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Exchange rate exposure and competition: evidence from the automotive industry☆

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Abstract

This study examines the effect of real exchange rate changes on multinational firms and incorporates the effect of intra-industry competition on the relation between exchange rates and firm value. To test the relation more effectively, tests are conducted using a sample of automotive firms from the United States and Japan. Consistent with theoretical predictions, there is significant exposure to exchange rate shocks. Moreover, there is evidence of time-variation in exchange rate exposure, which is consistent with changes in the competitive environment within the industry. Finally, evidence is presented that is consistent with foreign sales being a major determinant of exposure and the effectiveness of operational hedging through foreign production.

JEL classification: F31; G30; G39

Keywords: Exchange rate exposure; Risk management; Currency exposure; International corporate finance

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1. Introduction

Since the breakdown of the fixed exchange rate regime, the international economic environment has been characterized by substantial exchange rate volatility. This volatility occurs for both nominal and real exchange rates. Real exchange rate changes translate into deviations from purchasing power parity (PPP), which, for a multinational firm or global competitor, should have a direct effect on firm value.[1] A global competitor is a firm that faces substantial foreign competition. Empirical results of the effect of exchange rates on firm value and its implications have not been as strong or as consistent as expected based on theoretical predictions. These results raise questions regarding whether deviations from PPP are unimportant for global competitors or whether the existing tests fail to capture the effects these deviations have on firm value. It may be possible to improve on existing results by conducting tests for these effects on specific industries and exchange rates. Tests of a specific industry should allow for clearer analyses of the role of exchange rates on the value of the multinational firm or global competitor and the impact of industry structure on exchange rate exposure.

This study investigates the effect of real exchange rate changes on the value of firms in the automotive industry, taking into account the effect of industry structure and competition on the relation between exchange rates and firm value. Consistent with Marston (1996), this paper argues that the exchange rate exposure of a firm is a function of its net foreign revenues, the elasticity of demand of the products made by the firm and its competitors in foreign and domestic markets, and the location of its production. The assumption is that a firm facing high levels of foreign competition will also face high demand elasticity. Therefore, a useful test for the existence of exchange rate exposure would employ a sample of firms that both have high levels of foreign sales and face foreign competition. This sample should also provide for direct comparisons between firms.

The study documents significant exchange rate exposure for automotive firms from the United States and Japan from 1973 to 1995. An analysis of the determinants of a firm's exchange rate exposure is done by examining the market share of the firms in the U.S., Japan, and Germany to analyze the impact of foreign sales on exposure. This exercise is consistent with the idea that the currency exposure of a firm is a function of the export sales achieved and the competition encountered in a particular market. The results show that the exposure of U.S. firms to the yen and Japanese firms to the dollar are due to the Japanese sales in the U.S. market.

[1] Previous theoretical arguments include those by Shapiro (1975), Hekman (1985), Hodder (1982), and Levi (1994).

Exchange rate exposure in the automotive industry changes through time, mostly because of the changing structure of the industry over the sample period. The changes in dollar-to-yen exposures are strong for both U.S. and Japanese firms. The findings for the Japanese firms are consistent with the findings of He and Ng (1998) for Japanese firms in the transport sector. Perhaps surprisingly, we also find that U.S. firms benefit from a depreciation of the Deutschmark relative to the dollar. This result is consistent with U.S. firms gaining due to income from their European operations, at the expense of their non-German competitors when the Deutschmark depreciates. For all firms, the estimated exposure is stronger during periods of large and extended movements in real currency values of the countries tested, as well as, during periods of relatively high foreign competition.

A prediction of the theory is that a firm's exchange rate exposure depends on its foreign as well as its domestic demand elasticities. Therefore, because of the different characteristics of the firms in the world automotive industry, the components of this exposure should vary across markets. Consistent with this prediction, the findings show that exposure varies across firms from different countries.

In evaluating the exchange rate exposure of international firms, it is important to note that what is really being measured is the net exposure to exchange rates, or the exposure that remains after the firm has engaged in some hedging activity, whether through the use of derivatives or through its operations. The hedging effect must also be considered in the context of the level of a firm's foreign sales relative to its total sales which, according to previous studies, is the main determinant of exchange rate exposure.[2] To evaluate the importance of foreign sales on foreign exchange exposures along with the effects of foreign production on mitigating exposures, the impact of foreign sales and operations on the exposure of Japanese automotive firms is analyzed. The results are consistent with foreign sales increasing exposure and foreign operations reducing exposure.

This paper is organized as follows. Section 2 reviews previous literature and the motivation for this study. In Section 3, the main body of the work is discussed. Section 3 also includes a general theory of the exchange rate exposure of multinational firms and global competitors, and a discussion of the determinants of this exposure. In Section 4, the data selection method is reviewed, and predictions of the analysis are presented. In Section 5, the results of the exposure tests at the country level and firm-specific level are discussed. Section 6 evaluates the industry evolution and its impact on exchange rate exposures, while Section 7 examines the effect of the ratio of foreign sales to total sales and foreign production on exposures. Section 8 provides the conclusion.

[2] The impact of foreign sales ratio is argued in Shapiro (1975), and empirical results of this argument is presented in Jorion (1990) and Bodnar and Gentry (1993).

2. A review of exchange rate exposure

A small body of work investigates the exposure of multinational firms to changes in exchange rates. In these papers, the definition of exposure, based on Adler and Dumas (1984), is the sensitivity or correlation of the value of an asset or liability to a change in real exchange rates. Jorion (1990) looks at a sample of 287 U.S. multinationals, and finds cross-sectional and time variation in exchange rate exposure for the firms in the sample. The paper hypothesizes that the level of foreign operations may be a determinant of the exposure for multinational firms. Jorion shows that foreign sales ratios are a significant determinant of a firm's exchange rate exposure. Amihud (1994) finds no significant exchange rate exposure for a sample of 32 large U.S. exporters from 1979 to 1988.

Bodnar and Gentry (1993) use U.S., Japanese, and Canadian industry sectors to assess the impact exchange rate exposure. They find both that exchange rate exposure is significant for some industries and that there is significant dispersion in exchange rate exposure across industries. The paper shows that for the three countries, 20–35% of industries have statistically significant exchange rate exposure. Also, industry characteristics, such as export ratio, input penetration ratio, reliance on internationally priced inputs, and foreign to total assets ratio, systematically determine the relation between exchange rates and industry values. Bartov and Bodnar (1994) address the problem of weakly significant evidence of a contemporaneous exchange rate effect by evaluating a sample of exporting firms in periods of large foreign currency adjustments. The study uses the lagged return response to quarterly exchange rate changes and show a stronger exchange rate effect than that shown in previous studies.

He and Ng (1998) evaluate the exchange rate exposure of Japanese firms from 1979 to 1993. Using a sample of 171 Japanese multinational firms, the paper finds economically significant exposure in 25% of the firms. The paper shows that a depreciation in the value of the yen relative to a trade weighted index results in a positive impact on Japanese firm value. The exposures are concentrated in the electric machinery, precision equipment, and transport sectors. Allayannis (1996) looks at the time-variation of exchange rate exposure for U.S. firms and shows that there is time variation in exchange rate exposure for a sample of manufacturing firms. Allayannis discovers that the exchange rate exposure for 28% of these manufacturing firms varies systematically with changes in the imports and exports between 1978 and 1986. Additionally, 43% of the firms show similar results from 1986 to 1990.

Shapiro (1975) uses a two-country model to analyze the profit-maximizing strategy of an oligopolistic firm. The paper concludes that the major factors that influence a multinational firm's exchange rate risk are the proportion of export sales, the amount of competition it faces domestically, and the degree of substitutability it faces between local and imported factors of production. More recently, Marston (1996) argues that the type of competition displayed in an

industry affects the economic exposure of firms within the industry. Marston's model implies that as the industry structure changes, economic exposure should also change.

Previous studies that measure the extent of a firm's exposure to exchange rates mainly evaluate the exposure of industry portfolio and firms to a trade-weighted exchange rate. This aggregation of exchange rates can mute the effect of an exchange rate shock on firm value. This study investigates a firm's or a country's automotive industry exposure to individual currencies rather than to a trade-weighted index since the theory's predictions are currency-specific. The analysis also considers the role of industry competition on a firm's exchange rate exposure.

3. Exchange rate exposure and firm value

A multinational firm with export sales and costs denominated in the home currency should exhibit exchange rate exposure. The extent of exchange rate exposure should change with the net foreign currency position of the firm's operations and the competitiveness of the industry. In the simple case of an exporter with costs denominated in its home currency and sales in a foreign market with no local competitor, the firm's cash flows will be affected by changes in the foreign currency. The sensitivity of a firm's cash flow in its home currency to changes in the exchange rate is primarily a function of the elasticity of demand for the firm's product. Therefore, even with high export sales but low elasticity, the firm may have relatively low exposure. In this case, the firm can increase prices in the local market when faced with a depreciation in the value of the local currency, and thus lessen the impact on the home currency cash flows. In the case of a pure exporter, Bodnar et al. (1998) argue that the exposure will at best be perfectly proportional to profits.

As competition increases in the foreign market from local competitors, the sensitivity of the firm's cash flows to exchange rate changes should also increase. The introduction of a local competitor will impact the ability of the exporter to increase prices in response to a depreciation of the local currency. Therefore, as competition in the foreign market increases, the sensitivity of the exporter's cash flows to exchange rates will also increase. One way for the exporter to mitigate the sensitivity of its cash flows to the exchange rate is to have costs denominated in the local currency. In this case, as the firm faces a depreciation in the local currency, its costs in its domestic currency will also decrease. Therefore, the decrease in revenues in the domestic currency will be offset by a decrease in domestic currency costs, and thus domestic cash flows will be less sensitive to changes in foreign currency values.

Finally, a firm's exposure can be further affected if there are competitors from various countries in a particular market. The additional competitors may create

complex situations in which firms from different foreign countries are competing in a third market. In this situation, the net exposure effect will be determined by the dominating component of exchange rate exposure factors. Another possible complication will occur if a domestic firm produces in the foreign market and ships foreign market production to other markets. In both situations described, it is possible to have a net positive impact on cash flows to the exporting firm due to a depreciation in the local foreign currency in which the firm has production facilities. In the first case, if competition in a third market occurs between foreign firms from different countries, then the sign of the exposure for firms from the respective countries will be determined by the competitive gains or losses from a change in the foreign currency. For instance, a depreciation in the foreign currency relative to both currencies may lead to competitive gains for one firm and thus result in a positive exchange rate effect. Also, if a firm produces in a foreign market and ships production to a country whose currency is highly correlated with the firm's home currency, then an appreciation in the home currency relative to the foreign currency where the goods are produced could increase the domestic profits of the firm.

3.1. Exchange rate exposure, export sales, and industry structure

The discussion of the effects of an exchange rate shock on the value of a multinational firm is based on the change in the value of the firm in the following relation:

$$\frac{\mathrm{d}V}{\mathrm{d}S} = \frac{1-\tau}{\rho}\frac{\mathrm{d}\pi}{\mathrm{d}S}, \tag{1}$$

where V is firm value, S is the spot exchange rate, τ is the tax rate, π is firm profits, and ρ is the discount rate. An explicit assumption is that the discount rate and taxes are constant, and that profit expectations are static or $\mathrm{E}(\pi_t) = \pi$. Therefore, the main concern of this analysis is with the derivative of profits with respect to a change in the exchange rate.

Previous models of the effect of exchange rate shocks on the value of a multinational firm are based primarily on a monopolistic firm. The implication in these models is that net foreign revenue is the primary determinant of exchange rate shocks on firm value. For instance, if a monopolistic firm sells in the foreign and domestic markets, and it incurs costs in both markets, Marston (1996) shows that the firm's exposure is determined by its net foreign revenues. Marston also points out that the elasticity of the firm's product is not important. The exchange rate exposure of the monopolistic firm with the ability to pass its increases in costs through to customers may be small and undetectable. This setting is consistent with the findings in Bodnar et al. (1998), who point out that

industries with high pass-through have low exposures.[3] Moreover, because this exposure is easily forecasted, firms could manage it through simple financial instruments such as forward contracts.

The more interesting and relevant result in Marston's model is for firms facing Cournot competition. The Cournot model has two countries, domestic and foreign, and two firms, one based in each country. Additionally, each firm manufactures a heterogeneous product in its home country. The heterogeneity assumption is introduced to allow substitutability to play an explicit role in the value of the firm. Both firms sell in either of the two countries and there is no inflation, which implies that there are no transaction costs and an exchange rate shock is a real and permanent change.

The implication of Marston's model, under Cournot competition, is that the domestic firm's profits are a function of not only its net foreign currency revenue but also its own price elasticity of demand and the cross elasticities of demand with competitors. The profit function also depends on marginal costs and other derivatives of the demand and cost functions. The elasticity depends on the substitutability of the domestic firm's product with the importing firm's product. Therefore, the substitutability of the product plays a role in the firm's exchange rate exposure. For the exporting firm, the exposure is also a function of its costs, which are denominated in the home currency and face the prevailing exchange rates. This setting implies that firms facing Cournot competition should exhibit greater exchange rate exposure than monopolists. This larger exposure for firms facing Cournot competition results from lower pass-through into prices. In addition, we would also expect to see a larger exposure from Cournot competitive firms because of the difficulty of hedging exposure when exposure occurs as a function of other firms in the industry.

Because the main component of exchange rate exposure is the net foreign currency revenue, the exchange rate exposure of an exporting firm should change as the costs denominated in the foreign currency change. For example, if the exporting firm increases its ratio of foreign market costs to revenue, its exchange rate exposure should decrease. Conversely, a decrease in foreign market costs to revenue should increase exposure. In both cases, it is assumed that foreign market costs do not exceed foreign market revenues.

However, for cases in which all costs of the exporting firm arise in the foreign market and foreign market production is exported to a third market, the company's exposure to the foreign currency will shift to the translation of the foreign currency profits to the domestic currency. If the possible translation losses are dominated by the competitive gains and sales from local market production to the third market, a positive impact on domestic firm cash flows

[3] Goldberg and Knetter (1996) provide a discussion of the literature on exchange rates and prices. Campa and Goldberg (1995) also discuss similar evidence regarding the impact of investments on exchange rate changes and pass-through.

could result from a depreciation in the local currency. Moreover, competitive gains can occur if other competitors in the foreign market do not have foreign currency-denominated costs to offset foreign revenue.

The main implication of these arguments is that an industry facing high export sales and relatively high substitutability should experience greater exchange rate exposure. This argument is consistent with that of Bodnar et al. (1998) who show that as substitutability increases, the level of pass-through decreases and exchange rate exposure increases. If a firm changes the level of its local market-denominated costs, the firm can impact its exchange rate exposure. Moreover, as the industry's competitive structure gets more complex, so will exposure.

3.2. Evolution of exchange rate exposure and competition

Because exposure is a function of foreign sales, competitive reactions, and foreign costs, a firm's exchange rate exposure should change through time. As these determinants of a firm's exposure evolve over time, so should exchange rate exposure. For instance, the competitive makeup of the industry, its cost structure, and risk management practices all evolve through time. Additionally, as a firm's foreign sales increase or decrease as a percentage of its overall sales, its exchange rate exposure should change. Previous studies have found a relation between exchange rates and time. For example, Jorion (1990) shows that exposure varies through time, and Allayannis (1996) shows that there is time variation in exchange rate exposure for U.S. manufacturing firms. However, this paper is the first to empirically link changes in exchange rate exposure and the evolution of industry structure.

Global industries undergo structural changes that impact their competitive makeup and the exchange rate exposure of firms within the industry. This type of industry evolution has important implications for exposures for multinational firms and global competitors. For instance, if we begin with a firm that exports to a foreign market and does not compete directly with firms in that market, the firm's exposure is simply a function of its foreign currency revenues. In this situation, a firm may have national competition but little or no competition from foreign markets. If the foreign firm then faces competition in the local market, exposure becomes a function not only of its foreign currency revenues but also of the elasticity of its own and its competitor's product. The firm then becomes more internationally competitive and firms have to be more concerned with local competitors in a foreign market or foreign competitors in the firm's domestic market. The complexity of a firm's exchange rate exposure evolves as the industry becomes more global, wherein firms begin to produce in various markets, and those that are headquartered in different countries begin to compete in markets that are outside their own home market or that of their main competitor.

4. Exchange rate exposure: Sample selection and measurement

To evaluate the effect of an exchange rate shock on firm value, we must identify those shocks that are permanent and unanticipated. In the presence of nominal assets and liabilities in the foreign currency, a firm can be exposed to the nominal exchange rate because these assets and liabilities must be translated at the nominal rate. Therefore, the firm has translation exposure because the net effect of their asset-to-liability position is a function of the nominal exchange rate at the time of translation.[4] In the absence of foreign assets or liabilities, a nominal rate change that is offset by changes in price levels across the countries should have no effect on the real value of the firm. Therefore, the exchange rate change that should affect firm value is the real exchange rate change.

Fig. 1 shows the real exchange rate index for some of the world's major currencies from January 1973 to December 1995. Generally, there was an overall decrease in the value of the dollar from the breakdown of the Bretton Woods system of fixed exchange rates until the beginning of the 1980s. This decrease was followed by an increase of the dollar against the major currencies from the early to the mid 1980s. From 1985, around the time of the Plaza Accords, in which the group of five industrial countries agreed to depreciate the dollar against other major currencies, there was a decrease in the dollar value relative to other major currencies. In contrast, the yen-to-Deutschmark exchange rate fluctuated around the initial levels for the entire sample period.

4.1. Sample selection and data

The automotive industry is selected to test the theory of the determinants of currency exposures presented in Section 3. This industry is characterized by high export sales and competition. It also has strong international dependence for both production input and exports of finished products. Thus, it is likely to be sensitive in foreign exchange rates. Additionally, the industry is ideal for testing theories on the evolution of an industry and its impact on the exchange rate exposure of firms in the industry. The automotive industry has progressed from one of national competition, particularly in North America, to one of international competition, in which firms from the U.S. and Japan export to foreign markets, to one of global competition, in which firms produce and sell in many countries.

This study incorporates information regarding automotive firms that are headquartered in the U.S. and Japan. These firms control a large percentage of

[4] Stulz and Williamson (1996) examines the various types of exposure and how they impact firm value.

Fig. 1. Real exchange rate levels. The figure shows monthly real exchange rate levels for the British pound, German mark, Japanese yen, and the U.S. dollar from January 1973 to December 1995. January 1973 represents a level of 100. The nominal rates are deflated by the wholesale price index of each country.

the worldwide contestable cash flows associated with the automotive industry, and directly compete in the major markets. Contestable cash flows are those that are without significant barriers to foreign competition. Automotive firms in other countries either have protected markets or are primarily government owned, so that no shares are publicly traded for all or part of the sample period. Many countries, such as France, Italy, and Sweden, with large automotive manufacturers were government owned for all or part of the sample. German firms are eliminated because they do not face substantial competition for the majority of the sample period.

The information on returns, exchange rates, and price levels is from Datastream International. The price levels used to compute the real exchange rates are the monthly Wholesale Price Index for each country. Since price levels used in the computation of real exchange rates are observed monthly, I use monthly returns. The use of monthly returns also eliminates problems associated with nonsynchronous trading. The exchange rates and total returns index are taken on the fifteenth day of each month to account for any possible end-of-month effects associated with the announcement of macroeconomic data from each

country. The sample is comprised of the monthly return index for each firm on its home security market. Because we are interested in the average exposure level across firms, equally weighted portfolios of firms are used. The equally weighted portfolio is constructed of the automobile manufacturers in each country. The returns include all dividends and other disbursements by individual firms, and are reported in the home currency of each firm.

The information on monthly sales and U.S. production for each firm is obtained from the *Ward's Automotive Yearbook*. Monthly Japanese firm production in Japan and operations information is collected from the *Japanese Automotive Manufacturers Association*. Data on the foreign operations and affiliations through time of U.S. firms are collected from *Notable Corporate Chronologies*.

4.2. Currency exposure measurement

Using Eq. (1), from the previous section, we show how a firm's exposure to a specific currency impacts the firm's cash flows. Because we use the firm's stock return as a proxy for changes in firm value, we can only evaluate the elasticity of the firm value to exchange rate changes. Therefore, we evaluate the derivative of firm value with respect to a change in the exchange rate, or $(dV/V)/(dS/S)$, where V is a function of the industry structure, demand elasticity, location of operations, and cross elasticities. For the initial regressions of exchange rate exposure, we use the following model:

$$r_{j,t} = \alpha + \beta_j^{\mathrm{m}} R_{\mathrm{m}t} + \sum_{k=1}^{K} \beta_k^{\mathrm{e}} \Delta S_{kt} + \varepsilon_t, \tag{2}$$

where $r_{j,t}$ is the real stock return of a country-specific industry portfolio or firm j at time t, α is the intercept, ΔS_{kt} is the rate of change of the real exchange rate in country k at time t, and β_k^{e} measures the exposure of the country-specific industry portfolio of firm k. $R_{\mathrm{m}t}$ is the real return on the value-weighted country-specific market portfolio, β_j^{m} is the market risk of firms, and ε_t is the error term. This equation is consistent with the model in Jorion (1990), although it deviates from Adler and Dumas (1984) by including the market factor, which has been shown to be a significant component of the returns generating process.

Even after including the market, there can be correlation across country-specific industry portfolios or firms within each country. To account for this possibility, a seemingly unrelated regression (SUR) (Zellner, 1962) is used to improve estimates. If there is cross-sectional dependence in residuals, then using SUR will account for correlations. Also, SUR allows for tests of equivalence of coefficients across portfolios or firms. If there are no cross-sectional correlations, this approach is equivalent to an ordinary least squares (OLS) regression.

Because currencies are regressed relative to the home country and a depreciation should increase domestic firm value, a negative coefficient on variables that

measure direct exposures is predicted for export-oriented firms. Positive coefficients may result under specific circumstances discussed previously.

5. Exchange rate exposure in the U.S. and Japanese automotive industry

Before we investigate the exchange rate exposure of firms in the automotive industry, we evaluate the correlation of changes in exchange rates across the countries in which they compete. Table 1, Panel A reports the correlation of the real exchange rates. There is a relatively high correlation in the movement of the Deutschmark against the yen and the dollar. There is also relatively high correlation between the yen-to-dollar and Deutschmark-to-dollar rates, indicating that the movement of the dollar is generally against other major currencies. This high correlation across currencies could result in collinearity between the yen-to-dollar and the Deutschmark-to-dollar rates. The effect would be inflated standard errors that would result in lower *t*-statistics.

Panel B shows the correlation of the returns of the automotive and overall market portfolios. The correlation between the U.S. and Japanese automobile manufacturing industries is lower than the correlation of their market indices. The correlation of the Japanese automotive firms with the overall Japanese market is higher than the correlation of the U.S. automotive firms and the overall U.S. market. This result could be due to the relative proportion of each industry to that of the overall market in the respective countries.

Table 1
Exchange rate and returns correlation coefficients, 1973–1995

Panel A shows the correlation coefficients among the currencies of interest for the automotive industry for the full sample from 1/15/73 to 12/15/95. The currencies covered are the Deutschmark (DM), the U.S. Dollar ($), and the Japanese Yen (¥). Panel B is the correlation matrix for the monthly returns of the equally weighted portfolio of automotive firms for each country and the Datastream International value-weighted portfolio for each country from 1/15/73 to 12/15/95.

	¥/$	DM/$	
Panel A: Exchange rates			
DM/$	0.591		
¥/DM	0.382	− 0.519	
	U.S. Auto	Japan Auto	U.S. market
Panel B: Returns			
Japan Auto	0.224		
U.S. market	0.606	0.266	
Japan market	0.267	0.665	0.337

5.1. Industry and firm level exposures

To analyze a firm's exposure to exchange rate shocks, a long sample period is necessary to incorporate possible changes in the business cycle or other market fundamentals. Eq. (2) is estimated for the country-specific industry portfolio and each firm's returns for the full sample period, January 1973–December 1995. The results for the full sample are presented in Tables 2 and 3. The coefficients measure the currency exposure for the country portfolio. We are interested in both the significance of the coefficient and the sign. For the firm-specific level, Eq. (2) is estimated using a seemingly unrelated regression estimate for the firms in each country.

As Table 2 reports, the results for the U.S. portfolio show a significant exposure to both the yen and the Deutschmark with the expected negative sign for the yen and a positive sign for the Deutschmark. This result indicates that the U.S. portfolio loses value as the yen depreciates relative to the dollar, and gains in value as the Deutschmark depreciates relative to the dollar. At the

Table 2
U.S. portfolio and firm-specific exchange rate exposure

Regressions of the automotive industry for the total sample are shown using the following model:

$$r_t = \alpha + \beta^{m} R_{mt} + \sum_{i=1}^{n} \beta^{e} \Delta S_t + \varepsilon_t,$$

where β^{m} is the market risk, R_{mt} is the return on the country-specific market portfolio, β^{e} is the currency exposure of the portfolio, ΔS_t is the change in real exchange rates, r_t is the monthly return, and ε_t is the error term. Data is taken from Datastream International and represents 276 observations covering 1973–1995. For the results, \$ is the U.S. dollar, DM is the Deutschmark, and ¥ is the Japanese yen. Heteroscedastic-consistent t-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively. The adjusted R^2 shown is from the ordinary least squares regression. Firm variation is an F-test of the difference in exposure across firms.

Firm	Intercept	Country-specific market risk	¥/\$	DM/\$	Adjusted R^2 (%)
U.S. portfolio	0.0028	1.0588	− 0.3413	0.3544	37.3
	(0.741)	(13.697)***	(− 1.874)*	(2.098)**	
GM	0.0012	0.9197	− 0.3335	0.5170	32.4
	(0.312)	(11.879)***	(− 2.003)**	(2.959)***	
Ford	0.0044	1.0048	− 0.2422	0.1400	31.2
	(1.072)	(9.915)***	(− 1.233)	(0.789)	
Chrysler	0.0029	1.2495	− 0.4472	0.4067	23.0
	(0.464)	(9.568)***	(− 1.436)	(1.563)	
Firm variation [F-test]			[0.426]	[3.572]**	

Table 3
Japan portfolio and firm-specific exchange rate exposure

Regressions of the automotive industry for the total sample are shown using the following model:

$$r_t = \alpha + \beta^{m} R_{mt} + \sum_{i=1}^{n} \beta^{e} \Delta S_t + \varepsilon_t,$$

where, β^{m} is the market risk, R_{mt} is the return on the country-specific market portfolio, β^{e} is the currency exposure of the portfolio, ΔS_t is the change in real exchange rates, r_t is the monthly return, and ε_t is the error term. Data is taken from Datastream International and represents 276 observations covering 1973–1995. For the results, \$ is the U.S. dollar, DM is the Deutschmark, and ¥ is the Japanese yen. Heteroscedastic-consistent t-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively. The adjusted R^2 shown is from the ordinary least squares regression. Firm variation is an F-test of the difference in exposure across firms.

Firm	Intercept	Country-specific market risk	\$/¥	DM/¥	Adjusted R^2 (%)
Japanese portfolio	0.0052	1.0113	− 0.2196	− 0.1065	44.7
	(1.602)	(12.945)***	(− 1.423)	(− 0.700)	
Toyota	0.0096	0.8468	− 0.4068	0.0422	19.1
	(1.880)*	(7.343)***	(− 2.363)**	(0.213)	
Nissan	0.0036	0.8696	− 0.2487	− 0.0621	28.7
	(0.911)	(9.767)***	(− 1.736)*	(− 0.351)	
Honda	0.0068	0.9119	− 0.5234	− 0.3286	21.1
	(1.266)	(7.184)***	(− 1.817)*	(− 1.242)	
Isuzu	0.0030	1.4249	0.0601	0.2155	29.0
	(0.466)	(7.561)***	(0.224)	(0.770)	
Mazda	0.0006	1.0104	− 0.2273	− 0.2421	24.6
	(0.112)	(8.616)***	(− 1.096)	(− 1.122)	
Suzuki	0.0086	0.8589	− 0.2404	− 0.0564	14.8
	(1.462)	(7.631)***	(− 0.689)	(− 0.197)	
Mitsubishi	0.0045	1.1389	0.0527	− 0.3174	34.4
	(0.981)	(10.170)***	(0.279)	(− 1.632)	
Firm variation [F-test]			[1.103]	[1.174]	

firm-specific level, the results show that most of the significance of the portfolio is due to General Motors (GM). The full sample results of Ford and Chrysler show that they have insignificant exposure to both the yen and the Deutschmark. The positive and significant exposure of the portfolio to the Deutschmark is driven by GM.

If one thinks of U.S. automotive producers as exporters to Germany and as competing with German imports in the U.S., the basic theory would predict a negative exposure coefficient, so that U.S. producers would lose as the

Deutschmark depreciates. However, this interpretation is not the right way to think about the exposure of the U.S. automotive producers to the Deutschmark. During our sample period, European currencies are typically highly correlated with the Deutschmark, so that the Deutschmark-to-dollar exchange rate serves as a proxy for the exchange rate of European currencies relative to the dollar in general. Throughout the sample period, GM and Ford have production facilities in Europe that produce vehicles for almost all European sales. Opel is owned by General Motors, the second largest automotive firm in Germany in sales, and Ford of Europe has significant production and sales in the German market, even though Ford's main European market is the U.K. Chrysler has had an insignificant presence in the European market since the mid-1970s, but began production for the European market in Austria in 1989. Therefore, a depreciation in the value of the Deutschmark relative to the dollar would not lead to a decrease in the firm's cash flows denominated in European currencies. Such a depreciation could lead to a gain in market share relative to Japanese competitors which did not have production located in Europe for the majority of the sample period. A depreciation of the Deutschmark reduces the dollar value of a U.S. firm's cash flow denominated in a European currency, but as long as the cash flow increases by more than the percentage depreciation of the European currency relative to the dollar, the U.S. firm is better off. The evidence for Germany, which is presented in Section 3, is supportive of these arguments for a globally competitive industry. As shown in Fig. 2, the growth in the German market share for the Japanese firms was at the expense of the U.S. firms. German firms also failed to gain in market share during the sample period. With the exception of Volkswagen, German firms were not direct competitors to U.S. firms. The result of a Deutschmark depreciation relative to the dollar is therefore more of a competitive effect that benefits U.S. firms at the expense of Japanese firms in the German market.

To test directly for this effect, a separate regression is estimated for Eq. (2), with the yen-to-Deutschmark exchange rate as an independent variable and U.S. automotive portfolio returns as the dependent variable.[5] A negative and significant coefficient, at the 1% level, on the yen-to-Deutschmark variable is observed. This result is consistent with the idea of yen exposure for the U.S. firms in both North America and Europe. F-tests of significance of exchange rate exposure across firms show that there is no difference for the yen exchange rate, and that there is significant difference for the Deutschmark rate.

For the Japanese firms shown in Table 3, the sign of the sensitivity of the portfolio to both the dollar and the Deutschmark is negative. Sensitivity to the dollar is consistent with the previous arguments and arises due to the increased sales by Japanese firms competing in the U.S. market beginning in the early

[5] These results are not shown and are available from the author.

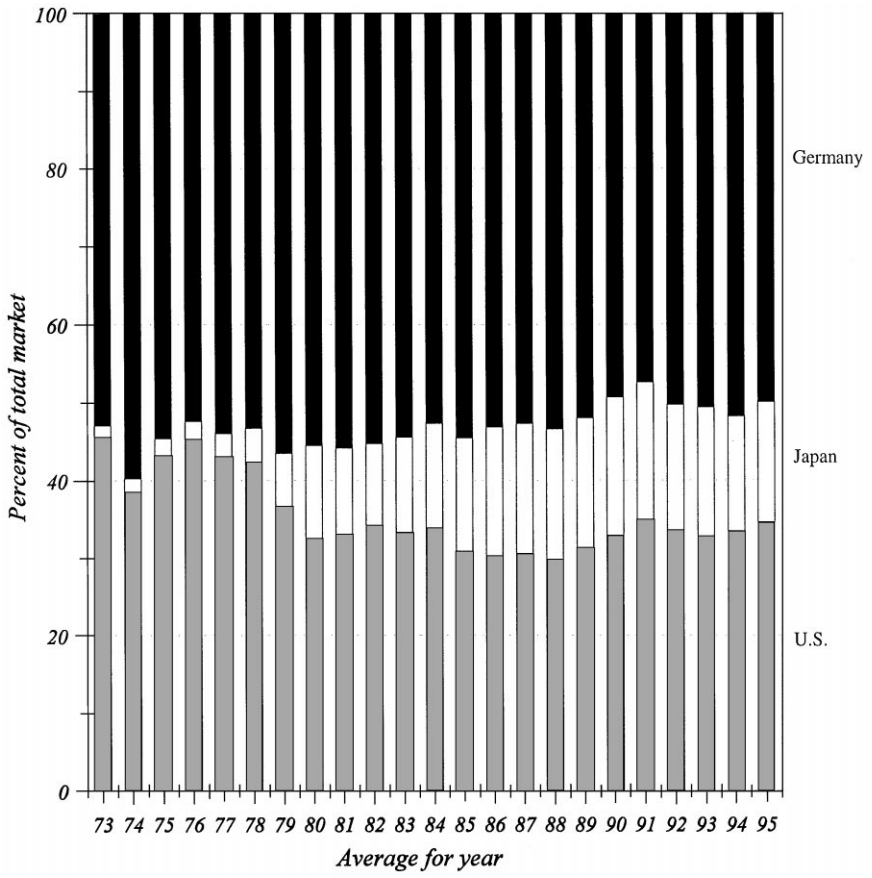

Fig. 2. Germany automobile market share. The figure shows the market share of U.S., Japanese, and German firms in Germany for the sample period. The firms are listed by the headquarters of the parent firm. The graph reflects the automobile market share, and does not reflect that of light trucks, which are becoming a higher percentage of vehicle sales for each firm.

1980s. Japanese firms also faced competition in the European market, although not for as long or with the intensity as that faced in North America. Sensitivity to the dollar is driven primarily by Toyota, with significance at the 5% level, and Nissan and Honda, with significance at the 10% level. This result is expected since these three firms have considerable sales in North America. The other Japanese firms with a relatively low percentage of total sales in the North American market show little exposure. The sign on the dollar sensitivity is as predicted for five of seven firms. Similarly, the sign of the Deutschmark-to-yen coefficient is negative for five firms, but the coefficient is never significant. Tests

of the difference in exposure across firms for the full sample period show that there is no significant difference across firms for either the dollar or the Deutschmark. Tables 2 and 3 show that the U.S. firms have exchange rate exposure to both the yen and the Deutschmark, whereas the Japanese firms show significant exposure only to the dollar.

5.2. Determinants of exposure

Marston (1996) argues that a firm's exchange rate exposure is a function of foreign sales, the elasticity of demand in the foreign market, and the elasticity of demand in the domestic market. Since we assume that the automotive industry is competitive and that competition serves as a proxy for elasticity of demand for a firm's product, the competition that the firm faces in the domestic and foreign markets should be a determinant of the firm's exposure in that particular market.

Therefore, a firm has more significant exposure to a particular currency not only if the firm has substantial sales in the foreign market but also if the firm faces competition in the same market. This also holds for the domestic market. If the firm faces competition from foreign firms, then the firm has exposure to the currency of that competitor. For U.S. automotive firms, results show that they have significant exposure to the Japanese yen, which is the home country currency of their major competitors. Additionally, since U.S. firms have low sales in Japan, the source of exposure should be from the Japanese firm's U.S. sales and not from U.S. firm's sales in Japan. Conversely, the exposure to the dollar for the Japanese firms should be from their U.S. sales and competition and not from sales of U.S. firms in Japan.

The impact of sales in each market is shown in Figs. 2–4, which depict market share in each country. Fig. 2 shows that in Germany, U.S. firms have a significant share of the market. Exposure to the Deutschmark can be positive because the main competition in that country is with Japanese firms in the European market. In addition, exposure to the Deutschmark can be positive because U.S. firms have European production. Fig. 3 shows that the U.S. market has become more competitive over time. The Japanese firms have been gaining market share in the U.S. and thus increasing their dollar exposure. At the same time, the exposure of U.S. firms to the Japanese yen is increasing. In Fig. 4, the Japanese firms have the dominant share of the home market. Therefore, one would not expect exposure of foreign firms to the yen to result from sales in Japan.

To test the exposure of a firm to competition in the home and foreign markets, the following regression for the U.S. portfolio or firm is examined. The regression includes the interaction between the country-specific industry portfolio's monthly market share in the particular country and the exchange rate. For the U.S. market, the actual market share for each month for the entire sample period

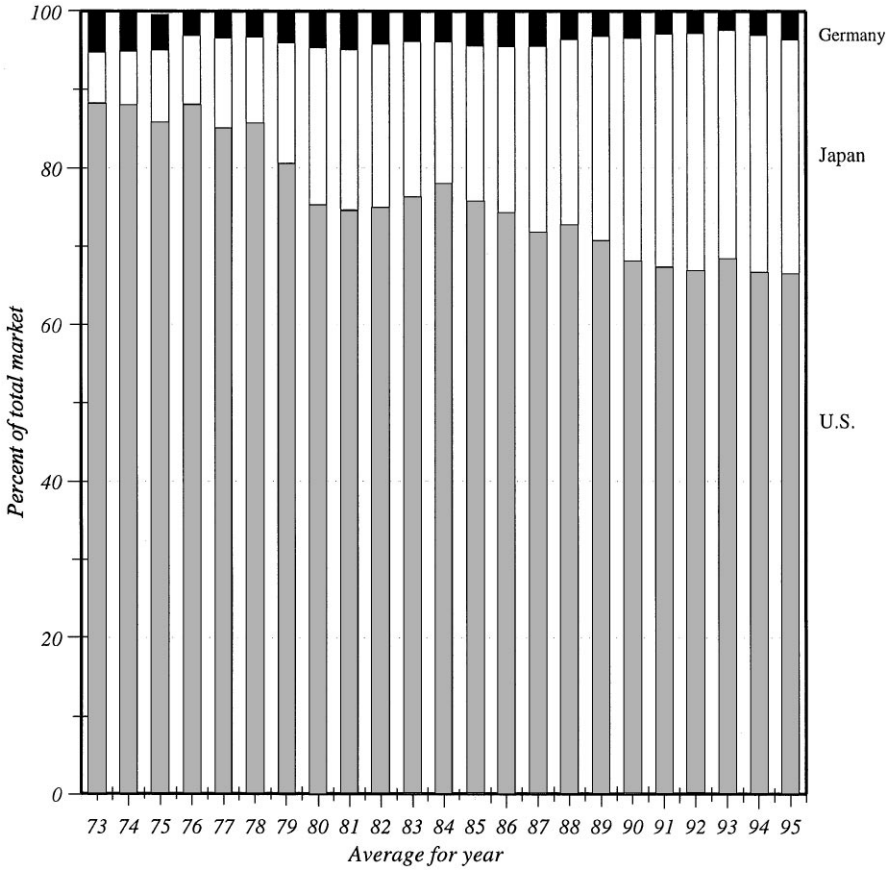

Fig. 3. U.S. automobile market share. The figure shows the market share of U.S., Japanese, and German firms in the United States for the sample period. The firms are listed by the headquarters of the parent firm. The graph reflects the automobile market share, and does not reflect that of light trucks, which are becoming a higher percentage of vehicle sales for each firm.

is used. For the Japanese and German markets the monthly market share values are obtained by using the annual seasonality factor for each country. Therefore, the market shares for both the Japanese and German markets only change annually. A similar regression model for the Japanese portfolio is evaluated with the appropriate adjustments for the exchange rate and market share;

$$r_t = \alpha + \beta^{\mathrm{m}} R_{\mathrm{m}t} + \gamma_1 \Delta S_{¥,t}\, MS_{\mathrm{JP,US}} + \gamma_2 \Delta S_{¥,t}\, MS_{\mathrm{US,JP}} + \delta_1 \Delta S_{\mathrm{DM},t}\, MS_{\mathrm{GR,US}} + \delta_2 \Delta S_{\mathrm{DM},t}\, MS_{\mathrm{US,GR}} + \varepsilon_t, \quad (3)$$

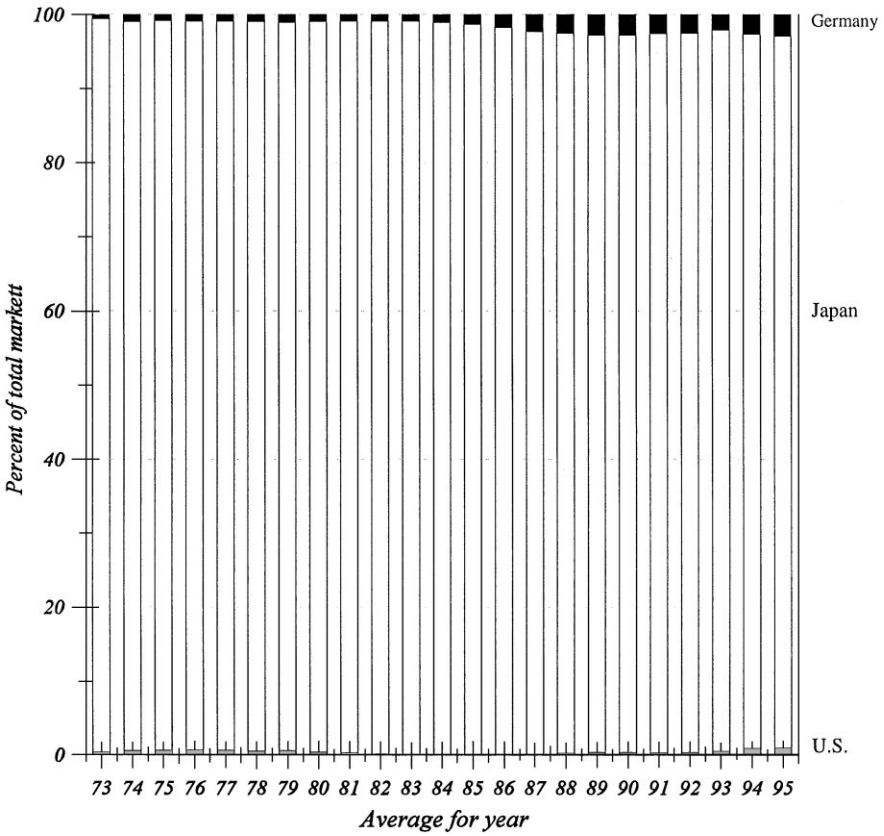

Fig. 4. Japan automobile market share. The figure shows the market share of U.S., Japanese, and German firms in Japan for the sample period. The firms are listed by the headquarters of the parent firm. The graph reflects the automobile market share and does not reflect that of light trucks, which are becoming a higher percentage of vehicle sales for each firm.

in which $MS_{A,B}$ represents the market share of portfolio of country A in country B and $\Delta S_{k,t}$ represents the rate of change of the real exchange rate in currency k at time t.

Table 4 shows the results of Eq. (3). As predicted, the U.S. portfolio's exposure to the yen is primarily due to the share of the U.S. market held by Japanese firms. The U.S. portfolio exposure to the Deutschmark, is due to the share of the German market held by American firms. The exposure to the dollar for Japanese firms is due primarily to their share of the U.S. market. However, the exposure to the Deutschmark for the Japanese firms is due to both their share of the German market and the share of the Japanese market held by German firms.

Table 4
Market share and exchange rate interaction

The table represents results from the following representative regression for each portfolio:

$$r_t = \alpha + \beta^{m} R_{mt} + \gamma_1 \Delta S_{¥,t}\, MS_{JP,US} + \gamma_2 \Delta S_{¥,t}\, MS_{US,JP} + \delta_1 \Delta S_{DM,t}\, MS_{GR,US} + \delta_2 \Delta S_{DM,t}\, MS_{US,GR} + \varepsilon_t,$$

where, β^{m} is the market risk, R_{mt} is the return on the country's market, γ_i and δ_i are the exposure of the interaction between the exchange rate and portfolio market share, ΔS_t is the rate of change in real exchange rates, $MS_{A,B}$ is the market share of portfolio A in country B, r_t is the monthly return, and ε_t is the error. Heteroscedastic-consistent t-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively.

	U.S. firms	Japanese firms
Intercept	0.0074 (1.460)	0.0057 (1.332)
Country-specific market risk	1.0524 (10.852)***	0.9213 (11.036)***
Interaction – U.S. market share for Japanese firms and ¥/$	− 4.0122 (− 2.152)**	
Interaction – Japanese market share for U.S. firms and ¥/$	55.1543 (1.284)	
Interaction – German market share for U.S. firms and DM/$	3.1938 (1.087)	
Interaction – U.S. market share for German firms and DM/$	− 13.0932 (− 0.468)	
Interaction – U.S. market share for Japanese firms and $/¥		− 2.4210 (− 2.114)**
Interaction – German market share for Japanese firms and DM/¥		8.7207 (1.563)
Interaction – Japanese market share for U.S. firms and $/¥		38.7183 (1.125)
Interaction – Japanese market share for German firms and DM/¥		− 65.2578 (− 1.708)*

This finding is interesting because the share of the Japanese market held by the German firms is relatively small, and the share of the German market held by Japanese firms is also relatively small. The significance is probably due to the high correlation between the Deutschmark and the British pound, and thus it serves as a proxy for both the sales figures in Germany, England, and other European countries and the exposure to the pound and Deutschmark.

The exposure of a firm to various exchange rates is a function of the elasticity of demand and thus of the competition that the firm faces in the markets in which it does business (Dornbusch, 1987). The source of this exposure depends on whether the exposure is due to the foreign firm's presence in the home market or the home firm's presence in the foreign market, or both. Table 4 shows that the relation between exchange rates and market share varies across countries.

We have now established that firms in the automotive industry exhibit exchange rate exposures and that foreign competition in their major markets affects their exposures. Because competition varies across time with the evolution of the industry, it is important to analyze the impact of this time variation in competition on the exchange rate exposure of the firms.

6. Time variation in exchange rate exposures

To test for time variation in exposures, the sample is broken into three equal periods which incorporate differing behaviors in exchange rates between the two countries and industry competition. The first period, 1973–1980, followed the breakdown of the Bretton Woods agreement. This period is characterized by volatile exchange rates and the oil crisis of the mid-1970s. Benign competition characterized the world automotive industry during this period, and Japanese firms did not pose a large threat to U.S. firms. Sales in the U.S. of Japanese firms as a percentage of their total sales ranges from 11% to 18% for this subperiod. Japanese vehicles were small and fuel efficient, and did not compete directly with the larger U.S. vehicles. Therefore, there was little substitutability between U.S. and Japanese vehicles. Competition within the industry was largely between companies from the same country. This type of competition should result in undetectable exchange rate exposures.

The second period, 1981–1988, is characterized by an appreciation of the dollar against the yen and Deutschmark during the first half followed by a sharp depreciation of the dollar around the Plaza Accord of September 1985. This period exhibited long-run deviations from PPP (Fig. 1). The automotive competitive landscape also changed, becoming more international. Japanese firms began to pose a more direct threat to U.S. firms because of the growing competition in the North American market. This competition accelerated when the U.S. consumer sought dependable fuel-efficient automobiles following the oil price shock of the 1970s. For Japanese firms, the range of U.S. sales to total sales was from 18% to 27% during this period, making U.S. sales a major component of total sales. Additionally, this percentage ranged from 30% to above 50% for firms such as Honda and Nissan. Consequently, one would expect large exposures for the U.S. firms to the yen and for the Japanese firms to the dollar over this period. U.S. production by some Japanese firms also began during this period.

The final period, 1989–1995, consisted of volatile yen exchange rates and continued real rate changes, coupled with a global recession and financial market concerns in both Japan and Europe. The industry continued to evolve into more global competition. The Japanese firms had established production facilities in North America and thus may have created a natural hedge against their dollar exchange rate exposure. Competition between U.S. and Japanese firms had also expanded outside North America to the European market. For the Japanese firms, U.S. sales as a percentage of total sales held steady at previous levels, but U.S. production as a percentage of U.S. sales grew from 30% in 1989 to over 60% in 1995. This percentage exceeded 50% for all but one Japanese firm by 1995. Two of the three U.S. firms had a strong presence in the European market and a high percentage of costs denominated in the local currency. The Japanese were beginning to increase market share in Europe, primarily from exports. To test for the existence of time variation in the exchange rate exposure, dummy variables are used to represent each of the three subperiods. The resulting equation is as follows:

$$r_{j,t} = \alpha + \beta_j^{\mathrm{m}} R_{\mathrm{m}t} + \sum_{k=1}^{K} \beta_k^{\mathrm{e}} \Delta S_{kt}\, PDUM + \varepsilon_t, \tag{4}$$

where *PDUM* reflects the dummy variable for each of the subperiods. The results of Eq. (4) are discussed below and shown in Tables 5 and 6.

6.1. U.S. industry and firm exposures

The results for the U.S. portfolio and individual firms for the subsample periods are shown in Table 5. The subperiods show strong evidence in support of exchange rate exposures changing with industry competitiveness. For the portfolio, the first and second subperiods show insignificant exposure to both the yen and the Deutschmark. Even though exposures are insignificant at the conventional levels for the second subperiod, there is higher significance during the second than the first period. The significant exposure for the yen includes the period of the beginning of the Japanese firm's initial entrance into the North American market. In the last subperiod, the exposure to the yen is significant at the 10% level, whereas the Deutschmark exposure is significant at the 1% level.

For the Deutschmark, the positive and significant coefficient is consistent with the discussion in Section 5. In Europe during the first subperiod, there was little competition from Japanese firms and the U.S. firms with local production faced little competition from local European firms. Therefore, there is no significant exposure associated with the Deutschmark. During the second subperiod, the Japanese firms began to compete in Europe and had little or no local production. This setting is consistent with the positive exposure to the Deutschmark for the U.S. portfolio, though not significant since Japanese firms were still

Table 5
Variation of U.S. portfolio and firm-specific exchange rate exposure

Regressions of the automotive industry for the total sample and three subperiods, using the following model:

$$r_t = \beta^{m} R_{mt} + \sum_{i=1}^{n} \beta^{e} \Delta S_t \, PDUM + \varepsilon_t,$$

where, β^{m} is the market risk, R_{mt} is the return on the country-specific market portfolio, β^{e} is the currency exposure of the portfolio, ΔS_t is the rate of change in real exchange rates, *PDUM* is the dummy variable for each of the three subperiods (1973–1980, 1981–1988, and 1989–1995), r_t is the monthly return, and ε_t is the error term. For the results, $ is the U.S. dollar, DM is the Deutschmark, and ¥ is the Japanese yen. Heteroscedastic-consistent *t*-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively. The adjusted R^2 shown is from the ordinary least squares regression with an *F*-test of the variation across time shown in brackets. Firm variation is an *F*-test of the difference in exposure across firms.

Firm	Country-specific market risk	First period		Second period		Third period		Adjusted R^2 (%) [Yen] [DM]
		¥/$ Dummy	DM/$ Dummy	¥/$ Dummy	DM/$ Dummy	¥/$ Dummy	DM/$ Dummy	
U.S. portfolio	1.0619	− 0.0393	0.0733	− 0.6673	0.3138	− 0.4184	0.8987	39.6
	(13.584)***	(− 0.165)	(0.260)	(− 1.482)	(1.063)	(− 1.690)*	(3.017)***	[1.125]
								[2.543]*
GM	0.9105	0.0918	0.0518	− 0.7549	0.8363	− 0.6313	0.9836	34.5
	(11.365)***	(0.158)	(0.204)	(− 2.116)**	(2.742)***	(− 2.113)**	(2.740)***	[2.610]*
								[3.816]**
Ford	1.0254	0.1935	− 0.0789	− 0.8481	0.3211	− 0.2856	0.4894	33.6
	(9.847)***	(0.647)	(− 0.279)	(− 2.207)**	(0.965)	(− 0.927)	(1.623)	[2.488]*
								[1.087]
Chrysler	1.2527	− 0.4114	0.2518	− 0.3933	− 0.2148	− 0.3432	1.2277	25.1
	(9.483)***	(− 0.999)	(0.589)	(− 0.473)	(− 0.438)	(− 0.908)	(2.836)***	[0.006]
								[2.306]*
Firm variation [*F*-test]		[1.195]	[0.514]	[0.396]	[2.521]*	[0.784]	[2.878]*	

Table 6
Variation of Japanese portfolio and firm-specific exchange rate exposure

Regressions of the automotive industry for the total sample and three subperiods, using the following model:

$$r_t = \beta^{m} R_{mt} + \sum_{i=1}^{n} \beta^{e} \Delta S_t \, PDUM + \varepsilon_t,$$

where, β^{m} is the market risk, R_{mt} is the return on the country-specific market portfolio, β^{e} is the currency exposure of the portfolio, ΔS_t is the rate of change in real exchange rates, *PDUM* is the dummy variable for each of the three subperiods (1973–1980, 1981–1988, and 1989–1995), r_t is the monthly return, and ε_t is the error term. For the results, \$ is the U.S. dollar, DM is the Deutschmark, and ¥ is the Japanese yen. Heteroscedastic-consistent *t*-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively. The adjusted R^2 shown is from the ordinary least squares regression with an *F*-test of the variation across time shown in brackets. Firm variation is an *F*-test of the difference in exposure across firms.

Firm	Country-specific market risk	First period		Second period		Third period		Adjusted R^2 (%) [\$] [DM]
		\$/¥ Dummy	DM/¥ Dummy	\$/¥ Dummy	DM/¥ Dummy	\$/¥ Dummy	DM/¥ Dummy	
Japanese portfolio	1.0079	0.1858	− 0.3454	− 0.6538	0.3938	− 0.0240	− 0.3032	46.5
	(13.073)***	(0.659)	(− 1.541)	(− 2.573)***	(0.996)	(− 0.190)	(− 1.877)*	[4.234]**
								[2.428]*
Toyota	0.8489	− 0.0554	− 0.1347	− 0.8374	0.4599	− 0.1205	− 0.1888	19.5
	(7.385)***	(− 0.222)	(− 0.463)	(− 2.557)**	(0.806)	(− 0.543)	(− 0.843)	[1.665]
								[0.722]
Nissan	0.8641	− 0.1051	− 0.0548	− 0.4443	0.2272	− 0.0998	− 0.3566	28.7
	(9.859)***	(− 0.411)	(− 0.194)	(− 1.747)*	(0.524)	(− 0.541)	(1.448)	[0.560]
								[0.812]
Honda	0.8830	0.5832	− 1.0145	− 1.3107	0.3750	− 0.6513	− 0.2021	24.8
	(7.231)***	(0.995)	(− 2.337)**	(− 3.623)***	(0.660)	(− 2.836)***	(− 0.603)	[7.566]***
								[3.100]**

Isuzu	1.4409 (7.587)***	0.5188 (1.132)	0.2224 (0.624)	− 0.8787 (− 2.161)**	1.0058 (1.647)*	0.8964 (1.825)*	− 0.7018 (− 1.749)*	31.4 [4.700]*** [2.697]*
Mazda	0.9901 (8.022)***	0.3569 (0.873)	− 0.6021 (− 1.565)	− 0.5704 (− 1.821)*	0.3388 (0.790)	− 0.4131 (− 1.365)	− 0.2918 (− 1.201)	25.2 [2.071] [1.402]
Suzuki	0.8424 (7.365)***	0.2499 (0.274)	− 0.6426 (− 1.122)	− 0.6394 (− 2.111)**	0.6181 (1.022)	− 0.1551 (− 0.641)	0.1266 (0.470)	15.7 [1.329] [2.075]
Mitsubishi	1.1432 (9.593)***	− 0.2201 (− 0.789)	− 0.2037 (− 0.601)	0.0842 (0.222)	− 0.2464 (− 0.541)	0.3766 (1.765)*	− 0.5034 (− 2.046)**	34.4 [0.816] [0.2308]
Firm variation [*F*-test]		[1.344]	[2.382]**	[2.551]**	[0.735]	[1.944]*	[0.790]	

not a substantial threat to U.S. firms in Europe. During the third subperiod, the Japanese firms expanded their European sales and began to present a more substantial threat to the U.S. firms. As expected, the increase in competition from the Japanese firms in Europe resulted in a positive and significant exposure to the Deutschmark for the U.S. portfolio. Japanese production in Europe expanded during this period, but at a much slower rate than their sales. *F*-tests of significance across subperiods show that we cannot reject the null hypothesis of equality of exposure for the yen, but that we can reject equality for the Deutschmark exposure.

At the firm level, we see that, during the first subperiod, U.S. firms were not sensitive to Japanese or German currencies. The first period can be characterized as a time of little international competition. For the second subperiod, Ford and GM show significant negative exposure to the yen, whereas GM shows significant positive exposure to the mark. Chrysler does not display significant exposure to either the yen or the Deutschmark. For the final subperiod, the U.S. portfolio and the results for GM show negative significant exposure to the yen. For all firms, the sign on the yen is negative, as would be predicted for a competitive industry. For exposure to the Deutschmark, two of the three firms show significant sensitivity.

An interesting result is the positive and significant exposure of Chrysler to the Deutschmark in the last subperiod. This result is consistent with a depreciation in the Deutschmark resulting in an overall weakening in the Japanese firms that benefits Chrysler and other U.S. firms. A positive and significant coefficient is consistent with a competitive component to Chrysler as a result of the competitive losses to the Japanese firms resulting from the depreciation of the Deutschmark to the yen and the dollar. If this competitive argument is consistent with the theory, then one would expect a negative coefficient on the Deutschmark-to-dollar exchange rate for the Japanese portfolio. This argument is supported by a negative, although insignificant, coefficient on the Japanese portfolio to the change in the Deutschmark-to-dollar rate. At various times during this period, Chrysler was involved in merger discussions with several European automotive firms. A depreciation in the Deutschmark-to-dollar would increase the dollar value of a merger or acquisition since the European firm would be cheaper in dollar terms, a situation that would benefit Chrysler. Also, Chrysler began joint venture production of some of its most profitable vehicles in Austria for sales in Europe, during this period.

The yen exposure is never significant for Chrysler. During the first part of the third subperiod, Chrysler held up to 25% of common shares in Mitsubishi Motors Corporation, which may impact the firm's yen exposure through its hedging effect. Holding shares in a firm with the opposite exposure to a particular currency creates a negative correlation to the firm's cash flows and thus acts as a hedge. Even though both Ford and GM had holdings in Japanese firms, the size of the holdings relative to the size of the total firm was much smaller than

that of Chrysler, thus reducing any possible total firm hedging effect. Another possible explanation for the weak significance of Chrysler's exposure coefficient to the yen could be the high variation in returns of the firm due to other firm-specific factors. From 1989 to1992, Chrysler was facing economic hardships that could swamp the effect of its exposure to exchange rates.

Even though the equally weighted portfolio did not show significant time-variation across subperiods for the yen, an F-test of time variation at the firm-specific level shows time variation for both GM and Ford. For the Deutschmark there is time variation for the portfolio as well as for GM and Chrysler. Also, tests of variation across firms show significant variation for the Deutschmark in the second and third subperiods. There is evidence that levels of exposure change as the competitive nature of the industry changes along with the volatility of exchange rates. Finally, there is evidence of time variation across firms and across the three subperiods as the industry evolves. This result is consistent with exposures changing with industry competitiveness and varying at the firm level.

6.2. *Japanese industry and firm exposures*

As shown in Table 6, in the first subperiod, exposures are insignificant for the Japanese portfolio and for the seven firms. The second subperiod, which was a time of real yen depreciation and subsequent real appreciation against the dollar, reflects significant exposure for the portfolio of Japanese firms and for all individual firms except one. This result occurs primarily due to the aggressive entrance of Japanese firms into North America, as they began direct competition with U.S. firms. The Japanese firms had low levels of local production, therefore eliminating any hedging effect of foreign production. The sign on the coefficient is as expected for a competitive industry for the portfolio and six firms. For the Deutschmark, the portfolio sensitivity is insignificant for six firms. For this period, the Deutschmark-to-yen exchange rate experienced only short-term deviations from PPP with relatively small variability.

The last subperiod, a period of continued appreciation of the yen against the dollar and only small changes in the real Deutschmark-to-yen rate, is also characterized by intense global competition. The exposure of the Japanese portfolio is insignificant for the dollar, but the signs on the coefficients reflect the expected directions. This result may seem surprising because one would expect significance due to the combination of real exchange rate changes and competition, which implies firm value changes. The lack of significance could result from the operational hedging impact of local production. Data on derivative activity of these firms during this period are not available, but firms had significant production operations in North America. Their production activities act as a partial hedge against exchange rate exposure, leaving only net profits from U.S. exposed to exchange rate changes. This question will be investigated further in the next section.

The exposure to the Deutschmark is negative and significant for the portfolio. There is little production in Europe by the Japanese firms during this period, so there is almost no counteracting operational hedging impact for Japanese firms. At the firm level, Honda continues to have significant exposure to the dollar. This result is expected since U.S. sales of Honda, as a percentage of total sales, ranges from 42% to 47% during the third subperiod. During this same period, both Isuzu and Mitsubishi have positive and significant exposure to the dollar and negative and significant exposure to the Deutschmark. The U.S. sales for both firms arise primarily from U.S. production facilities and may benefit from dollar depreciation relative to other Japanese competitors.

Formal tests of variation across firms during each subperiod and over time are also included in Table 6. The results show that there is significant time variation in both dollar and Deutschmark exchange rate exposures for the equally weighted portfolio. The results are driven primarily by Honda, which is dependent on its foreign operations for profits that continued to expand during the sample period. Tests of variation across firms show significant differences to the dollar for both the second and third subperiods. Differences are significant for the Deutschmark rate for the first subperiod.

As with the U.S. firms, Japanese firms display significant exposure to the home currency of their major competitors. *F*-tests of significance across time and firms show that there is time and cross-sectional variation in exposure for the Japanese firms. Both results are consistent with predictions. As a check of robustness, the results in Tables 2–6 are evaluated after trimming the data at the 5% level for both returns and exchange rate changes to eliminate any outliers that may be driving the results. The implications are even stronger after this procedure.

7. Foreign sales, operations, and exposure

Although net exposure has been emphasized, it is important to note that factors affecting this net exposure vary across firms and across time for some firms. This variation in exposure could be a result of the firm's operations. If a firm has foreign-denominated costs, this could be a natural hedge for the firm's foreign-denominated revenue.

In the earlier sections on the exposure of the Japanese firms, results show that the Japanese automotive firms exhibit significant exchange rate exposure during the period 1981–1988. This exposure occurred during a period of substantial competition in the U.S. market for these firms. Most of these Japanese firms exhibit insignificant exposure during the final subperiod in which there is even more intense competition. Additionally, several Japanese firms shifted production to the U.S. The foreign operations and affiliations of U.S. and Japanese firms since 1970 are shown in Table 7. Note that foreign production by U.S.

Table 7
Major foreign production, operations, and affiliations of U.S. and Japanese automotive firms since 1970, by year of initiation of operations.

Year	Company	Activity
Before 1970	Ford	Ford begins sales in Europe prior to WWII primarily in the U.K; exact date is unclear
	General Motors	GM buys Adam Opel of Germany in 1929 to begin its European operations
1971	Isuzu/GM	Affiliation agreement is signed by GM and GM purchases 24.2% of Isuzu
	Mitsubishi/Chrysler	Tie-up between Chrysler Corporation and Mitsubishi Corporation is announced
	Chrysler	Retains majority ownership in Chrysler de Mexico
1978	Honda	Honda of America Manufacturing, Inc. is established in Ohio, U.S.A.
1979	Ford/Mazda	Ford acquires 25% of Mazda
1980	Nissan	Nissan acquires shares in Motor Ibérica, S.A. in Spain
1981	Suzuki/GM	Tie-ups with General Motors Corporation of the U.S. and with Isuzu Motors Ltd. are concluded
1982	Suzuki	The first Suzuki passenger car comes off the line at Pakistan plant Production and sales contract for automobiles is formally concluded with Maruti Udyog LTD of India
1983	Nissan	Production of the Safari (Patrol) starts at Motor Ibérica, S.A. in Spain First Nissan truck rolls of the line in Tennessee
	Suzuki	The first Suzuki car comes off the line at Maruti Udyog LTD of India
1984	Honda	Automobile manufacturing company is established in Canada
	Nissan	Nissan begins sales of the Santana produced through cooperative agreement with Volkswagen
	Toyota/GM	Toyota–GM joint venture (New United Motor Manufacturing, Inc.) in U.S. starts production
	Chrysler	Chrysler purchases 16% of Maserati of Italy
1985	Mazda	Mazda Motor Manufacturing (USA) Corp. starts the construction of its Michigan plant
	Nissan	The Tennessee, USA plant begins production of the Sunny (Sentra) passenger car

Table 7 (*continued*)

Year	Company	Activity
1986	Honda	Production of Accords commences in Canada
	Mitsubishi/Chrysler	The plant of Diamond-Star Motors, an Mitsubishi Motors Corporation and Chrysler joint undertaking, is established
	Nissan	NMUK's vehicle assembly plant in North East England commences production of the Bluebird Arizona Test Center, Inc. (ITC) is established to bring the Company into closer contact with the world maker and begins operations
1987	Honda	Engine production commences in the U.S.
	Mazda	Vehicle production begins in U.S. plant
1988	Mitsubishi/Chrysler	Diamond-Star starts production of the new sports coupe
	Nissan	Nissan European Technology Centre Ltd. (NETC) in the U.K. begins to strengthen Nissan's research and development activities in Europe
	Toyota	Toyota Motor Manufacturing, U.S.A., Inc. starts production
		Toyota Motor Manufacturing Canada Inc. starts production
1989	Isuzu	New production plant in the U.S. for Isuzu and Subaru
	Nissan	Nissan Mexicana, S.A. de C.V. is established
	Chrysler	Joint venture begins with Steyr-Daimler-Puch of Austria to produce minivans and Jeeps for Europe
	Ford	Ford acquires Jaguar of the U.K.
	GM	GM purchases 50% of Saab of Sweden
1990	Suzuki	Suzuki reaches the basic agreement for production of passenger cars in Hungary by way of a joint venture with C. Itoh & Co., Ltd. and Autokonszern RT
1991	Mitsubishi	Mitsubishi Motors, the Dutch State, and Volvo Car Corporation sign an agreement on joint car production in The Netherlands
1992	Honda	Production of Accord begins in the U.K.
	Nissan/Ford	The Quest multipurpose vehicle, developed in a joint program with Ford Motor Co. of the U.S., begins production at a Ford plant in Ohio
	Suzuki	Automobile production starts in Hungary
	Toyota	Toyota Motor Manufacturing (U.K.) Ltd. starts production

firms remained stable by country during the entire sample period. Therefore, exposure would not have been impacted by foreign country production. Additionally, monthly production data for U.S. firms in foreign markets are unavailable. Table 7 shows that there was a major effort by Japanese firms to produce vehicles outside its home market. North America was the primary destination for the foreign operations of the Japanese firms. Foreign production could have reduced the exposure because of the hedging value of dollar-denominated costs.

Japanese firms increased their vehicle sales in North America from 1.9 million in 1981 to 2.9 million in 1989. From 1989 to 1995, Japanese firms' U.S. sales went from 2.9 million to 3.3 million. The U.S. production as a percentage of U.S. sales by Japanese firms grew from almost zero in 1981 to approximately 30% in 1989, then grew to approximately 60% by 1995. Therefore, along with reduced sales growth during the last subperiod, we observe an increase in U.S. production for the Japanese firms, which could decrease exposure. This impact could be mitigated if any reduction in exposure from production in the U.S. market was offset by an increase in U.S. sales as a percentage of global sales. Another caveat is that Japanese firms did not decide to produce in North America simply for its hedging value but for its overall strategic value. For instance, there were pressures on the U.S. government during the 1980s to limit the number of Japanese imports to the U.S. Japanese manufacturers agreed to limit the number of imports, while at the same time increased North American production to increase the supply of vehicles in the U.S. Even with foreign production, the profits of the firm still face yen-to-dollar translation exposure.

To evaluate the impact of foreign sales to total sales for each firm and the impact of foreign operations on the firm's exposure, the following regression is evaluated:

$$r_t = \alpha + \beta^{\mathrm{m}} R_{\mathrm{m}t} + \gamma_1 S_{¥,t}\, TS_{\mathrm{JP}} + \lambda_2 S_{¥,t}\, Pr_{\mathrm{JP,US}} + \varepsilon_t, \tag{5}$$

in which TS and Pr is the interaction of the change in the yen-to-dollar exchange rate and U.S. sales to total sales and the interaction of the change in the yen-to-dollar exchange rate and U.S. production to U.S. sales for the Japanese firms, respectively. The regression is from the beginning of U.S. production for each firm. The U.S. sales data of the Japanese firms include both exports from Japan and U.S. production in the U.S.

The coefficient on U.S. sales to total sales is predicted to be negative, because as foreign sales increase in a competitive market, the exchange rate exposure should also become more negative. The sign on the foreign operation should be positive, because foreign production should act as a natural hedge for foreign sales, assuming that hedging of the costs in the foreign market offsets the exposure of the firm's foreign profits. The results of this analysis are shown in Table 8.

As expected, the sign on U.S. sales to total sales is negative and significant for the sample. The sign is also negative for all firms except Suzuki, which had low

Table 8
Foreign sales, production, and exchange rate interaction for Japanese firms

Regressions are shown of the Japanese firms for the full sample, using the following model:

$$r_t = \alpha + \beta^{m} R_{mt} + \gamma_1 S_{¥,t}\ TS_{JP} + \lambda_2 S_{¥,t}\ Pr_{JP,US} + \varepsilon_t,$$

where, β^{m} is the market risk, R_{mt} is the return on the country-specific market portfolio, Pr is the U.S. production as a percentage of U.S. sales, TS is the sales in the U.S. as a percentage of total global sales, S_t is the change in real exchange rates, r_t is the monthly return, and ε_t is the error term. Heteroscedastic-consistent t-statistics are in parentheses, and ***,**, * denotes 1%, 5%, and 10% significance levels, respectively.

Firm	Intercept	Country-specific market risk	U.S. sales/ total sales	U.S. production/ U.S. sales	Adjusted R^2 (%)
Japanese portfolio ($n = 154$)	0.0058 (1.657)*	0.8040 (10.533)***	− 2.5832 (− 3.198)***	0.6253 (1.363)	52.2
Toyota ($n = 109$)	0.0095 (1.442)	0.6532 (4.530)***	− 5.9955 (− 2.601)***	2.8295 (2.223)**	25.5
Nissan ($n = 127$)	0.0055 (1.040)	0.6924 (7.364)***	− 2.6039 (− 2.346)**	0.4734 (0.681)	33.3
Honda ($n = 154$)	0.0091 (1.445)	0.6000 (4.671)***	− 1.3228 (− 1.069)	− 0.7832 (− 0.711)	20.3
Isuzu ($n = 70$)	0.0206 (1.586)	2.0067 (6.539)***	− 1.5506 (− 0.399)	1.0346 (0.482)	57.8
Mazda ($n = 98$)	0.0094 (1.288)	0.9372 (6.871)***	− 2.8415 (− 1.147)	0.3245 (0.207)	39.1
Mitsubishi ($n = 70$)	0.0074 (1.222)	0.9208 (6.827)***	− 7.9494 (− 1.481)	2.0001 (1.813)*	57.7
Suzuki ($n = 70$)	0.0129 (1.696)*	0.7575 (5.582)***	18.4532 (1.011)	− 0.9972 (− 1.394)	37.8

North American production over the sample period. The sales component is significant at the 5% level for Toyota and Nissan but surprisingly insignificant for Honda, which has relatively high levels of U.S. sales to total sales. This result may be due to the lack of variation in Honda's U.S. sales to total sales since initiation of U.S. production in 1981.

For the U.S. production to U.S. sales component, we see a positive sign for the full sample, even though it is not significant. At the firm level, only Toyota and Mitsubishi have a positive and significant sign. This result may seem surprising since it is assumed that foreign production acts as a natural hedge. What this result may be indicating is that, since we observe a reduction in the exposure for these firms in the third sample period, the firms may be hedging using financial instruments rather than depending solely on foreign production. Again, the

results on Honda are counterintuitive. One would expect a firm with relatively high levels of U.S. sales to total sales and U.S. production to U.S. sales to display stronger results in both components. A possible explanation is that Honda may be doing high levels of risk management through financial contracts to reduce its dollar exposure. Additionally, the dollar-denominated profit exposure of the firm may be greater than the benefit of its U.S. operations.

On average, the results are consistent with the prediction that an increase in foreign sales is a major determinant of a firm's exchange rate exposure. This finding is even more pronounced if the firm faces competition in the foreign market from domestic firms. Additionally, the evidence supports the argument that foreign production lowers the exchange rate exposure of a globally competitive firm.

7.1. Yen exposure and the automotive industry

A final note in the discussion of exchange rate exposure in the automotive industry is the currency of exposure of automotive firms from the U.S. and Japan. It has been established that U.S. firms have direct exposure to the yen as a result of Japanese firms' competition in the U.S. market. Also. U.S. firms experience positive exposure to the Deutschmark due to the competition with Japanese firms in Europe. Additionally, exposure of the Japanese firms to the dollar results from sales and competition in the U.S., and exposure to the Deutschmark is from the competition in Europe with U.S. firms. Therefore, exposure of the firms from each country results from their competition with each other in combination with their net foreign currency cash flows. Also, because these firms compete in many other markets, we should observe an overall exposure of the same magnitude but opposite sign to the yen.

When a regression is evaluated of the yen to trade-weighted exchange rate against the returns on the Japanese and U.S. portfolios, the coefficients on the exchange rate are of similar magnitude and opposite sign with both being significant at the 1% level (results not shown). This finding is consistent with previous arguments which suggest that what we observe is a yen exposure for firms from both countries, lending support to the theoretical discussion about competition playing a substantial role in the exchange rate exposure of firms within an industry.

8. Conclusion

Using a sample of automotive firms from the U.S. and Japan, we find evidence supportive of the theoretical determinants of foreign exchange rate exposures for firms in a globally competitive industry. By looking at an industry with known exposures, this study expands on previous studies on exchange rate exposure,

and shows that there exists time-varying foreign exchange rate exposure across countries for multinational firms and global competitors. This exposure changes as the structure of the industry and its competition changes through time. Formal tests of time and cross-sectional variation show that there are differences in exposure across country-specific industry portfolios and across the firms in the world automotive industry. More importantly, industry competition and the structure of the firm's operations play vital roles in the exchange rate exposure to firm-value relation.

At the firm level, there is further evidence of significant exchange rate exposure for certain firms and insignificant levels for other firms that is consistent with theories of the determinants of exposure. *F*-tests of differences in exposure across firms show that there are significant differences in exposure to exchange rate shocks across firms from the same country.

The currency exposure of a firm is a function of its foreign sales, the cost structure of the foreign competition as well as the degree of competition, and the firm's hedging practices. Using market shares of the firms in the respective markets and competition faced by the firm in each market, results show that domestic competition from foreign firms is an important determinant of exposure, particularly for U.S. automotive firms. Finally, formal tests reveal that the ratio of foreign sales to total sales and competition are major determinants of exchange rate exposure, and that foreign production decreases exchange rate exposure. The findings of this paper are consistent with models that predict an exchange rate exposure for multinational firms in a globally competitive industry. This result implies that the change in competitiveness of an industry should be considered in future work on exchange rate exposure. We hope to see work on exposure more richly model the competitive aspects of industry structure.

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