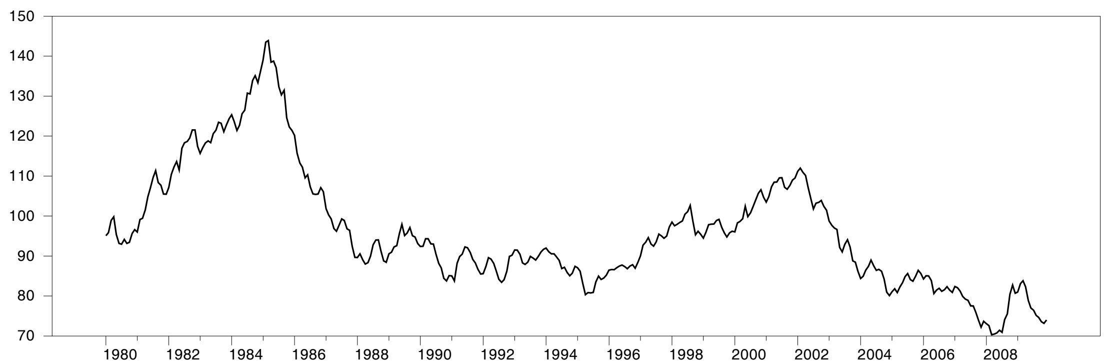
[1] Major currency index includes the Euro Area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden.
[2] Countries whose currencies are included in the other important trading partners index are Mexico, China, Taiwan, Korea, Singapore, Hong Kong, Malaysia, Brazil, Thailand, Philippines, Indonesia, India, Israel, Saudi Arabia, Russia, Argentina, Venezuela, Chile and Colombia.
[3] The data are available at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/.

are not only imported or exported by the U.S. Consumer Goods industry (Hshld) but also by the U.S. wholesale or retail industries. Nevertheless, the trade data may still help us gain some understanding of the currency exposure.

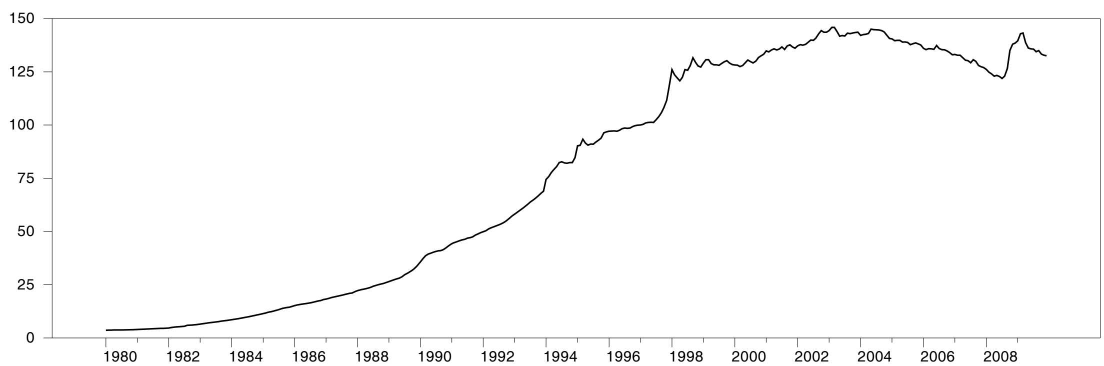
We focus on a similar sample period as in FHH, the post-1980 period. More precisely, our sample covers the period from January 1980 to December 2009. Panel A of Figure 1 shows the MCI index series over our sample period, where Panel B shows the OITP index series. As we can see, the value of the dollar changes substantially over our sample period. Table 1 shows the summary statistics of our 30 industry portfolios.

Figure 1 Major Currency Index (MCI) and Other Important Trading Partner Index (OITP) 1980:1-2009:12

Panel A MCI



Panel B OITP



Panel A of Figure 1 shows the MCI index series over our sample period, where Panel B shows the OITP index series. As we can see, the value of the dollar changes substantially over our sample period.

Table 1 Summary Statistics for Industry Excess Returns (1980:1-2009:12)

Industry	Mean	Variance	CAPM β
Food	1.29	19.96	0.61
Beer	1.43	28.96	0.66
Smoke	1.57	47.58	0.63
Games	1.12	49.97	1.25
Books	0.96	33.92	1.03
Hshld	1.09	22.13	0.73
Clths	1.11	42.18	1.05
Hlth	1.16	23.24	0.76
Chems	1.05	32.79	1.02
Txtls	1.04	62.25	1.12
Cnstr	0.97	38.10	1.14
Steel	0.89	65.85	1.40
FabPr	0.94	42.75	1.23
ElcEq	1.35	42.19	1.21
Autos	0.94	55.84	1.17
Carry	1.15	41.08	1.04
Mines	0.86	69.29	0.91
Coal	1.40	110.66	1.12
Oil	1.14	32.36	0.74
Util	1.00	16.54	0.45
Telcm	0.97	26.89	0.83
Servs	1.22	47.04	1.31
BusEq	1.01	58.91	1.38
Paper	1.02	28.69	0.92
Trans	1.05	33.38	0.99
Whlsl	0.99	28.38	0.98
Rtail	1.25	31.73	0.96
Meals	1.11	29.26	0.87
Fin	1.08	30.71	1.01
Other	0.69	34.39	1.03

Table 1 shows the summary statistics of our 30 industry portfolios.

Empirical Methodology and Results

Standard Approach

The standard approach in the literature is to regress monthly stock returns on the market return and the percentage change in the foreign exchange rate index (e.g. Adler and Dumas (1983), Bartram (2007)):

$$r_{it} = \alpha_i + \beta_{i,M} M_t + \beta_{i,FX} FX_t + \varepsilon_{it} \quad (1)$$

where r_{it} is the excess return on asset *i* in period *t*, M_t is the excess returns of the market factor, and FX_t is the percentage change in the foreign exchange rate index. The β's are the associated factor loadings, and ε_{it} is the disturbance. β_{FX} is assumed to be constant over time and not to depend on the regime of stock returns.

Since we examine two trade-weighted currency indexes as in FHH, our benchmark model in this paper is:

$$r_{it} = \alpha_i + \beta_{i,M} M_t + \beta_{i,MCI} MCI_t + \beta_{i,OITP} OITP_t + \varepsilon_{it} \qquad (2)$$

where MCI_t and $OITP_t$ are the percentage changes in the *MCI* and the *OITP*. Table 2 shows the least-squares results for the 30 industry portfolios over our entire sample period from 1980 to 2009. The t-ratios are based on Newey-West HAC standard errors with the lag parameter set to 12. We focus on the exposure to the currency indexes, and the significant factor loadings (at the 5% level for the two-sided test) are in bold. We also report the average trade balances for the 21 manufacturing industries.

Table 2 Fixed Foreign Exchange Exposure Least-squares Estimates (1980:1-2009:12)

Industry	β_M	β_{MCI}	β_{OITP}	**Trade Balance with MCI ($1,000)**	**Trade Balance with OITP ($1,000)**
Food	**0.61**	-0.10	0.17	1052476	322915
Beer	**0.65**	-0.16	0.09	-285133	-39573
Smoke	**0.63**	-0.04	0.08	223945	73821
Games	**1.25**	0.18	-0.16	-173999	-1619881
Books	**1.04**	**0.21**	-0.10	125306	-17945
Hshld	**0.74**	0.07	0.04	-859461	-1533359
Clths	**1.06**	**0.33**	-0.21	-275878	-2762729
Hlth	**0.77**	-0.06	**0.24**	-43720	29768
Chems	**1.01**	-0.03	-0.15	239503	995073
Txtls	**1.11**	**0.31**	**-0.54**	-21893	-179577
Cnstr	**1.13**	-0.05	-0.11	-518432	-482290
Steel	**1.37**	-0.20	-0.34	-553546	-290017
FabPr	**1.20**	-0.10	**-0.41**	-500448	1197132
ElcEq	**1.21**	0.03	0.01	-105764	-171135
Autos	**1.17**	0.11	-0.11	-4977314	-788119
Carry	**1.04**	0.18	-0.11	833093	1119816
Mines	**0.85**	**-0.68**	-0.38	67645	-19674
Coal	**1.04**	-0.33	**-1.25**	196824	31866
Oil	**0.72**	-0.18	-0.26	-1397252	-2201703
Util	**0.44**	-0.14	0.00	-	-
Telcm	**0.85**	0.05	**0.33**	-	-
Servs	**1.32**	0.10	0.09	-	-
BusEq	**1.38**	0.07	-0.18	509524	-1863198
Paper	**0.91**	-0.04	-0.05	-506882	214245
Trans	**1.00**	**0.18**	0.09	-	-
Whlsl	**0.98**	0.08	-0.02	-	-
Rtail	**0.99**	**0.45**	0.12	-	-
Meals	**0.88**	0.19	-0.03	-	-
Fin	**1.02**	0.19	-0.05	-	-
Other	**1.04**	0.03	0.09	-	-

Table 2 shows the least-squares results for the 30 industry portfolios over our entire sample period from 1980 to 2009. The t-ratios are based on Newey-West HAC standard errors with the lag parameter set to 12.

As we can see, only 6 out of 30 or 20% of the industry portfolios have statistically significant exposure to the *MCI*. Books (Printing and Publishing), Clths (Apparel), Txtls (Textiles), Trans

(Transportation), and Rtail (Retail) have significant positive exposure, while Mines (Precious Metals, Non-Metallic, and Industrial Metal Mining) has significant negative exposure. The exposure signs for the manufacturing industries are generally consistent with the trade pattern: three out of four industries have the expected signs. Mines has a negative exposure because with a positive trade balance it is an exporting industry and suffers from an appreciation of the dollar. Apparel and Textiles have positive exposure because they are importing industries and benefit from an appreciation of the dollar (see also Jorion, 1990).

Similarly, only 5 out of 30 or 17% of the industry portfolios have statistically significant exposure to the *OITP*. Two out of four manufacturing industries have the expected signs that are consistent with the trade pattern. Since the trade data are not based on the firm-level imports and exports and currency exposure can be due to non-trade related reasons, it may not be surprising to see a relatively weak connection between currency exposure and trade.

In brief, we have found that our estimates produce similar results of low exposure as in previous studies if we do not allow for time variation and regime dependence in currency exposure. Therefore, we next take into account the time and regime dependence in currency exposure.

Two-Step Quantile Regression Methodology

Regime Dependence

Currency exposure may be regime dependent. As SW argue, foreign exchange exposure may be more significant when firms have high levels of short-term leverage, low liquidity and less internal funds. If high leverage and low liquidity mean high risk and therefore low prices/returns, foreign exchange exposure should depend on prices/returns of stocks. That is, exchange exposure should be particularly strong when returns are low or depressed. Other mechanisms may cause exchange exposure to be strong when returns are high. The insight of SW is that researchers should look at foreign exchange exposure conditional on prices/returns of stocks.

We therefore use the quantile regression technique invented by Koenker and Bassett (1978) to capture any potential asymmetry in foreign exchange exposure across the different regimes of the return distribution. We define different regimes as different quantiles of the excess return of an industry, conditioned on the market excess return and the foreign exchange indices. When the distribution of the excess return of an industry, conditioned on a specific market return and foreign currency indices, remains the same across the different values of the conditioning variables, the degree of currency exposure, measured by the factor loading β_{FX} in Eq. (1), will remain the same over the various regions (regimes or quantile) of the excess return distribution. However, if the conditional distribution of an industry's excess return is changing (i.e. regime dependent) across the values of the conditioning variables, then the impacts of foreign currency indices on the industry's excess return will be different for different regimes of the return distribution.

In the latter case, traditional least-squares regression, which provides an estimate of the conditional mean relationship between an industry's excess return and exchange rate indices near the center of the excess return distribution, will not be able of discern this variation in the degree of foreign currency exposure over the entire excess return distribution. Quantile regression, on the other hand, provides an estimate of the conditional relationship for any quantile (regime) of the industry's excess return on market excess return and the foreign currency indices and, hence, is capable of revealing the variation in the degree of currency exposure. See Koenker (2005, Chapter 1) and Koenker and Hallock (2001) for the motivations and advantages of using the quantile regression technique.

Let $e_{it} = r_{it} - \alpha_i - \beta_{i,M} M_t - \beta_{i,FX} FX_t$ denote the residuals in Eq. (2). The τ -th quantile (100τ percentile) regression coefficients $\beta_{i,M}^{\tau}$, $\beta_{i,MCI}^{\tau}$ and $\beta_{i,OITP}^{\tau}$ minimize the following objective function:

$$\sum_{i:e_t>0} (\tau)\left(r_{it} - \alpha_i^{\tau} - \beta_{i,M}^{\tau} M_t - \beta_{i,FX} FX_t\right) + \sum_{t:e_t\le 0} (1-\tau)\left(r_{it} - \alpha_i^{\tau} - \beta_{i,M}^{\tau} M_t - \beta_{i,FX} FX_t\right) \text{for any } 0 < \tau < 1 .$$

Positive residuals are assigned a weight of τ while negative residuals receive a weight of $(1-\tau)$ in the objective function. Hence the τ -th quantile regression plane dissects the data points into two portions with $100\tau\%$ of them falling above and $100(1-\tau)\%$ of them below the plane. The special case of $\tau = 0.5$ corresponds to the median regression plane which divides the data points into two equal halves, one falling above and the other below the plane. As a result, the τ -th quantile regression coefficients $\beta_{i,M}^{\tau}$, $\beta_{i,MCI}^{\tau}$ and $\beta_{i,OITP}^{\tau}$ estimate the marginal effect of the market excess return, *MCI* and *OITP*, respectively, on the τ -th quantile of the *i*-th industry's excess return after controlling for the effects of the other included conditioning variables. Hence, the quantile regression coefficients $\beta_{i,MCI}^{\tau}$ and $\beta_{i,OITP}^{\tau}$ that correspond to the higher values of τ that are closer to one provide estimates on the degree of foreign currency exposure near the upper tail of the industry's excess return distribution while the coefficients that correspond to the lower values of τ estimate the degree of the foreign currency exposure in the lower end of the excess return distribution.

Time Variation

FHH, among others, emphasize the importance of time variation of currency exposure. They take into account the time variation in currency exposure by using a conditional asset pricing model, which requires a model of investor expectation. If the model has specification errors, test results based on the model can be misleading.

In this paper, we adopt a reduced-form approach instead and consider a random coefficient model. We assume that the currency exposure in every period $\beta^{\tau}_{t,i,FX}$ is equal to a constant plus a random shock:

$$\beta^{\tau}_{t,i,FX} = \tilde{\beta}^{\tau}_{i,FX} + u_{it} \quad (3)$$

where *FX* is either the *MCI* index or the *OITP* index, and $\tilde{\beta}_{i,FX}$ represents the location parameter of the distribution of $\beta^{\tau}_{t,i,FX}$ and u_{it} has a mean 0 as in most regression formulations.

To estimate $\tilde{\beta}^{\tau}_{i,FX}$, we use a two-step procedure which is motivated by the two-step regression of Fama and MacBeth (1973). The first step is to run time-series regressions to obtain the currency exposure of each industry in each month by estimating Eq. (2) in a rolling regression fashion. More specifically, currency exposure is estimated with 5 years of data to obtain meaningful estimates. Consequently, the test period starts in 1985:1. We update estimates monthly by dropping the earliest observation and adding the latest observation.

The second step is to empirically estimate Eq. (3) by regressing the estimated currency exposure from the step one on a constant and an error term, and test for the significance of $\tilde{\beta}^{\tau}_{i,FX}$. Since we use rolling overlapping samples in the first step, we artificially introduce strong autocorrelation in the error term. We therefore use the *t*-ratios based on Newey-West HAC standard errors with the lag parameter set to 12 for statistical inference.[4] Empirically, we first use OLS in our two-step procedure. The idea is to see how much more explanatory power we can gain by only allowing the time variation in currency exposure. Then, we utilize quantile regression technique (discussed in the previous section) to further allow the regime dependence in currency exposure.

The results based on the OLS are reported in Table 3. We focus on the exposure to the currency indexes, and the significant factor loadings (at the 5% level for the two-sided test) are in bold. We also report the average trade balances for the 21 manufacturing industries. As we can see, if we allow the time variation in currency exposure, 17 out of 30 or 57% of industry portfolios have significant exposure to the *MCI*, and 12 out of 30 or 40% of industry portfolios have significant exposure to the OITP. Again, the exposure to the MCI is more consistent with the trade pattern. 7 out of 12 exposures to the MCI have expected signs, where only 2 out of 8 exposures to the OITP have expected signs. Again, since the trade data are not based on the firm-level imports and exports and currency exposure can be due to non-trade related reasons, it may not be so surprising to see a relatively weak connection between currency exposure and trade.

[4] The results are robust for different lag parameters.

Table 3 Time-Varying Foreign Exchange Exposure Least-squares Estimates (1980:1-2009:12)

Industry	β_M	β_{MCI}	β_{OITP}	**Trade Balance with MCI ($1,000)**	**Trade Balance with OITP ($1,000)**
Food	**0.67**	-0.07	-0.06	1052476	322915
Beer	**0.71**	**-0.13**	**-0.29**	-285133	-39573
Smoke	**0.68**	0.01	**-0.51**	223945	73821
Games	**1.21**	**0.21**	-0.06	-173999	-1619881
Books	**0.96**	**0.24**	**-0.24**	125306	-17945
Hshld	**0.77**	**0.05**	**-0.10**	-859461	-1533359
Clths	**1.10**	**0.28**	-0.04	-275878	-2762729
Hlth	**0.84**	**-0.11**	0.01	-43720	29768
Chems	**0.97**	0.06	-0.20	239503	995073
Txtls	**0.96**	**0.50**	**-0.76**	-21893	-179577
Cnstr	**1.11**	0.01	**-0.24**	-518432	-482290
Steel	**1.33**	-0.09	**0.21**	-553546	-290017
FabPr	**1.19**	-0.07	-0.04	-500448	1197132
ElcEq	**1.20**	0.01	0.09	-105764	-171135
Autos	**1.09**	**0.18**	-0.09	-4977314	-788119
Carry	**0.98**	**0.20**	-0.08	833093	1119816
Mines	**0.73**	**-0.47**	-0.16	67645	-19674
Coal	0.98	-0.21	-0.24	196824	31866
Oil	**0.67**	**-0.16**	**-0.25**	-1397252	-2201703
Util	**0.41**	-0.07	-0.34	-	-
Telcm	**0.90**	-0.03	**0.37**	-	-
Servs	**1.37**	0.01	0.25	-	-
BusEq	**1.45**	**-0.10**	0.17	509524	-1863198
Paper	**0.88**	-0.05	-0.03	-506882	214245
Trans	**1.00**	**0.17**	**0.22**	-	-
Whlsl	**0.96**	**0.11**	**-0.16**	-	-
Rtail	**1.05**	**0.40**	0.08	-	-
Meals	**0.91**	**0.19**	**-0.43**	-	-
Fin	**1.02**	**0.26**	-0.13	-	-
Other	**1.00**	0.09	-0.27	-	-

Table 2 shows the least-squares results for the 30 industry portfolios over our entire sample period from 1980 to 2009. The t-ratios are based on Newey-West HAC standard errors with the lag parameter set to 12.

We next further allow the regime dependence in currency exposure. The results are reported in Tables 4 and 5. To save space, we only present the currency exposure with the significant factor loadings (at the 5% level for two-sided tests) highlighted in bold face. Again, we also report the average trade balances for the 21 manufacturing industries.

Strikingly, as soon as we allow for time variation and regime dependence in currency exposure, we find that most industries exhibit significant foreign exchange exposure in at least one of the ten regimes (or quantiles signified by τ in discrete steps of 0.1 from 0.1 to 0.9). Table 4 shows that 26 out of 30 or 87% of industry portfolios have significant exposure to the *MCI* in at least one of the regimes, where Table 5 demonstrates that 23 out of 30 or 77% of the industry portfolios have significant exposure to the *OITP* in at least one of the regimes. Again, the exposure to the MCI is more consistent with the

Table 4 Two-step Quantile Regression Foreign Exchange Exposure Estimates Using MCI (1980:1-2009:12)

	τ									
Industry	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**Trade Balance**
Food	-0.08	**-0.16**	**-0.19**	**-0.17**	**-0.13**	-0.06	-0.10	-0.10	0.14	1052476
Beer	-0.16	-0.07	-0.09	-0.04	-0.08	-0.02	-0.02	-0.09	-0.11	-285133
Smoke	**0.55**	0.14	0.07	0.04	-0.05	**-0.20**	**-0.30**	**-0.30**	-0.04	223945
Games	0.14	0.13	**0.16**	**0.15**	**0.15**	**0.23**	**0.27**	**0.37**	0.52	-173999
Books	**0.27**	**0.21**	**0.11**	**0.14**	**0.21**	**0.25**	**0.28**	**0.23**	0.23	125306
Hshld	0.10	**0.25**	**0.21**	**0.13**	**0.12**	**0.11**	**0.07**	0.03	-0.02	-859461
Clths	**0.28**	**0.26**	**0.30**	**0.31**	**0.33**	**0.38**	**0.43**	**0.37**	0.11	-275878
Hlth	**-0.22**	**-0.20**	-0.10	-0.09	-0.07	-0.04	-0.03	-0.07	**-0.18**	-43720
Chems	0.16	0.18	0.15	0.12	0.11	0.06	-0.01	-0.03	0.08	239503
Txtls	**0.48**	**0.47**	**0.45**	**0.46**	**0.41**	**0.39**	**0.42**	**0.44**	**0.34**	-21893
Cnstr	**0.12**	0.07	**0.08**	0.07	0.09	0.02	-0.04	**-0.19**	**-0.22**	-518432
Steel	0.02	**-0.25**	**-0.25**	**-0.25**	-0.12	-0.08	-0.12	**-0.19**	-0.11	-553546
FabPr	-0.03	0.03	0.02	-0.08	**-0.17**	**-0.21**	**-0.20**	**-0.22**	-0.15	-500448
ElcEq	-0.15	-0.07	-0.05	-0.04	-0.02	**0.11**	0.07	0.07	0.02	-105764
Autos	0.07	**0.12**	**0.22**	**0.19**	**0.23**	**0.18**	0.14	0.12	0.09	-4977314
Carry	**0.32**	**0.25**	0.14	**0.17**	**0.25**	**0.26**	**0.16**	0.02	0.00	833093
Mines	-0.10	**-0.19**	-0.19	-0.15	**-0.27**	**-0.52**	**-0.77**	**-0.90**	**-0.93**	67645
Coal	-0.10	-0.17	-0.23	-0.17	-0.05	-0.02	-0.18	-0.13	-0.26	196824
Oil	**-0.24**	-0.16	**-0.20**	-0.17	-0.12	-0.08	-0.10	-0.11	-0.03	-1397252
Util	-0.05	-0.03	-0.07	-0.07	-0.06	-0.14	**-0.17**	**-0.19**	-0.09	-
Telcm	0.08	0.07	-0.02	-0.04	-0.08	-0.04	-0.03	-0.13	-0.14	-
Servs	**0.21**	0.04	-0.02	-0.03	-0.09	-0.07	-0.07	**-0.12**	-0.03	-
BusEq	**-0.31**	**-0.27**	**-0.14**	**-0.12**	**-0.13**	-0.09	-0.09	-0.08	-0.11	509524
Paper	-0.03	-0.08	-0.02	0.00	**-0.08**	-0.08	**-0.11**	**-0.18**	-0.06	-506882
Trans	0.04	**0.15**	**0.18**	**0.22**	**0.17**	**0.17**	**0.21**	**0.35**	**0.44**	-
Whlsl	**0.12**	**0.16**	**0.15**	**0.19**	**0.19**	**0.18**	**0.20**	**0.17**	-0.04	-
Rtail	**0.53**	**0.49**	**0.48**	**0.43**	**0.42**	**0.39**	**0.37**	**0.36**	**0.35**	-
Meals	**0.17**	**0.21**	**0.22**	**0.22**	**0.16**	**0.18**	**0.18**	**0.18**	**0.25**	-
Fin	**0.17**	**0.29**	**0.35**	**0.33**	**0.29**	**0.28**	**0.27**	**0.28**	**0.36**	-
Other	0.13	0.05	-0.01	0.03	0.06	**0.07**	**0.17**	**0.18**	0.13	-

We use the t-ratios based on Newey-West HAC standard errors with the lag parameter set to 12 for statistical inference. To save space, we only present the currency exposure with the significant factor loadings (at the 5% level for two-sided tests) highlighted in bold face.

trade pattern. 11 out of 18 exposures to the MCI have expected signs, where only 7 out of 16 exposures to the OITP have expected signs. The relatively weak connection between currency exposure and trade, again, may be due to the measurement errors in our trade data and non-trade related determinants of currency exposure.

It is therefore evident that allowing the time-and regime dependence in currency exposure enables us to discover much stronger currency exposure. Let's focus on the Food (Food Products) industry as an example. This industry appears to have no significant currency exposure if we do not allow both the time and the regime dependence in exposure (recall Tables 2 and 3). However, the Food industry, based on our trade data, is a top exporting industry in the U.S. (with the highest exports to developed countries and the fourth highest exports to developing countries). It is also impossible for such an industry to completely

Table 5 Two-step Quantile Regression Foreign Exchange Exposure Estimates using OITP 1980:1-2009:12

	τ									
Industry	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**Trade Balance**
Food	0.10	0.03	-0.06	-0.17	**-0.24**	**-0.26**	**-0.23**	-0.06	-0.03	322915
Beer	-0.16	-0.23	**-0.21**	**-0.28**	**-0.43**	**-0.51**	**-0.49**	**-0.40**	**-0.54**	-39573
Smoke	-1.02	-0.66	-0.07	-0.12	-0.09	-0.08	-0.09	-0.28	**-0.63**	73821
Games	-0.30	-0.19	-0.05	0.06	-0.02	-0.13	-0.02	0.00	-0.10	-1619881
Books	**-0.38**	**-0.41**	**-0.21**	**-0.24**	**-0.22**	**-0.20**	-0.15	**-0.24**	**-0.28**	-17945
Hshld	0.15	-0.01	-0.10	-0.10	-0.09	**-0.13**	**-0.14**	**-0.13**	**-0.21**	-1533359
Clths	0.03	0.05	-0.03	0.02	0.12	0.06	-0.14	-0.06	0.07	-2762729
Hlth	0.10	0.09	0.01	0.00	0.01	0.05	0.07	0.01	0.00	29768
Chems	-0.08	-0.09	-0.11	-0.11	-0.21	-0.24	**-0.32**	**-0.33**	-0.18	995073
Txtls	-0.39	**-0.98**	**-0.87**	**-0.83**	**-0.80**	**-0.76**	**-0.73**	**-0.81**	**-1.07**	-179577
Cnstr	-0.11	-0.21	-0.18	-0.19	-0.21	-0.14	**-0.26**	**-0.40**	**-0.26**	-482290
Steel	0.28	**0.53**	**0.68**	**0.67**	**0.58**	**0.33**	0.08	-0.02	-0.25	-290017
FabPr	0.19	0.11	-0.09	-0.01	0.09	0.14	0.02	-0.09	**-0.60**	1197132
ElcEq	0.27	**0.22**	0.00	0.04	0.14	0.08	0.08	0.05	**0.35**	-171135
Autos	-0.44	0.13	**0.23**	**0.32**	**0.45**	**0.43**	**0.40**	0.25	-0.04	-788119
Carry	-0.51	-0.48	-0.33	-0.16	-0.13	-0.11	0.28	**0.57**	**0.57**	1119816
Mines	**-0.68**	**-0.50**	-0.05	0.20	-0.02	-0.03	-0.08	-0.18	0.02	-19674
Coal	**0.87**	0.60	**0.66**	0.25	-0.27	**-0.78**	**-0.68**	**-0.88**	**-1.04**	31866
Oil	0.27	0.17	0.09	-0.07	**-0.33**	**-0.42**	**-0.55**	**-0.52**	**-0.63**	-2201703
Util	-0.52	-0.38	-0.42	-0.42	-0.36	-0.30	-0.20	-0.16	-0.23	-
Telcm	**-0.40**	0.06	0.13	**0.23**	**0.31**	**0.31**	**0.41**	**0.47**	**0.91**	-
Servs	**-0.27**	-0.03	0.18	0.15	0.19	0.25	0.21	0.39	**0.53**	-
BusEq	0.28	0.28	0.12	0.18	0.24	0.23	0.20	0.32	0.30	-1863198
Paper	-0.02	0.09	-0.04	-0.10	-0.04	0.06	-0.09	-0.07	0.24	214245
Trans	**0.71**	**0.53**	**0.26**	0.15	0.15	0.13	0.14	0.07	-0.04	-
Whlsl	0.16	-0.12	-0.13	-0.19	**-0.24**	**-0.24**	**-0.30**	**-0.38**	**-0.38**	-
Rtail	**0.26**	0.07	-0.04	-0.05	-0.05	-0.02	0.09	0.20	0.25	-
Meals	-0.24	-0.36	**-0.52**	**-0.57**	**-0.53**	**-0.49**	**-0.48**	**-0.41**	-0.34	-
Fin	-0.07	-0.13	-0.21	-0.19	-0.11	-0.10	-0.09	-0.12	-0.07	-
Other	**-0.28**	-0.28	-0.37	**-0.40**	-0.35	-0.31	-0.13	-0.12	-0.17	-

We use the t-ratios based on Newey-West HAC standard errors with the lag parameter set to 12 for statistical inference. To save space, we only present the currency exposure with the significant factor loadings (at the 5% level for two-sided tests) highlighted in bold face.

hedge away currency risk (see SW for a detailed discussion). Therefore, it would be an anomaly if the Food industry had no currency exposure. As we show, as soon as we allow both the time and the regime dependence in exposure, this industry is found to have significant negative exposure to both the MCI and the OITP in some low return regimes. For instance, the exposure to the MCI when $\tau = 0.5$ is -0.13 and it is -0.24 to the OITP which are all significant at the 5% level. The sharp difference therefore highlights the importance of the time and regime dependence of currency exposure.

As we can see, U.S. industries are sensitive to both the *MCI* index and the *OITP* index, which suggests that hedging may not be a convincing explanation for the exposure puzzle. If hedging were important, we would expect that U.S. industries be more sensitive to the *OITP* than to the *MCI* (because as FHH point out, it is more difficult for U.S. firms to hedge against the exchange rate risk of the developing countries currencies). However, the results in Tables 3 and 4 are clearly inconsistent with this conjecture. Therefore, we strengthen the findings in FHH and SW in that we find strong currency exposure as soon as we take into account the time variation and regime dependence in currency exposure.

Conclusions

Although it is widely believed that most U.S. corporations are exposed to foreign currency risk, previous empirical studies usually find that only a small proportion of U.S. firms have significant foreign exchange exposure. This anomaly is called the "exposure puzzle" in the exchange rate literature. Bartram (2008) and Bartram, Brown, and Minton (2010) explain the exposure puzzle by arguing that firms use hedges to greatly reduce currency exposures to observed low levels.

Two recent studies, however, suggest that methodological weakness, not hedging, may explain the insignificance of currency risk in previous studies. One study by Francis, Hasan, and Hunter (2008) emphasize the time variation in foreign exchange exposure, where another study by Stacks and Wei (2005) stresses the regime dependence of foreign exchange exposure. In this paper, we extend the literature based on these two studies.

Empirically, we find if we do not allow for time variation and regime dependence in exposure, only 6 out of 30 or 20% of the U.S. industry portfolios have significant foreign exchange exposure to the Major Currencies Index, and only 5 out of 30 or 17% have significant exposure to the Other Important Trading Partners Index. This is consistent with the findings in previous studies (i.e. Jorion, 1990). However, as soon as we take into account the time variation and regime dependence in exposure using a random coefficient model and the quantile regression technique invented by Koenker and Bassett (1978), we find that 26 out of 30 or 87% of the U.S. industry portfolios exhibit significant foreign exchange exposure (in at least one regime) to the Major Currencies Index, and 23 out of 30 or 77% show significant exposure (in at least one regime) to the Other Important Trading Partners Index. Therefore, our results strengthen the findings in FHH and SW, and suggest that methodological weakness, not hedging, explains the insignificance of currency risk in previous studies.

References

Adler, M., and Dumas, B., 1983. “International portfolio choice and corporate finance: a synthesis.” *Journal of Finance,* 38, 925-984.

Adler, M., and Dumas, B., 1984. “Exposure to currency risk: definition and measurement.” *Financial Management*, 13, 41-50.

Allayannis, G., 1997. “The time-variation of the exchange rate exposure: An industry analysis,” Working paper, Darden Graduate School of Business, University of Virginia

Bartov, E., and G.M. Bodnar 1994. “Firm Valuation, Earnings Expectations, and the Exchange Rate Exposure Effect,” *Journal of Finance*, 44:5: 1755-1785.

Bartram, S. M., 2004. “Linear and nonlinear foreign exchange rate exposures of German nonfinancial corporations,” *Journal of International Money and Finance*, 23. 673-699.

Bartram, Sohnke M., 2007, “Corporate Cash Flow and Stock Price Exposures to Foreign Exchange Rate Risk,” *Journal of Corporate Finance*, 13, 981-994.

Bartram, Sohnke M., 2008, “What Lies Beneath: Foreign Exchange Rate Exposure, Hedging and Cash Flows,” *Journal of Banking and Finance*, 32, 1508-1521.

Bartram, Sohnke M., G.W. Brown and B. Minton, 2010, “Resolving the Exposure Puzzle: The Many Facets of Exchange Rate Exposure,” *Journal of Financial Economics*, 95, 148-173.

Bodnar, G.M., and Wong, M. H. F., 2003, “Estimating exchange rate exposures: issues in model structure. *Financial Management*, 32, 35-67.

Chen, N.F., R. Roll, and S. Ross, 1986, “Economic Forces and the Stock Market,” *Journal of Business*, 59, 383-403.

Chow, E.H., Lee, W.Y., and Solt, M.E., 1997, “The exchange-rate risk exposure of asset returns.” *Journal of Business*, 70, 105-123.

Fama, E. F., and J. D. MacBeth, 1973, “Risk, Return and Equilibrium: Empirical Tests,” *Journal of Political Economy*, 81, 607-636.

Francis, B., I Hasan, and D. Hunter, 2008, “Can hedging tell the full story? Reconciling differences in U.S. aggregate- and industry-level exchange rate risk premium,” *Journal of Financial Economics*, 90, 169-196.

Frankel, J., and Rose, A., 1995, “Empirical research on nominal exchange rates.” In: Grossman, G., Rogoff, K. (Eds.), Handbook of International Economics. Elsevier Science, Amsterdam, pp.1689–1729.

Jorion, P., 1990, The exchange-rate exposure of U.S. multinationals. *Journal of Business*, 63, 331-345

Khoo, A., 1994, “Estimation of foreign exchange rate exposure: an application to mining companies in Australia.” *Journal of International Money and Finance*, 13, 342-363.

Koenker, R., 2005, “Quantile Regression.” Cambridge University Press, Cambridge.

Koenker, R., and Bassett, G., 1978, “Quantile Regression,” *Econometrica*, 46, 33-51.

Koenker, R., and Hallock, K., 2001, “Quantile Regression: An Introduction,” *Journal of Economic Perspectives*, 15, 143-156.

Starks, L. T., and Wei, K. D., 2005, “Foreign exchange exposure and short-term cash flow sensitivity.” Working paper, University of Texas, Austin, TX.