Resolving the Exposure Puzzle: The Many Facets of Exchange Rate Exposure

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Abstract

Empirical research has documented a low stock price reaction to exchange rate movements. We examine a global sample of 1,161 manufacturing corporations from 16 countries and show that the weak response is due to a combination of factors at the industry and firm level. Specifically, we extend prior theoretical results which model a firm's foreign exchange rate exposure as a function of market share, product substitutability, pass-through, sales and cost in foreign currency, so that they may be applied to global industries. Using this model, we show empirically that corporations are able to manage exchange rate risk via three complementary channels. First, firms pass part of exchange rate changes through to customers. Second, most global manufactures utilize operational hedges (e.g., matching foreign sales with foreign production). Third, corporations employ financial risk management strategies such as issuing foreign currency denominated debt and entering into foreign exchange rate derivatives transactions. All of these channels are important. We estimate that for a typical firm pass-through and operational hedging each reduce exposure by 10% to 15% and financial hedging reduces exposure by 45% to 50% (depending on model parameterization). Finally, our evidence suggests that the combination of these factors is sufficient for explaining the observed levels of foreign exchange rate exposure.

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1 Introduction

For many corporations foreign exchange rate (FX) fluctuations represent a major financial risk. For example, global companies regularly cite exchange rate movements as a cause of earnings surprises. The recent strength of the U.S. Dollar during the 2001 recession even led to the creation of the *Coalition for a Sound Dollar*, a group of over 100 major U.S. trade associations which lobbies the U.S. government for a weaker currency. Theoretical models (such as Bodnar, Dumas, and Marston, 2002) also predict that many firms should have significant exchange rate exposures. Despite these anecdotal indications and theoretical predictions of significant exchange rate exposures, academic studies have documented only weak relationships between exchange rate changes and stock returns (see, for example, Jorion, 1990).

The goal of this paper is to resolve the discrepancy between theoretical predictions of exchange rate exposure and observed levels of exchange rate exposure in the broad cross-section of global corporations. We undertake this by combining a variety of insights from the extant literature to form a more comprehensive analysis of exchange rate exposure. In essence, our analysis examines how firms combine three different mechanisms at their disposal for mitigating exchange rate risk. First, firms can (to varying degrees) pass through to customers changes in costs due to exchange rate movements. Second, firms can often affect their exchange rate exposure by choosing the location and currency of costs (e.g., where factories are located). Third, firms can utilize an array of financial products, such as foreign currency denominated debt and financial derivatives, as exchange rate risk management tools. Our results show that each of these factors plays an important role in mitigating observed exchange rate exposure and together they account for the vast majority of the discrepancy between prior theoretical predictions and observed exposures.

Our analysis has three parts. First, we examine the global automotive industry as a motivating example. Using a simple model of exchange rate exposure by Bodnar and Marston (2002), we show that global automakers have large theoretical exposures to exchange rates based simply on their high levels of foreign sales. Accounting for foreign production reduces the theoretical exposure of automakers by about 50%. Finally, simple corrections for the use of foreign exchange rate derivatives and foreign currency debt reduce the theoretical exposure by an addi-

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tional 40%. Consequently, the final theoretical exposure of global automakers to exchange rate risk is fairly low.

Second, we expand the theoretical model of Bodnar, Dumas, and Marston (hereafter BDM, 2002) to examine the exchange rate exposures of a global firm that can compete and produce in both a foreign and local market. In the BMD model, the exporting firm cannot sell in its own market and the local firm cannot produce abroad. By assuming that global foreign exchange rate exposure is a weighted average of a firm's foreign exchange exposure in the foreign market and the domestic market, we can derive optimal pass-through decisions and the resulting foreign exchange exposures of global firms in competitive industries. Our enhanced BDM model generates exposures as a function of market share, product substitutability, pass-through, sales, and cost in foreign currency that are smaller than the original BDM model under most conditions, and in some cases the enhanced model generates negative foreign exchange rate exposures. Overall, our enhanced model allows for a richer, more realistic set of exposures.

Third, we analyze a large sample of global manufacturing firms in 16 countries using the enhanced BDM model. We show that pass-through and operational hedging are important for reducing the level of exchange rate exposure. However, after accounting for pass-through and operational hedging, theoretical exposures are still larger than observed exposures. We document that firms with high theoretical exposures are both more likely to have foreign currency debt and more likely to use exchange rate derivatives. We estimate the reduction in exposure due to each channel for a typical firm. Depending on the level of product substitutability, pass-through reduces exposure by about 10% to 15%. Operational hedging reduces exposure by similar amounts, while financial risk management (foreign currency debt and FX derivatives) accounts for a further 45% to 50% reduction in exposure. Thus, firms reduce their gross exchange rate exposure by about three quarters via the three channels together. Consequently, for reasonable parameter values, it is not possible to reject the enhanced BDM model after correcting for the estimated effects of financial risk management.

Our study contributes to the literature in several ways. First, we take a more comprehensive approach to studying exchange rate exposure. For example, the model we derive allows for global firms in an imperfectly competitive global market. Furthermore, the sample of firms and the number of countries we study is among the largest examined to date and includes financial

risk management variables that have not been considered in such a large and diverse sample. Finally, and most importantly, we are able to resolve a major puzzle in financial economics by carefully demonstrating the close relationship between theoretical and observed foreign exchange rate exposures.

The paper is organized as follows. Section 2 provides a review of the extant literature. Section 3 demonstrates in a simple framework the impact of various factors such as the competitiveness of a firm, operational hedging, and financial hedging on the exchange rate exposure of firms in the global automotive industry. Subsequently, in Section 4 we develop an extended framework for assessing foreign exchange rate exposures and pass-through, based on the theoretical model of Bodnar, Dumas and Marston (2002). This enhanced BDM model is estimated for a global set of manufacturing firms in Section 5. Finally, Section 6 concludes.

2 Motivation and Related Literature

Studies on exchange rate exposures such as Adler and Dumas (1984), Hekman (1985), Shapiro (1975), Flood and Lessard (1986), von Ungern-Sternberg and von Weizsäcker (1990), and Marston (2001) develop theoretical models of firm behavior to examine foreign exchange exposure. These papers do not provide empirical estimates of their models. In a more recent paper, Bodnar, Dumas, and Marston (2002) specify a theoretical model of exchange rate exposure that explicitly incorporates optimal export pricing behavior and provide direct estimates of the structural model. Specially, BDM develop a model of exporting firms under duopoly to study exchange rate exposure and pass-through behavior of firms. An exporting firm competes with a foreign firm in that export market. The costs of the exporting firm are based in the domestic or foreign currency, while the foreign firm only has foreign costs. BDM are able to derive optimal pass-through decisions and the resulting exchange rate exposure. They show that as substitutability between home-produced and foreign-produced goods (holding market shares constant) increases, exposure increases and pass-through declines. Holding product substitutability fixed, increases in market share reduce both exposure and pass-through elasticities. However, their empirical analysis is limited to a few industries in Japan and the empirical results are mixed.

Dekle (2005) studies the impact of substitutability between foreign and export products and the type of competition on exchange rate exposure. For 15 Japanese export industries, product substitutability is found to be high, and ten of these 15 industries are better characterized as

Cournot competitors in foreign markets than as colluders. While there is heterogeneity in the exposure elasticities, collusive exporters tend to have higher elasticities than competitive exporters. This result is consistent with the theoretical predictions of the paper.

In some ways, the analysis of the location of costs and the effects of market competition on pricing policy are equivalent to mechanisms characterized in the literature as 'operational hedges.' For example, locating a production facility in a foreign country aligns costs with revenues, whereas passing-through exchange rate changes to output prices aligns revenues with costs. Several theoretical models explicitly model how firms should choose the location of production facilities (i.e., the currency of costs) in the presence of FX risk (see, for example, Mello, Parsons, and Triantis, 1995, and Chowdhry and Howe, 1999).[1] However, the two methods differ in some respects. The location of production is largely under the control of management (though it may be costly to change) and is a real investment decision for the firm. To the contrary, the ability to pass-through price changes depends on the nature of competition in the product market and is presumably not under the control of management if managers choose a value-maximizing strategy.

There also exists a substantial empirical literature which examines the effects (and management) of exchange rate fluctuations. A number of studies estimate the exchange rate sensitivity of stock prices and typically document small exposures.[2] However, several studies report differences in exposures across industry classes and countries (e.g., Campa and Goldberg, 1999, Bodnar and Gentry, 1993, Marston, 2001, and Allayannis and Ihrig, 2001). Williamson (2001) shows that auto manufacturers have higher foreign exchange rate exposure if they have high levels of foreign sales and face foreign competition. Bartram and Karolyi (2003) find that the foreign exchange rate exposure of nonfinancial firms is systematically related to firm characteristics (sales, the percentage of foreign sales in general and in Europe in particular), regional factors (geography, strength of currency) and industry characteristics (competition, traded goods). Other

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[1] The general method in the theoretical literature has been to focus on deriving either optimal pricing policies (i.e., considering production locations and costs fixed) or optimal location of production (e.g., considering unit prices fixed).

[2] See, for example, Jorion (1991), Amihud (1993), Bodnar and Gentry (1993), Bartov and Bodnar (1994), Bartov, Bodnar, and Kaul (1996), Choi and Prasad (1995), He and Ng (1998), Chow, Lee and Solt (1997), Griffin and Stulz (2001), and Bartram and Bodnar (2005).

studies also have examined the association between foreign exchange exposures and macroeconomic and firm activities. For example, Parsley and Hopper (2002) and Dahlquist and Robertson (2001) find significant associations between exchange rate exposures and currency arrangements.

Empirical research has also examined the relationship between FX exposure and various types of exchange rate risk management. For example, Allayannis and Ofek (2001), Wong (2000), Simkins and Laux (1996), and Hagelin and Prambourg (2002) document significant negative associations between foreign exchange exposures and the use of financial derivatives and foreign debt. Nain (2004) shows that an unhedged firm's foreign exchange exposure increases with the extent of hedging in the industry. Recent studies also examine the associations between exposure and proxies for operational hedging (Pantzalis, Simkins and Laux (2001) and Carter, Pantzalis and Simkins (2003)). For example, Carter, Pantzalis and Simkins (2003) examine the use of derivatives and operational hedges on foreign exchange exposures and examine whether operational hedges act as real option strategies. They document that exposures vary not only as to whether a firm is a net exporter or net importer but also across weak and strong dollar states. They interpret these results as evidence that operational hedges serve as real options. Allayannis, Ihrig, and Weston (2001) find that operational hedging strategies only benefit shareholders when used in combination with financial hedging strategies. Dewenter, Higgins, and Simin (2005) find evidence that financial and operating hedging may help explain low exchange rate sensitivities of firms during the 1993 peso crisis in Mexico and the 1997 devaluation of the Thai Baht.

In summary, the objective of our analysis is to combine the many insights described in this section into a single comprehensive analysis using a large sample of global firms and then determine if low observed FX exposures can be explained by the combined effects.

3 Exchange Rate Exposure in the Automotive Industry

In this section, we present a brief industry case study of global automotive production to motivate our subsequent, broader analysis. The goal of this section is to illustrate in a simple, yet powerful, way the potential effects of competition, operational hedging, and financial hedging on the FX exposure of firms. First, we show that *Gross Exposures* (estimated from foreign sales and profit margins) are often quite large for global automakers. Next, we show that *Model Expo-*

sures, which account for foreign costs (i.e., operational hedges), are significantly lower. Finally, we estimate the effect of financial hedging with foreign currency debt and foreign exchange rate derivatives and show that these *Residual Exposures* are much closer to the actual foreign exchange rate exposures estimated from stock price data.

We choose the auto industry for several reasons. First, it is a well-known, mature, and competitive industry. In addition, the industry is truly global with major companies headquartered (as well as manufacturing) in Asia, Europe, and North America. The auto industry has a strong anecdotal history of being affected by exchange rates and consequently taking exchange rate risk seriously.[3] Finally, we are by no means the first to study the foreign exchange exposure of the auto industry, so we can rely on existing results for some of our discussion. In particular, Williamson (2001) studies the auto industry from 1973 to 1995 to examine the effect of real exchange rate changes on the value of firms.

In his analysis, Williamson takes into account the effect of industry structure and competition among U.S., German, and Japanese firms. Among other findings, Williamson documents statistically significant but economically small exchange rate exposures that change over time. Consistent with theoretical predictions, changes in exposure are related to changing industry structure (e.g., competition) as well as "large and extended" movements in real exchange rates. Our subsequent analysis differs from Williamson on various dimensions. First, we examine a somewhat more global auto industry by expanding the sample of firms in Williamson's analysis from 10 to 16 firms. Second, in addition to industry structure and competition, we explicitly examine the impact of financial hedging in the form of foreign exchange rate derivatives and foreign currency debt on firms' foreign exchange exposures. Third, we extend the measures of industry structure, competition, and export sales to examine the differences in global and regional competition measures.

Table 1 reports selected descriptive statistics on the global auto industry. The sample includes 16 firms, representing six countries (France, Germany, Italy, Japan, South Korea, and the United States). Panel A reports firms' sales for North America, Europe, Japan, and all other regions of the world. The data indicate that for most auto manufacturers the largest fractions of

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[3] See, for example, "Foreign Exchange Hedging Strategies at General Motors" (2004 Harvard Business School Case) by Mihir Dasai and Mark Veblen.

sales occur in their own region. For example, except for DaimlerChrysler, European firms' sales are predominantly in Europe with negligible sales volume in Japan. Panel B of Table 1 reports firms' production volume around the world. The data show how firms have geographically diversified production with roughly one third of output (on average) produced outside their home country. Panel C of Table 1 reports the difference between sales and production percentages for each firm and each region of the world. A positive (negative) number indicates that in the region of interest, a firm has more (less) sales volume than production volume. In some cases firms have larger fractions of foreign production than fractions of foreign sales. However, most firms produce more than they sell locally (e.g., all Japanese firms). These values are of interest because they are closely related to net operating exposures. As discussed previously, firms can operationally hedge to manage exchange rate exposure and as expected, the values show that firms will to varying degrees locate production in regions of the world in which they have sales. For example, for European firms the North American production, in part, acts as an exchange rate hedge to the European firms' North American sales.

More interesting is the possible effect of global competition on the regional markets. Panel A shows that North American firms sell the second largest volume of autos in Europe.[4] Thus, European firms can have significant foreign exchange exposure from their import competition. However, the nearly balanced production and sales for both U.S. and European manufacturers in Europe will tend to limit large competitive exposures. In contrast, other firms choose to have relatively low production relative to sales in certain regions. The most extreme examples are Mazda and Hyundai, which each have sales in North America and Europe exceeding production in those regions by 16.2% to 31.1%.

As noted already, we seek to understand how these operating hedges (or lack thereof) combine with competitive forces and financial risk management decisions to determine an overall foreign exchange exposure. Similar to Williamson (2001) and others, we base our analysis on theoretical measures of exposure. For this part of the analysis, we estimate the simple model of exchange rate exposure derived in Bodnar and Marston (2002), which show that the exchange rate exposure elasticity (δ) can be expressed as

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[4] Ford and General Motors both have acquired European automakers. For example, Ford acquired Jaguar in 1989 and Volvo in 1999. General Motors acquired Adam Opel in 1929 and 50% of SAAB in 1989.

$$\delta = h_1 + (h_1 - h_2)\left(\frac{1}{r} - 1\right) \qquad\qquad (1)$$

where h_1 is the foreign currency denominated revenue as a percent of total revenue, h_2 is foreign currency denominated costs as a percent of total costs, and r is the firm's profit margin.

In Table 2, we examine the foreign exchange exposure of global automakers based on this model. The first two columns of Table 2 report the total percentage of foreign sales and the gross profit margin. On average, more than half of automakers' sales are foreign. Gross profit margins are fairly similar across firms with the spread between the lowest (Isuzu) and the highest (Honda) equal to 0.16. The next column reports a value for *Gross Exposure*, which is an estimate of the foreign exchange rate exposure before accounting for foreign production (i.e., operational hedging) and is obtained by evaluating equation (1) for each firm with h_2 set equal to zero. These *Gross Exposure* values tend to be large. The average gross exposure of 2.70 indicates that if automakers produced only in their home country, their stock prices should decline on average 2.7% in response to 1% appreciation of the local currency. The simple model by Bodnar and Marston (2002) illustrates how important industry competition and profit margin can be to overall exchange rate exposure. For example, if we assume that a less competitive firm has a lower profit margin, it will also have a higher exposure, *ceteris paribus*.[5] Consequently, the automakers with the lowest gross profit margins (Isuzu, DaimlerChrysler, and Mitsubishi) are the ones with the highest *Gross Exposures*.

The next column of Table 2 labeled *Model Exposure* reports results obtained from evaluating equation (1) using actual values of foreign production (h_2). The important role of foreign production as an operational hedge is evident from the substantial drop in estimated exposure for each firm. Several companies have estimated exposures close to zero, and the average of all firms drops by more than half to 1.26.

Of course, automakers also use financial tools to manage foreign exchange rate risk. The use of financial risk management tools has grown substantially over the last 30 years to the point where the majority of large corporations with foreign operations use some type of financial in-

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[5] This is because the less profitable firm will have the same nominal exchange rate exposure, but a lower firm value. We also note that this analysis stretches the application of the Bodnar and Marston (2002) model, which is for a monopolist. We explicitly consider exposure in a model with a competitive product market in the next section.

strument that can mitigate FX risk. Two of the most common methods are issuance of foreign currency (FC) denominated debt and the use of FX derivatives.[6] FC Debt is widely regarded by financial executives as an effective method for mitigating FX risk. For example, Graham and Harvey (2001) report that 85.8% of surveyed Chief Financial Officers respond that the ability to provide a 'natural hedge' is important or very important in the decision to use FC Debt. Additional evidence that FC debt is used as a financial risk management tool is provided by Allayannis and Ofek (2001). Similarly, Bartram, Brown, and Fehle (2003), among other studies, show that FX derivative use is widespread among global firms with foreign sales.

Financial risk management tools have some distinct advantages over the other types of FX risk mitigations techniques. First, financial decisions are very much under the control of financial managers and less subject to constraints in the product market (e.g., geographic availability of skilled labor and raw materials or the competitive landscape of the local market). Second, financial hedges are likely to have low implementation costs and positions are usually reversible or easily adjusted. Third, financial hedges are unlikely to introduce additional new risks that might be associated with some operational hedges (e.g., the risk of foreign assets be expropriated or nationalized). On the other hand, financial risk management tools, especially FX derivatives, are likely to have relatively short horizons.

The next columns report the outstanding value of foreign currency debt and foreign exchange rate derivatives as a percent of firm value. All of the automakers use foreign exchange rate derivatives to some extent, though some (like Mitsubishi and Renault) are clearly much larger users than others (like Ford and Toyota). On average, automakers hold derivatives with notional values equal to 0.41% of firm value. Automakers' use of foreign currency debt, while relatively low, also reduces their exchange rate exposure.[7]

The next column of Table 2 adjusts the *Model Exposure* numbers by subtracting the level of foreign exchange rate derivatives and foreign currency debt to obtain an estimate of *Residual*

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[6] Because local currency debt can be effectively converted to foreign currency debt with FX derivatives, and vice-versa, there is not necessarily a clear distinction between these two strategies (see Allayannis, Brown, and Klapper, 2003). For example, synthetic FC debt can be created using a currency swap. Synthetic FC debt might be preferable to natural FC Debt for tax, accounting, and regulatory reasons.

[7] The use of FC debt is sometimes difficult to determine for automakers because of poor disclosure by some firms, so we make conservative assessments in obtaining these values.

Exposure. These values for *Residual Exposure* are our estimates of theoretical foreign exchange rate exposure taking into account the level of foreign sales, industry competition (via gross profit margin), operational hedging (via foreign costs), and financial hedging (via foreign exchange rate derivatives and foreign currency debt). On average, these values are considerably lower than the estimates for the *Model Exposure*. The *Residual Exposures* range from negative values to positive values, much like the values for *Actual Exposure* derived from a regression model (and tabled in the following column).[8] Figure 1 shows that there is a clear positive relationship between these estimates even though the theoretical estimates of *Residual Exposure* are significantly more volatile than the statistical estimates of *Actual Exposure*.[9] These results are consistent with the finding in Bartram (2005) that the insignificance of foreign exchange rate exposures of aggregate performance measures, such as total cash flow or stock price, can be explained by hedging at the firm level.

In summary, this section has used global automakers to illustrate how various factors such as the competitiveness of a firm, operational hedging, and financial hedging can have dramatic effects on foreign exchange rate exposure. Specifically, our "quick" estimates of theoretical foreign exchange rate exposure that account for risk management are quite similar to estimates of actual foreign exchange rate exposure obtained from stock returns.

4   An Expanded Empirical Framework

Despite the encouraging results presented in the previous section, the calculated *Residual Exposure* still (i) overestimates exposures on average and (ii) predicts a wider range of exposures than actually observed among automakers. One potential explanation for these results is our use of a relatively simple model as an illustrative example. Specifically, the Bodnar and Marston (2002)

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[8] Following the existing literature on exchange rate exposure (see Bartram and Bodnar (2004) for a summary of this research), we regress separately for each firm its excess stock return on the excess return of the local market index (Market) and the percentage change in a trade-weighted exchange-rate index (FX). The regressions are estimated using weekly data for the period from 2000 to 2004. Overall, the results in Table 2 show that firms have either no statistically significant foreign exchange exposure or positive exchange rate exposure. The exchange rates are defined in terms of local currency per unit of the foreign currency. Thus, a positive coefficient estimate is consistent with extant research results on the exposure of exporting or import-competing firms (See Bartram and Bodnar, 2004; Bartram, 2004). The coefficient on the trade-weighted exchange-rate index is positive and significant for only five of the 16 firms.

[9] The estimated slope obtained from a regression of Residual Exposure on Actual Exposure is 0.66 with a *p*-value of 0.029.

model is for a monopolist with exogenously specified cash flows. In our analysis of automakers, we analyze the effect of product market competition on foreign exchange rate exposure by assuming that the gross profit margin is a sufficient statistic for describing a firm's level of overall competitiveness. In this section, we present a more realistic model of the foreign exchange rate exposure of a global firm in a globally competitive market based on the results of Bodnar, Dumas, and Marston (2002).

BDM examine a firm selling in a foreign market. The firm in their model can produce (i.e., have costs) in both the local and the foreign country, and it competes with another firm that produces (i.e., has costs) only in the foreign market. The authors examine pass-through of exchange rate changes for firms based on the type of competition (price or quantity), the relative cost structures, and product substitutability. While the model very precisely examines the effect of competition and the currency denomination of costs on exchange rate exposure, its empirical relevance is limited by simplifying assumptions. To facilitate our empirical analysis, we extend the BDM model in two straightforward ways. First, we consider a market where *both* firms have costs in local and foreign currency. Second, we consider firms that sell *both* locally and in foreign markets. These are relatively simple extensions of the BDM model that make it applicable to a much broader sample of global firms.[10] In addition, these extensions produce a substantially broader set of predicted exchange rate exposures. For example, our model considers the case of a firm that produces in a foreign market, sells in the local market, and faces import competition. This firm can have a negative exposure to exchange rate changes – something not allowed for in the original BDM model. We refer the reader to BDM for a full discussion of the base model and begin our analysis with a derivation of a global firm's exchange rate exposure.[11]

4.1 Exchange Rate Exposure of a Global Firm that Competes Globally

Total exchange rate exposure for a global firm (δ) is defined as the sales-weighted average of exchange rate exposures from foreign operations (δ_f) and domestic operations (δ_d) so that

$$\delta = \phi\delta_f + \left(1-\phi\right)\delta_d \tag{2}$$

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[10] Because our goals are ultimately empirical (and to keep the exposition parsimonious), we examine only quantity competition. However, expanding the analysis so as to also examine price competition would be straightforward.

[11] The full model corresponding to BDM (2002) is available from the authors upon request.

where ϕ is the percentage of foreign sales.[12] To keep the analysis tractable, we proceed by assuming that two symmetric firms compete in a single foreign market and derive the exposure of each firm. We then treat the exposure of the "foreign firm" as equivalent to δ_f and the exposure of the "local firm" as δ_d. Of course, the essential difference in exposure between the local firm and the foreign firm is the reported currency denomination of profits, since each is potentially "global" with regards to its production and sales. To facilitate the exposition, we conform to the notation of BDM and define the profits (π_i^*) in home currency as

$$\pi_i^* = SP_i X_i - \left(C_i^* + SC_i\right)X_i \tag{3}$$

where S is the exchange rate (in domestic currency relative to foreign currency), P_i is the equilibrium price of firm i's product, X_i is the equilibrium quantity of product sold by firm i, and C_i^* (C_i) are the marginal costs in home (foreign) currency ($i = 1, 2$). However, we note that unlike BDM, we allow both firms to have costs in foreign currency so that the relative cost ratio in home currency is

$$R = \frac{C_2^* + SC_2}{C_1^* + SC_1}. \tag{4}$$

In Appendix A, we show that the equilibrium exposure measures δ_f and δ_d are equivalent to

$$\delta_f = \frac{d\ln\pi_1^*}{d\ln S} = 1 + \left(1 - \lambda_f\right)\rho_f\mu_f + \frac{\left(1 - \lambda_f\right)\lambda_f\rho_f^2\mu_f}{1 - \rho_f\left(1 - \lambda_f\right)} \tag{5}$$

$$\delta_d = \frac{d\ln\pi_2}{d\ln S} = \left(1 - \lambda_d\right)\rho_d\mu_d + \frac{\left(1 - \lambda_d\right)\lambda_d\rho_d^2\mu_d}{1 - \rho_d\left(1 - \lambda_d\right)} \tag{6}$$

where for $j \in (d, f)$,

$$\mu_j = \left(1 - \gamma_{j1}\right)\gamma_{j2} - \gamma_{j1}\left(1 - \gamma_{j2}\right),$$

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[12] This is equivalent to assuming that a global firm is made up of completely separate domestic and foreign divisions that can be examined independently.

λ_j is the equilibrium market share in market j,

γ_{ji} is the fraction of marginal costs in foreign currency in market j for firm i, and

$\rho_j \in (0,1)$ measures substitutability between the firms' products in market j.

Thus, the overall exchange rate exposure for a global firm can be expressed as

$$\delta = \phi \left[1 + (1-\lambda_f)\rho_f \mu_f + \frac{(1-\lambda_f)\lambda_f \rho_f^2 \mu_f}{1-\rho_f(1-\lambda_f)} \right] + (1-\phi)\left[(1-\lambda_d)\rho_d \mu_d + \frac{(1-\lambda_d)\lambda_d \rho_d^2 \mu_d}{1-\rho_d(1-\lambda_d)} \right]. \qquad (7)$$

While our exposure expression is significantly more complicated than the original BDM model, the underlying factors determining exposure are the same. In fact, the exposure equation from BDM is a special case of the above equation where $\phi=1$ and $\gamma_{f2}=1$. The terms μ_f and μ_d capture the combined relative effects of marginal costs in foreign currency for firm 1 (γ_{f1}) and firm 2 $(1-\gamma_{f2})$.

Since $0 \leq \gamma_{j1}$ and $\gamma_{j2} \leq 1$, it follows that $-1 \leq \mu_j \leq 1$. Therefore, in our expanded model the lowest obtainable exposure is -2.0 as opposed to +1.0 in the BDM model. This quite negative exposure would be predicted for a firm that produces only abroad, sells only locally, has competitors that do the same, has a high degree of product substitutability, and low market share. The negative exposure in this case is intuitive since this type of firm would benefit from an appreciating local currency. Overall, our model allows for a wide range of negative exposures and positive exposures (up to +3.0). These positive exposures are expected for most firms that have exporting activities and/or face import competition.

4.2 Exchange Rate Pass-Through of a Global Firm that Competes Globally

In a similar way, we derive the pass-through of exchange rate risk for a global firm as the foreign sales-weighted average of pass-through from foreign operations (η_f) and domestic operations (η_d)

$$\eta = \phi \eta_f + (1-\phi)\eta_d. \qquad (8)$$

Pass-through is defined as the partial derivative of the equilibrium price of firm i's product, P_i, to the exchange rate. Appendix B shows that the equilibrium pass-through measures η_f and η_d are obtained as

$$\eta_f = \frac{d \ln P_1}{d \ln S} = \left(\gamma_{f1} - 1\right) + \lambda_f \rho_f \left[\left(1 - \gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1 - \gamma_{f2}\right)\right] \tag{9}$$

$$\eta_d = \frac{d \ln P_2}{d \ln S} = \left(1 - \gamma_{d2}\right) + \lambda_d \rho_d \left[\left(1 - \gamma_{d1}\right)\gamma_{d2} - \gamma_{d1}\left(1 - \gamma_{d2}\right)\right] \tag{10}$$

Thus, the overall pass-through of exchange rate risk by the global firm can be expressed as

$$\eta = \phi\left[\left(\gamma_{f1} - 1\right) + \lambda_f \rho_f \mu_f\right] + \left(1 - \phi\right)\left[\left(1 - \gamma_{d2}\right) + \lambda_d \rho_d \mu_d\right], \tag{11}$$

where all parameters are defined as above for the foreign exchange rate exposure of the firm (δ). This pass-through expression also is more involved compared to the BDM model, but again the original model is subsumed and a special case of parameter values $\phi=1$ and $\gamma_{f2}=1$. (BDM multiply their pass-through estimates by minus one so that the elasticity is positive.) In the BDM model, pass-through is between zero and one. In contrast, in the expanded BDM model, pass-through, η, ranges from negative one to positive one ($-1 < \eta < +1$). Overall, our expanded model allows for a wider range of pass-through values. In the extreme case of η nearly equal to minus one, an appreciation of the exporter's currency ($d\ln S < 0$) leads to a nearly 100 percent pass-through to the price of the good. In this case, the firm increases its output price by the extent of the exchange rate move in order to off-set the currency conversion loss in local currency profits. Since exchange rate changes may change marginal costs in a firm's home currency if it has foreign-currency based costs and may cause firms to change their markup, pass-through is likely to be less than proportionate (i.e. > -1). The expanded range of pass-through between 0 and +1 in the enhanced BDM model allows for an appreciation in the exporter's currency ($d\ln S > 0$) to result in a decrease in price.

4.3 Enhanced Model Analysis and Comparative Statics

Figure 2 plots the feasible space of exchange rate exposures as a function of product substitutability (ρ). The shaded area above $\delta=+1.0$ represents the exchange rate exposures allowed by the BDM model for various values of ρ. The shaded area below +1.0 represents the additional range of exchange rate exposures for global firms that compete with other global firms in the enhanced version of the model. Given that prior empirical work documents that most firms have low exchange rate exposures, this additional range has substantial empirical relevance. The fact that the

range of theoretical exposures expands as product substitutability increases reinforces the notion that product market competition can have a significant effect on firms' exchange rate exposures.

A key aspect of the enhanced model is the ability to consider the exposure of firms with both foreign and domestic sales. Figure 3 plots maximum and minimum exposure as a function of foreign sales percentage. Again we note that the range of possible exposures is significantly greater than in the BDM model – even for the case when foreign sales equal 100%. This result derives from the ability of *both* firms in the enhanced model to have costs in *both* domestic and foreign currency. This difference is reflected in μ_f. More specifically, the second term of δ_f captures the impact of the exchange rate on the share of total foreign expenditures accruing to the exporting firm. Unlike BDM, this term can be zero and in some cases negative. The sign of this second term will depend on the magnitude of μ_f. Recall that

$$\mu_f = \left(1 - \gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1 - \gamma_{f2}\right),$$

where γ_{f1} and $(1-\gamma_{f2})$ represent the fraction of marginal costs due to foreign currency based inputs for firm 1 and firm 2, respectively. The smaller the fraction of foreign cost of firm 1 and the larger the fraction of foreign cost for firm 2, the larger is the value of μ_f. For example, if $\gamma_{f1} = (1-\gamma_{f2}) = 0.7$, then μ_f equals -0.4. In contrast, if $\gamma_{f1} = (1-\gamma_{f2}) = 0.1$, then μ_f equals 0.8. Finally, μ_f equals zero when $\gamma_{f1} = \gamma_{f2}$.

The third term of δ_f captures the impact of the foreign exchange rate on the domestic currency profit margin of the exporter. Like the second term, the sign and magnitude of the third term will depend on μ_f. If μ_f is negative (positive), then the third term is negative (positive). As noted already, μ_f can be zero, and thus, the third term will also be zero if $\gamma_{f1} = \gamma_{f2}$. Since the model is symmetric, similar arguments apply to μ_d, the relative costs in foreign currency for firm 1's domestic market. Altogether these results show that for a global firm both the sign and the magnitude of the exchange rate elasticity depends on the sign and magnitude of the relative costs in foreign currency, μ_j.

Figure 3 also plots the actual exchange rate exposures as a function of foreign sales percentage for the global automakers discussed in Section 3. It is evident from the scatter-plot that the actual exposures of all global automakers easily plot inside the allowed region for the enhanced model. However, it is also the case that most of the actual exposures are below the

minimum values allowed for by the BDM model (even after making an adjustment for the fact that the BDM model assumes all sales are in the foreign country).

To obtain an intuitive feel for the relative importance of the various model inputs, we examine exposure values for a range of parameter values. Figure 4 shows plots of exposure (on the vertical axis) as a function of the model input parameters where we hold all parameters (besides the one of interest) fixed at values close to the averages of sample firms we examine in the next section.[13] Panel A shows exposure for values of the percentage of foreign sales (ϕ_f) ranging from 0% to 100%. As expected, exposure values increase rapidly with the level of foreign sales. The exposure for a firm with no foreign sales is close to zero (0.03) whereas a pure exporter will have an exposure of around 1.2. Panel B shows the sizeable effect of foreign costs (γ_{f1}) on exposure. As foreign costs increase, the natural hedge from foreign operations reduces exposure significantly from about 0.8 for a firm with no foreign costs to about 0.3 for a firm with only foreign costs. Panels C and D show the effects on exposure of competitors cost structures in both the domestic and foreign markets. Panel C reveals that as competitors costs in the domestic market (γ_{d1}) are denominated more in local currency, exposure declines though the effect is relatively small (since for the base case most exposure comes from foreign operations). Panel D reveals the greater sensitivity to the currency of competitors' costs in the foreign market (γ_{f2}). Specifically, as competitors' costs switch from all domestic to all foreign currency, the firm's exposure increases from 0.41 to 0.76.

Panel E of Figure 4 shows that as product substitutability increases so does exposure. The clear non-linear relationship highlights the importance of product market competition in determining overall exposure, and in particular, that firms in very competitive industries face quite high relative exposures. Finally, Panel F plots the relationship between exposure and the degree of import competition. The graph reveals the relatively low sensitivity to the percentage of competition that comes from imports in the foreign market (λ_f). For the full range of possible values, exposure only varies by about 0.1. A similar, but even weaker, relationship holds for the percentage of competition that comes from imports in the domestic market (λ_d) so we do not plot it here.

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[13] Specifically, for the base case we set ϕ_f=0.5, γ_{f1}=0.3, γ_{d1}=0.6, γ_{f2}=0.6, ρ_f=ρ_d=0.7, λ_f=0.3, and λ_d=0.7.

An important part of overall exchange rate exposure for global firms is determined by how much of exchange rate exposure can be passed through to customers via price changes. In the enhanced BDM model, the relationship between product market characteristics and pass-through can be quite complex. For example, pass-through can decrease or increase with increases in product substitutability. To see this, recall that the impact of product substitutability depends on the values of μ_f and of μ_d. For example, consider

$$\mu_f = \left(1 - \gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1 - \gamma_{f2}\right),$$

where γ_{f1} and $(1-\gamma_{f2})$ represent the fraction of marginal costs due to foreign currency based inputs for firm 1 and firm 2, respectively. The smaller the fraction of foreign cost of firm 1 and the larger the fraction of foreign cost for firm 2, the larger is the value of μ_f. Since the model is symmetric, similar arguments apply to μ_d, the relative costs in foreign currency for firm 1's domestic market. Consequently, for a global firm, both the sign and the magnitude of the pass-through depend on the sign and magnitude of the relative costs in foreign currency, μ_j.

Market share also impacts the size of the pass-through. Considering η_f, the sign and magnitude of $d\eta_f / d\lambda_f$ depend on the sign and magnitude of the relative costs in foreign currency, μ_f, and the magnitude of product substitutability such that

$$\frac{d\eta_f}{d\lambda_f} = \rho_f \mu_f \, .$$

Thus, higher market share increases pass-through when μ_f is negative (i.e. pass-through is more negative and thus larger). In this case, the larger is the fraction of foreign cost of firm 1 and the smaller is the fraction of foreign cost for firm 2. If, on the other hand, μ_f is positive, higher market share decreases pass-through.

Altogether, the results in this section show that for a global firm both the sign and the magnitude of the exchange rate elasticity (exposure) and pass-through depend on the sign and magnitude the relative costs in foreign currency, μ_j. With the enhanced model in hand, we now turn to a more rigorous analysis of exchange rate exposure using a large sample of global corporations.

5   Estimation of the Enhanced Model

5.1 Data

Our sample is comprised of 1,161 firms from 16 countries.[14] The sample includes all manufacturing firms with accounting data for either the year 2000 or 2001 on the Thomson Analytics database, that have an annual report in English for the same year on the Global Reports database, and that have at least 25 non-missing weekly stock returns on Datastream during the year of the annual report.[15] Accounting data including information on foreign sales and foreign assets originate from the Thomson Analytics database. To reduce the effect of data errors we exclude observations that fall in the top and bottom one percentile or whose value exceeds five standard deviations from the median.[16] We collect data on foreign currency debt and derivatives use via an automated search of each firm's fiscal year 2000 or 2001 annual report (see Bartram, Brown and Fehle, 2004, for details). We create dichotomous variables for the use of foreign currency debt and foreign exchange rate derivatives usage.

Firms are classified into industries on the basis of 4-digit SIC codes. For the years 1999, 2000 and 2001, data on industry competitiveness, production, exports and imports are collected from various sources as follows: We generate measures of import competition using the United Nations Industrial Development Organization (UNIDO) Industrial Statistics Database and the Structural Statistics for Industry and Services (SSIS) database of the OECD. Trade data are used to calculate an import penetration ratio by taking imports as a percent of imports plus domestic production.[17] We also obtain GDP data and calculate for each country and industry a measure of foreign import penetration as weighted averages of the import penetration variables of all foreign

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[14] The countries represented are Australia, Austria, Canada, Denmark, France, Germany, Indonesia, Ireland, Japan, Mexico, Netherlands, Norway, Singapore, Switzerland, United Kingdom, and the United States. In some parts of the analysis, we are able to expand the set of firms to a total of 2,234 non-financial firms from 19 additional countries (Argentina, Belgium, Brazil, Czech Republic, Finland, Greece, Hungary, India, Italy, Korea, New Zealand, Poland, South Africa, Spain, Sweden, Taiwan, Thailand, Turkey, and Venezuela).

[15] Global reports (www.global-reports.com) is an online information provider of public company documents in portable document format (PDF).

[16] In order to avoid the results being influenced by the effect of the economic cycle, we use three-year averages of variables where this impact seems most relevant (e.g. gross profit margin).

[17] Similar results are obtained by using a permutation of imports as a percent of production plus imports minus exports. However, this measure can have extreme values in countries with large exports in certain industries, so we do not use it in the primary analysis.

countries. Because the UNIDO data are only available by International Standard Industry Classification (ISIC, Rev. 3), we calculate for each 4-digit SIC code the mean of the statistics for the corresponding ISIC. In addition, we calculate Herfindahl indices using all WorldScope firms with sales data to measure competition at the industry and country level. For all of these measures, we use the value in the year prior to the firm observation.[18]

All capital market data (i.e. the firms' stock returns, stock index returns, interest rates, exchange rates) are from Datastream. We create weekly return series to reduce microstructure effects such as bid-ask bounce. For each firm, we calculate stock returns in local currency, local currency returns of the corresponding Datastream national stock market index, and the percentage change in a trade-weighted foreign exchange rate index (in local currency relative to the basket of foreign currencies). All time series are limited to the year of the firm's annual report. We winzorize the return observations in the top and bottom 0.1% in order to mitigate some obvious data errors. Consistent with prior research, we use these data to estimate augmented market model (time series) regressions that include returns on exchange rate indices. Specifically, we estimate for each firm

$$ R_{jt} = \alpha_j + \beta_{jM} R_{Mt} + \beta_{jFX} R_{FXt} + \varepsilon_{jt} , \tag{12} $$

where R_{jt} is the stock return in excess of the risk-free rate, R_{Mt} is the return of the market index in excess of the risk-free rate, and R_{FXt} is the percentage change of the exchange rate index. The resulting coefficients on the exchange rate variable (β_{FX}) represent our estimates for actual (firm-specific) exchange rate exposure.

Table 3 reports summary statistics for the full sample. The first row reports actual estimated foreign exchange rate exposures obtained from equation (12). Exposures average 0.071 with a standard deviation of 1.945. The inner quartile runs from -0.806 to 1.058. Because the model we examine does not account for financial leverage, we multiply the estimated exposure by the market value of equity divided by firm value to obtain estimates of unlevered foreign exchange rate exposure. These values, which are reported in the second row of Table 3, are very similar to the unadjusted exposure values though, of course, somewhat smaller in magnitude.

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[18] In a few cases, industry data are not available for the prior year, in which case we use the value from 2 years prior.

Table 3 also reports that foreign sales average 34.5% of total sales, and foreign assets average 19.1% of total assets. Overall, 87.1% of the firms in our sample have foreign currency debt and 65.9% use FX derivatives. Import penetration averages 24.1% for the country-industry combinations in which our sample of firms operate.

5.2 Model Parameters and Estimated Exposures

In this section, we discuss our empirical proxies for the model parameters and estimate the model for the sample of global firms discussed above. In the next section, we examine the association between residuals of the enhanced BDM model and firms' usage of foreign currency debt and foreign exchange derivatives. This analysis allows us to discuss the impact of financial hedging decisions on firms' exposure having examined the impact of pass-through and operational hedging via the enhanced BDM model.

In order to make the enhanced BDM model operational, it is necessary to find acceptable proxies for each of the input parameters. Table 4 lists the required parameter inputs for the model, their description, and the empirical proxy that we utilize. As our proxy for ϕ, we simply use foreign sales as a percent of total sales. Measures of γ (fractions of marginal costs in foreign currency) are not as straightforward. Intuitively, the various γ parameters describe the currency of costs for a firm and its competitors in both domestic and foreign markets. As a proxy for foreign productive capacity, we use the ratio of foreign assets to total assets. Thus our proxy for γ_{f1}, the firm's fraction of marginal costs in the foreign market due to foreign currency inputs, is the ratio of foreign assets to total assets. Likewise, our proxy for γ_{d2}, the firm's fraction of marginal costs in the domestic market, is one minus the ratio of foreign assets to total assets.

We calculate the competitors' costs by market and currency by taking a weighted average of γ_{f1} and γ_{d2} for all other firms in the same industry. Specifically, we calculate γ_{f2}, the competitors' fraction of marginal costs in the foreign market due to foreign currency inputs, as the weighted average of γ_{f1} for local firms and γ_{d2} for all foreign firms in the same industry. First, we calculate the foreign sales-weighted average of γ_{f1} for all local firms in the same industry and country. Next, we calculate the domestic sales-weighted average of γ_{d2} for all firms in the same industry in all other countries. These measures are averaged using our measure of foreign import penetration (the GDP-weighted average of the import penetration ratio of all other countries) and one minus this measure as weights, respectively. In the same vein, the competitors' fraction of

marginal costs in the domestic currency is calculated as the weighted average of γ_{d2} for local firms in the same industry and γ_{f1} for foreign firms. Here, we use the import penetration ratio and one minus the import penetration ratio as weights.

The parameters λ_f and λ_d, respectively, represent the market shares of the firm in the foreign and domestic market. Intuitively, these parameters measure the level of competition from foreign firms in the domestic and foreign markets. Consequently, we utilize import penetration ratios for the firm's industry to calculate our proxies for these values. Specifically, we set λ_f equal to the rest-of-world GDP-weighted average of import penetration ratios, and λ_d equal to one minus the domestic market import penetration ratio. The final parameters necessary for estimating the model are ρ_f and ρ_d, the degrees of product substitutability in the foreign and domestic markets. These parameters are specified exogenously. In our empirical tests, we set $\rho_f = \rho_d = 0.7$. However, we also frequently report results for values of ρ that are appreciably lower ($\rho_f = \rho_d = 0.5$) and higher ($\rho_f = \rho_d = 0.9$) so we can examine the effects of product substitutability as well as discuss the robustness of our findings.

Table 5 reports selected descriptive statistics on the model parameters for our sample of firms. Average production cost parameters vary substantially for firms and their competitors in both the domestic and foreign markets. The firm's percentage of foreign currency costs in the foreign market, γ_{f1}, average 19.1%, but the inner quartile ranges from 2.2% to 27.7%. The low average value is intuitive, since most markets are dominated by domestic firms. Similarly, the average firm's fraction of marginal cost in domestic currency, γ_{d2}, is quite high with an average of 80.9%. The competitors' costs in the foreign market, γ_{d1}, average 63.1%, which reflects that this is a combination of the fraction of foreign costs for exporters and the fraction of domestic cost for other import-competing firms. Similar values are obtained for the percentage of domestic costs of competitors, γ_{f2}, since this is also a weighted average of the fraction of domestic costs of other exporters and the fraction of foreign costs of import-competing firms. Overall, the values for currency denomination of production costs seem very plausible.

Table 5 also reports the values for the relative costs by currency for the foreign and domestic markets, μ_f and μ_d, respectively. Recall, that the parameter equivalent to μ_f for the original BDM model is restricted to positive values because the competing firm's costs were only al-

lowed to be in foreign currency. In contrast, in the enhanced model, we find that our proxy for μ_f is positive on average (0.470), but it is negative in some cases. This suggests that the second and third terms of the δ_f will sometimes reduce exposure rather than always increase exposure (as is suggested by the original BDM model). As expected, our proxy for μ_d is positive and fairly small in magnitude (0.177), which indicates that on average domestic operations also generate some exchange rate exposure. Estimated values for λ_f and λ_d, which measure the level of import competition in the foreign and domestic markets, average 0.294 and 0.759, respectively.

Using these firm-specific inputs (and exogenously specified values of ρ_f and ρ_d) to evaluate equation (7) for each firm results in our overall measures of exchange rate exposure (and pass-through) for global firms. Summary statistics are provided in the last six rows of Table 5. The results indicate that on average firms tend to have positive exposures to exchange rates for reasonable values of ρ_f and ρ_d (i.e., 0.5, 0.7, and 0.9). As suggested by Figure 4, a greater value of ρ results in a larger magnitude of exposure. We note that both the predictions and estimates of the model are consistent with the results of Campa and Goldberg (1999), Allayannis and Ihrig (2001), and BDM, who document that exposures tend to be higher for more competitive industries. Examining the case when $\rho_f=\rho_d=0.7$ indicates that the average firm has a model exposure of 0.477, yet some firms have negative model exposures. For this case, the largest model exposure is 1.577.

While model exposures are mostly positive, they are typically smaller than those suggested by other theoretical models (e.g., the original BDM model). Nonetheless, the model exposures are on average substantially larger than the actual exposures estimated from equation (12). Recall from Table 3 that the actual exposures averaged less than 0.10 for the raw and unlevered estimates. Statistical tests (reported and discussed later) reject the model for producing exposure estimates that are too high. However, it is important to note that we have not adjusted the model exposures for any financial risk management undertaken by the firms.

The last three rows of Table 5 present the summary statistics for model pass-through estimates. Similar to the results for model exchange rate exposures, the enhanced BDM model allows for a wider range of values than the original BDM model. Firms have, on average, negative pass-through estimates. Consistent with the predictions of the model, the pass-through estimates

decrease with product substitutability. While the mean and median values are negative, pass-through estimates are positive in many cases (i.e. at the 75th percentile).

5.3 Analysis of Exposures from the Enhanced BDM Model

We further examine the theoretical exposures from the enhanced BDM model by splitting the sample along the calculated level of model exposure. This split might allow us to identify the role of other characteristics such as financial risk management and industry structure in determining foreign exchange rate exposure. Table 6 reports the results from this analysis. First, we note that the spread between the calculated model exposure for high exposure and low exposure firms is about 0.5, which is a sizeable difference. Interestingly, even though the *actual* estimated exposures obtained from stock returns are substantially smaller, the difference between the high and low exposure groups is statistically different. This is true for both the raw and unlevered estimates. One possible explanation for the lower level of estimated exposures from stock returns is that firms with high model exposures are more likely to undertake financial risk management (or undertake it to a greater extent). Our data on foreign currency debt and foreign exchange rate derivatives use support this hypothesis. In particular, the next two rows of Table 6 show that firms with high model exposure are both more likely to have foreign currency debt and to use foreign exchange rate derivatives. Specifically, 97.8% of firms with high model exposure have foreign currency debt as compared to only 76.5% of firms with low model exposure. Similarly, 80.1% of firms with high model exposure use foreign exchange rate derivatives as compared to only 51.9% of firms with low model exposure. Both of these differences are significant at the 0.001 level.

We also relate the model exposures to the level of global competition in each firm's industry. Results for import penetration ratios reported in Table 6 reveal that firms with high model exposures face significantly higher global competition in their home market. In contrast, competition in the foreign market is similar for firms with high and low model exposures. We also have collected sales data for the WorldScope universe of manufacturing firms (which is considerably larger than our sample) and use these to calculate a Herfindahl index as a measure of industry concentration, alternatively by global industry or by industry and country. A common assumption in the literature is that less concentrated industries are more competitive. Interestingly, there is no significant difference in global industry concentration. In fact, when we calculate Herfindahl indices for each country-industry combination, firms with high model exposure

are in industries that are somewhat *more* concentrated than firms with low model exposure. These results indicate that local industry concentration is not (directly) related to our theoretical measure of foreign exchange rate exposure.

Together, these results suggest that financial risk management may play an important role in explaining why the observed level of foreign exchange rate exposure for global firms is considerably less than theoretical predictions. We further examine this hypothesis by estimating regressions at the firm level to see if the use of foreign currency debt and foreign exchange rate derivatives is related to the difference between model exposures and actual exposures. Specifically we estimate regressions of the following form

$$\hat{\beta}_{FX,i} - \hat{\delta}_i = \alpha + \beta_1 FCDebt_i + \varepsilon_i$$
$$\hat{\beta}_{FX,i} - \hat{\delta}_i = \alpha + \beta_2 FXDerivatives_i + \varepsilon_i \qquad (13a - 13c)$$
$$\hat{\beta}_{FX,i} - \hat{\delta}_i = \alpha + \beta_1 FCDebt_i + \beta_2 FXDerivatives_i + \varepsilon_i$$

where $\hat{\delta}$ is the calculated model exposure from equation (7), $\hat{\beta}_{FX}$ is the estimated, unlevered actual exposure from equation (12), *FCDebt* is a dummy variable for foreign currency debt use, and *FXDerivatives* is a dummy variable for FX derivatives usage. If FC debt and FX derivatives are important for reducing actual foreign exchange rate exposure, then the coefficients β_1 and β_2 should be negative.

Panel A of Table 7 shows results of estimating equations (13a − 13c) for various values of ρ_f and ρ_d using the full sample of firms. The results are encouraging. The first set of results confirms that the enhanced model provides exposure estimates that are consistently too high (i.e., the model intercept is statistically negative). The next set of results, obtained by estimating Equation (13a), shows that once controlling for a firm's use of foreign currency debt, the enhanced BDM model cannot be rejected. These estimates imply that firms with foreign currency debt have about half the foreign exchange rate exposure of a firm without foreign currency debt. Estimating Equation (13b) shows that the use of FX derivatives also is related to lower exposure, but the coefficients are not significant at conventional levels. The last part of Panel A shows results from estimating Equation (13c). The coefficients on both foreign currency debt and exchange rate derivatives are negative, but again only the results for foreign currency debt are sta-

tistically significant. The estimated coefficients of around -0.3 for FC Debt are essentially un-changed.

In Panel B of Table 7, we report the results of regressions that control for various combinations of FC debt and FX derivatives use. Specifically, we create new dummy variables for firms that i) use only FC debt only, ii) use FX derivatives only, and iii) use both FC debt and FX derivatives. The results complement those in Panel A. As expected, we still observe that for all values of $\rho_f=\rho_d$, the intercepts are small and not statistically different from zero, indicating that the enhanced BDM model cannot be rejected. More interesting is that the most significant hedging effects are for firms that use both FC Debt and FX Derivatives suggesting that FX derivatives may play a 'fine-tuning' role in exchange rate risk management.

Overall, the results in Table 7 support our hypothesis that corporations manage exchange rate risk via three complementary channels. First, firms pass part of exchange rate changes through to customers. Second, most global manufactures utilize some operational hedges. Both of these effects are captured by the enhanced BDM model estimates of exposure. Third, the regression results examining model error suggest corporations employ financial risk management strategies such as issuing foreign currency denominated debt and entering into foreign exchange rate derivatives transactions.

5.4 Relative Importance of Mitigating Channels and Discussion

In order to assess the importance of these different forms of hedging, we evaluate Equation (8) for different values of the parameters. Results are presented in Table 8. First, we set $\gamma_{f1} = 0$, $\gamma_{d2} = 1$, $\lambda_f = \lambda_d = 0$, $\rho_f=\rho_d = (0.5, 0.7, 0.9)$, and other values at their sample means. This allows us to assess the exchange rate exposure of an atomistic firm without operational or financial hedges. In other words, we calculate exposure for an otherwise typical firm with no market power (and thus limited ability to pass-through exchange rate changes), no foreign assets, and no foreign debt or FX derivatives. The values for exchange rate exposures range from 0.580 to 0.768 as ρ_f $=\rho_d$ varies from 0.5 to 0.7. These exposure values are relatively large and, as expected, increase with the level of product substitutability.

The second row of Table 8 provides estimates of the reduction in exposure due to the pass-through channel by setting $\lambda_f = 0.294$ and $\lambda_d = 0.759$ (the sample averages). The results indicate that pass-through reduces exposure for our typical firm by 16.3% when product substi-

tutability is relatively low ($\rho_f = \rho_d = 0.5$) and only 9.7% when product substitutability is relatively high ($\rho_f = \rho_d = 0.9$). Intuitively, greater product market competition from similar goods reduces the potential to pass through exchange rate movements to customers.

To assess the marginal effect of operational hedging for a typical firm, the third row of Table 8 shows exposure values for a firm with the average level of foreign assets, γ_{f1}=0.191 and γ_{d2}=0.809. The results suggest that matching the currency of costs and revenues results in a reduction of exposure between 8.6% and 16.0%. Interestingly, the effect of operational hedges increases with product substitutability so that the combined reduction in exposure from both channels is relatively constant (around 25%) for the typical firm.

The results in Table 7 suggest that financial hedging and in particular the use of foreign currency debt has a significant effect on exchange rate exposure. To estimate the relative importance of financial hedging, we subtract the sum of the estimated coefficients on FC Debt and FX derivatives (Panel A of Table 7) from the previous exposure estimates. The fourth row of Table 8 shows that financial hedging produces a relatively large reduction in exposure equivalent to 45% to 50% of the base case exposure. Altogether, these estimates suggest that a typical firm employing all three channels of risk mitigation reduces its overall exchange rate exposure by about three quarters. We also note that the reduction in exposure is fairly independent of the level of product market competition (i.e., product substitutability).

That each of the channels plays a noteworthy role in reducing exposure is both informative and intuitive. We further examine each of these channels by generating scatter-plots of exposure as a function of firm characteristics. We group firms by industry and plot points for the 27 industries for which we have at least 10 firms. Panel A of Figure 5 shows the strong negative relationship between pass-through and exposure (R^2 of an OLS regression equals 0.75). This relationship highlights the fact that firms with high exposure also tend to have large (negative) pass-through. Pass-through is determined in part by the level of import competition. Panel B shows the expected positive relationship between exposure and foreign import competition, but the relationship is not as strong as one might expect (R^2=0.18) given the strong relationship in Panel A.

Panel C shows a positive relationship between exposure and foreign assets at the industry level. This contrasts with the results for an individual firm (e.g., Panel B of Figure 4) where for-

eign assets reduce exposure, *ceteris paribus*. These results indicate that firms with more foreign assets are likely to have higher exposure (e.g., because they typically have more foreign sales) and that operational hedges provide only a partial hedge for exchange rate movements. Nonetheless, the observed relationship between exposure and foreign assets also is somewhat weak (R^2=0.18). These weak relationships for foreign import penetration and foreign assets are quite surprising because the values for the enhanced BDM model exposure estimates are mechanically related to these variables.

Panel D of Figure 5 reveals a strong positive relationship between the use of FC debt or FX derivatives and BDM model exposure (R^2=0.54). The plot confirms that firms with high FX exposures as a result of their operations are more likely to undertake financial risk management. We stress that these variables are *not* related via the enhanced BDM model.

The analysis to this point has relied heavily on the assumptions of the enhanced BDM model accurately characterizing firms' foreign exchange exposure. However, other firm-specific characteristics not explicitly modeled might be important for determining foreign exchange rate exposure and thus might explain the differences between the model and actual exposures. If other firm-specific factors were consistently important, this would suggest that the theoretical model is not a sufficiently complete model of foreign exchange rate exposure. We examine this issue by regressing the residuals from the model in Table 7 (with $\rho_f=\rho_d=0.7$) on firm size, gross profit margin, tangible assets, line-of-business diversification, leverage, debt maturity, a dividend payout dummy, and holdings of cash (and short-term investments).[19] Results are reported in the first column of Table 9. The findings indicate that other firm characteristics are not generally significant determinants (at the 5% level) of residual foreign exchange rate exposure. Gross profit margin is related to model error at the 10% confidence level. The negative coefficient suggests that actual exposures may be higher than model exposures for firms that have high profit margins.

We also estimate residuals from the simpler Bodnar and Marston (2002) model (estimated in a manner similar to that for automakers) because we have data available for a much larger number of firms. Results from this estimation are also in Table 9 and show consistent rela-

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[19] These characteristics are not available for all firms which reduces the sample size to 978 firms.

tionships between residual exposures and firm-specific factors for firm size and tangible assets, which are positively related to residual exposure, as well as cash and short-term investment, which exhibit a negative relationship. This is consistent with large local currency cash holdings that are not subject to foreign exchange rate fluctuations or with firms using cash holdings as a crude risk management tool (see Opler et al., 1999). In contrast to our support of the enhanced BDM model, these findings along with the large positive intercept suggest that the simpler Bodnar-Marston (2002) model is not a sufficient model for explaining firm-level foreign exchange rate exposure.

6   Conclusions

An important topic in international finance and economics (as well as corporate strategy) is the relationship between a firm's exposure to exchange rates and the extent to which adverse changes in exchange rates are incorporated into the prices charged by firms in foreign markets. In order to mitigate the effects of currency fluctuations, corporate financial managers can use pricing policies, operational hedging (e.g. international allocation of production costs), and financial hedging strategies. Moreover, these decisions are not made under the assumption that the firm operates in isolation, but rather after detailed analysis of the industry's situation and the actions of industry peers. Thus, by reflecting the broader economic context the firm is operating in and the nature of competition it is facing, firm-level decisions make foreign exchange exposure endogenous. Nevertheless, little academic research has investigated the interrelationships between these determinants of corporate strategy (i.e., the associations between exchange rate exposure, product market competition, and corporate risk management). This paper takes a step toward filling this gap by examining these relationships for a global sample of non-financial companies.

Our results suggest that *each* of the three channels for mitigating exchange rate exposure is important for our sample of large global manufacturing firms. In particular, exchange rate pass-through and operational hedging are each responsible for about a 15% reduction in exposure, and financial risk management accounts for about another 46% decrease in exposure relative to a hypothetical firm that cannot mitigate exposure at all. Thus, firms reduce their gross exchange rate exposure by about three quarters via the three channels together.

Our analysis suggests that the weak foreign exchange rate exposure, which has been considered a puzzle, is actually to be expected once accounting for all the relevant factors. In particular, firms implicitly appear quite aware of their exposures and adjust their operations and financing activities to account for this. These findings may have important policy implications. For example, given the apparent success of global corporations in insulating their stock prices from exchange rate movements, one might conclude that much of the ire expressed by local companies in the face of a strong currency is simply public relations or rent seeking. In other words, most (presumably well-run) companies seem to be able to manage exchange rate risk quite effectively.

Finally, our results point toward a need for further research examining the precise role of financial risk management in globally competitive corporations. While our enhanced version of the BDM model allows for the empirical examination of a richer set of firms, we do not attempt to explicitly model the interaction between financial hedging and product market competition for our global firm.[20] Similarly, we treat our global firm as having independently operating foreign and domestic divisions when in reality there may exist important interactions between local and foreign markets not captured by our extension of the BDM model.

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[20] See Adam, Dasgupta, and Titman (2005) and Mello and Ruckes (2005) for theoretical models of financial risk management in imperfectly competitive markets.

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Appendix A: Derivation of Foreign Exchange Rate Exposure

A.1 The Exporting Firm

Note, that for the derivation of the exposure of the exporter, "foreign" always refers to the country of firm 2 (the foreign, import-competing firm) and "domestic" always refers to the country of firm 1 (the exporter). The exposure of a firm that produces domestically and abroad, but sells all of its output abroad (exporter) under quantity competition is derived as follows. We begin the derivation by defining profits of the exporter in its domestic currency as

$$\pi_1^* = SP_1X_1 - (C_1^* + SC_1)X_1$$

and the cost ratio in domestic currency as

$$R = \frac{C_2^* + SC_2}{C_1^* + SC_1}.$$

Substituting for equilibrium price (P_1) and quantity (X_1) yields

$$\pi_1^* = S \frac{C_1^* + SC_1}{S\rho_f(1-\lambda_f)} \cdot \lambda_f Y \frac{S\rho_f(1-\lambda_f)}{(C_1^* + SC_1)} - (C_1^* + SC_1) \cdot \lambda_f Y \frac{S\rho_f(1-\lambda_f)}{(C_1^* + SC_1)}$$

$$= S\lambda_f Y - \lambda_f Y S\rho_f(1-\lambda)$$

$$= S\lambda_f Y \left[1 - \rho_f(1-\lambda_f)\right]$$

$$\ln \pi_1^* = \ln S + \ln \lambda_f + \ln Y + \ln \left[1 - \rho_f\left(1-\lambda_f\right)\right]$$

Differentiating with respect to the natural logarithm of the exchange rate (in domestic currency relative to foreign currency) yields

$$\frac{d\ln\pi^*}{d\ln S} = 1 + \frac{d\ln\lambda_f}{d\ln S} + \frac{d}{d\ln S}\left[1 - \rho_f\left(1-\lambda_f\right)\right]$$

$$= 1 + \frac{d\ln\lambda_f}{d\ln S} + \frac{\rho_f\lambda_f}{1-\rho_f(1-\lambda_f)} \cdot \frac{d\ln\lambda_f}{d\ln S}$$

$$= 1 + \left[1 + \frac{\rho_f\lambda_f}{1-\rho_f\left(1-\lambda_f\right)}\right] \cdot \frac{d\ln\lambda_f}{d\ln S}$$

$$= 1 + (1-\lambda_f)\rho_f\left[\left(1-\gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1-\gamma_{f2}\right)\right] + \frac{(1-\lambda_f)\lambda_f\rho_f^2\left[\left(1-\gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1-\gamma_{f2}\right)\right]}{1-\rho_f\left(1-\lambda_f\right)}$$

where $\gamma_{f1} = \dfrac{SC_1}{C_1^* + SC_1}$ and $\gamma_{f2} = \dfrac{SC_2}{C_2^* + SC_2}$.

We define:

- λ_f is the market share of the exporting firm in the foreign market

- γ_{f1} is the exporter's share of cost in foreign currency (due to foreign currency inputs or foreign production)

- γ_{f2} is the import-competing firm's share of cost in foreign currency (note, this is basically the fraction of cost in "local" currency for the import-competing firm and thus equal to one in the BDM model, where the import-competing firm only produces in its local market)

Derivation of $\dfrac{d\ln\lambda_f}{d\ln S}$:

$$\frac{d\ln\lambda_f}{d\ln S}=\frac{1}{\lambda_f}\cdot\frac{d\lambda_f}{d\ln S}=\frac{1}{\lambda_f}\cdot\frac{d}{d\ln S}\left[\frac{\alpha R^{\rho_f}}{1+\alpha R^{\rho_f}}\right]=\frac{1}{\lambda_f}\cdot\frac{d\left[\alpha R^{\rho_f}\right]}{d\ln S}\cdot\frac{d\left[\dfrac{\alpha R^{\rho_f}}{1+\alpha R^{\rho_f}}\right]}{d\left[\alpha R^{\rho_f}\right]}$$

$$=\frac{1}{\lambda_f}\cdot\frac{d\left[\alpha R^{\rho_f}\right]}{d\ln S}\cdot\left[\frac{1}{\left(1+\alpha R^{\rho_f}\right)^2}\right]=\frac{1}{\lambda_f}\cdot\frac{d\left[\alpha R^{\rho_f}\right]}{d\ln S}\cdot\left[\left(1-\frac{\alpha R^{\rho_f}}{1+\alpha R^{\rho_f}}\right)^2\right]$$

$$=\frac{\left(1-\lambda_f\right)^2}{\lambda_f}\cdot\frac{d}{d\ln S}\left[\alpha R^{\rho_f}\right]=\frac{\left(1-\lambda_f\right)^2}{\lambda_f}\cdot\alpha\rho_f R^{\rho_f-1}\cdot\frac{dR}{d\ln S}$$

$$=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f-1}}{\lambda_f}\cdot\frac{d}{d\ln S}\left[\frac{C_2^*+SC_2}{C_1^*+SC_1}\right]=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f-1}}{\lambda_f}\cdot\frac{d}{d\ln S}\left[\frac{C_2^*+C_2 e^{\ln S}}{C_1^*+C_1 e^{\ln S}}\right]$$

$$=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f-1}}{\lambda_f}\cdot\frac{C_2 S\left(C_1^*+SC_1\right)-\left(C_2^*+SC_2\right)SC_1}{\left(C_1^*+SC_1\right)^2}$$

$$=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f-1}}{\lambda_f}\cdot\frac{C_1^*SC_2+SC_1 SC_2-SC_1 C_2^*-SC_1 SC_2}{\left(C_1^*+SC_1\right)^2}$$

$$=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f-1}}{\lambda_f}\cdot\frac{C_1^*SC_2-SC_1 C_2^*}{\left(C_1^*+SC_1\right)^2}=\frac{\left(1-\lambda_f\right)^2\alpha\rho_f R^{\rho_f}}{\lambda_f R}\cdot\frac{C_1^*SC_2-SC_1 C_2^*}{\left(C_1^*+SC_1\right)^2}$$

$$=\frac{\left(1-\lambda_f\right)\rho_f}{R}\cdot\frac{\left(1-\lambda_f\right)\alpha R^{\rho_f}}{\lambda_f}\cdot\frac{C_1^*SC_2-SC_1 C_2^*}{\left(C_1^*+SC_1\right)^2}=\frac{\left(1-\lambda_f\right)\rho_f}{R}\cdot\frac{C_1^*SC_2-SC_1 C_2^*}{\left(C_1^*+SC_1\right)^2}$$

$$=\left(1-\lambda_f\right)\rho_f\cdot\frac{C_1^*SC_2-SC_1 C_2^*}{\left(C_2^*+SC_2\right)\left(C_1^*+SC_1\right)}=\left(1-\lambda_f\right)\rho_f\cdot\frac{C_1^*}{\left(C_1^*+SC_1\right)}\cdot\frac{\left(SC_2-\dfrac{SC_1 C_2^*}{C_1^*}\right)}{\left(C_2^*+SC_2\right)}$$

$$=\left(1-\lambda_f\right)\rho_f\left(1-\gamma_{f1}\right)\cdot\left[\frac{SC_2}{C_2^*+SC_2}-\frac{SC_1 C_2^*}{C_1^*\left(C_2^*+SC_2\right)}\right]$$

$$= \left(1 - \lambda_f\right)\rho_f \left(1 - \gamma_{f1}\right) \cdot \left[\gamma_{f2} - \frac{C_2^*}{\left(C_2^* + SC_2\right)} \cdot \frac{SC_1}{C_1^*}\right]$$

$$= \left(1 - \lambda_f\right)\rho_f \left(1 - \gamma_{f1}\right) \cdot \left[\gamma_{f2} - \left(1 - \gamma_{f2}\right) \cdot \frac{SC_1}{C_1^*}\right]$$

$$= \left(1 - \lambda_f\right)\rho_f \left(1 - \gamma_{f1}\right) \cdot \left[\gamma_{f2} - \left(1 - \gamma_{f2}\right) \cdot \frac{\gamma_{f1}}{1 - \gamma_{f1}}\right]$$

$$= \left(1 - \lambda_f\right)\rho_f \cdot \left[\left(1 - \gamma_{f1}\right)\gamma_{f2} - \gamma_{f1}\left(1 - \gamma_{f2}\right)\right]$$

A.2 The Import-Competing Firm

Formally, we can derive the exposure by first keeping the setting of the BDM model, and later adjusting for the fact that we need to consider an import-competing firm in the country of the exporter in order to be able to combine both into one global firm. We begin the derivation by defining profits of the import-competing firm in its domestic currency as (the exchange rate is defined as in the above derivation for the exporter)

$$\pi_2 = P_2 X_2 - (\frac{C_2^*}{S} + C_2) X_2$$

and the cost ratio as

$$R = \frac{C_2^* + SC_2}{C_1^* + SC_1}.$$

Substituting for equilibrium price (P_2) and quantity (X_2) yields

$$\pi_2 = \frac{C_2 + \frac{C_2^*}{S}}{\rho_f \lambda_f} \cdot \frac{\left(1 - \lambda_f\right) Y \rho_f \lambda_f}{C_2 + \frac{C_2^*}{S}} - \left(C_2 + \frac{C_2^*}{S}\right) \cdot \frac{\left(1 - \lambda_f\right) Y \rho_f \lambda_f}{C_2 + \frac{C_2^*}{S}}$$

$$= \left(1 - \lambda_f\right) Y - \left(1 - \lambda_f\right) Y \rho_f \lambda_f$$

$$= \left(1 - \lambda_f\right) Y \left(1 - \rho_f \lambda_f\right)$$

$$\ln \pi_2 = \ln\left(1 - \lambda_f\right) + \ln Y + \ln\left(1 - \rho_f \lambda_f\right)$$

Differentiating with respect to the natural logarithm of the exchange rate yields

$$\frac{d\ln \pi_2}{d\ln S} = \frac{d\ln\left(1-\lambda_f\right)}{d\ln S} + \frac{d\ln\left(1-\rho_f\lambda_f\right)}{d\ln S}$$

$$= \frac{1}{1-\lambda_f}\cdot\frac{d\left(1-\lambda_f\right)}{d\ln S} + \frac{1}{1-\rho_f\lambda_f}\cdot\frac{d\left(1-\rho_f\lambda_f\right)}{d\ln S}$$

$$= \frac{-1}{1-\lambda_f}\cdot\frac{d\lambda_f}{d\ln S} - \frac{\rho_f}{1-\rho_f\lambda_f}\cdot\frac{d\lambda_f}{d\ln S}$$

$$= \frac{-1}{1-\lambda_f}\cdot\lambda_f\cdot\left(1-\lambda_f\right)\rho_f\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right] - \frac{\rho_f}{1-\rho_f\lambda_f}\cdot\lambda_f\cdot\left(1-\lambda_f\right)\rho_f\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right]$$

$$= -\lambda_f\rho_f\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right] - \frac{\left(1-\lambda_f\right)\lambda_f\rho_f^2\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right]}{1-\rho_f\lambda_f}$$

where $\gamma_{f1} = \dfrac{SC_1}{C_1^* + SC_1}$ and $\gamma_{f2} = \dfrac{SC_2}{C_2^* + SC_2}$.

Note, that the import-competing firm has no transaction exposure from sales at home, thus there is no "1" as for the exporter.

A.3 The Global Firm

Total exchange rate exposure for the global firm (δ) is defined as the foreign sales-weighted average of exchange rate exposures from foreign operations (δ_f) and domestic operations (δ_d) so that

$$\delta = \phi\delta_f + (1-\phi)\delta_d.$$

In particular, we interpret the exposure from foreign operations (δ_f) as the exposure of a firm that produces domestically and abroad, but sells all of its output abroad (exporter). Similarly, we interpret the exposure from domestic operations (δ_d) as the exposure of a firm that produces domestically and abroad, but sells all of its output at home (import-competing firm).

While we can take the exposure of the exporter as derived above, we need to consider an import-competing firm *located in the country of the exporter,* in order to be able to combine both to form the global firm. In other words, we wish to analyze an import-competing firm but from the currency perspective of the exporting firm above, in order to have the same currency perspective. This is like looking at an import-competing firm located in the country of the exporter. It is still the exposure of a firm that produces domestically and abroad, but sells all of its output domestically (import-competing firm) under quantity competition. In order to be able to combine the exposure of the exporter with that of the import-competing firm, we need to make the following adjustments to the above exposure of the import-competing firm:

- The sign of the exposure has to be changed since the currency perspective is opposite.
- $(1-\lambda_f)$ is the market share of the import-competing firm in the foreign market. Therefore, we replace this with λ_d which we define as the market share of the import-competing firm in its local market.
- Replace ρ_f with ρ_d.
- γ_{f1} is the exporter's share of cost in foreign currency (due to foreign currency inputs or foreign production). We replace γ_{f1} with γ_{d1}, which is the fraction of domestic cost of foreign firms exporting into the local market and the fraction of domestic cost of local competing firms.

- γ_{f2} is the import-competing firm's share of cost in foreign currency. We replace γ_{f2} with γ_{d2}, which is the fraction of domestic cost of the import-competing firm.

$$\delta_d = (1-\lambda_d)\rho_d\left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right] + \frac{(1-\lambda_d)\lambda_d\rho_d^2\left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right]}{1-\rho_d(1-\lambda_d)}$$

Thus:

$$\delta = \phi\left[1+(1-\lambda_f)\rho_f\left[(1-\gamma_{f1})\gamma_{f2} - \gamma_{f1}(1-\gamma_{f2})\right] + \frac{(1-\lambda_f)\lambda_f\rho_f^2\left[(1-\gamma_{f1})\gamma_{f2} - \gamma_{f1}(1-\gamma_{f2})\right]}{1-\rho_f(1-\lambda_f)}\right]$$
$$+(1-\phi)\left[(1-\lambda_d)\rho_d\left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right] + \frac{(1-\lambda_d)\lambda_d\rho_d^2\left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right]}{1-\rho_d(1-\lambda_d)}\right]$$

$$\delta = \phi\left[1+(1-\lambda_f)\rho_f\mu_f + \frac{(1-\lambda_f)\lambda_f\rho_f^2\mu_f}{1-\rho_f(1-\lambda_f)}\right] + (1-\phi)\left[(1-\lambda_d)\rho_d\mu_d + \frac{(1-\lambda_d)\lambda_d\rho_d^2\mu_d}{1-\rho_d(1-\lambda_d)}\right]$$

with

$$\mu_f = \left[(1-\gamma_{f1})\gamma_{f2} - \gamma_{f1}(1-\gamma_{f2})\right]$$

and

$$\mu_d = \left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right]$$

Note: In order to obtain the exposure of the exporter in the BDM model, set $\phi=1$ and $(1-\gamma_{f2})=0$, i.e. $\gamma_{f2}=1$, which means that the import-competing firm has only cost in the foreign country, i.e. its local market). Similarly, in order to obtain the exposure of the import-competing firm in the BDM model, set $\phi=0$ and $(1-\gamma_{f2})=0$, i.e. $\gamma_{f2}=1$, which means that the import-competing firm has only cost in the foreign country, i.e. its local market.

Appendix B: Derivation of Foreign Exchange Rate Pass-Through

B.1 The Exporting Firm

Note, that for the derivation of the pass-through of the exporter, "foreign" always refers to the country of firm 2 (the foreign, import-competing firm) and "domestic" always refers to the country of firm 1 (the exporter). The pass-through of a firm that produces domestically and abroad, but sells all of its output abroad (exporter) under quantity competition is derived as follows. Pass-through is the derivative of output price with regards to the exchange rate. Differentiating the output price of the exporter (P_1) with respect to the natural logarithm of the exchange rate (in domestic currency relative to foreign currency) yields

$$\frac{d\ln P_1}{d\ln S} = \frac{d\ln}{d\ln S}\left[\frac{C_1^* + SC_1}{S\rho_f(1-\lambda_f)}\right] = \frac{S\rho_f(1-\lambda_f)}{C_1^* + SC_1} \cdot \frac{d}{d\ln S}\left[\frac{C_1^* + SC_1}{S\rho_f(1-\lambda_f)}\right]$$

$$= \frac{S\rho_f(1-\lambda_f)}{C_1^* + SC_1} \cdot \frac{d}{d\ln S}\left[\frac{C_1^* + e^{\ln S}C_1}{e^{\ln S}\rho_f(1-\lambda_f)}\right]$$

$$= \frac{S\rho_f(1-\lambda_f)}{C_1^* + SC_1} \cdot \left[\frac{SC_1 S\rho_f(1-\lambda_f) - (C_1^* + SC_1)\cdot\frac{d}{d\ln S}\left[S\rho_f(1-\lambda_f)\right]}{S^2\rho_f^2(1-\lambda_f)^2}\right]$$

$$= \frac{S\rho_f(1-\lambda_f)}{C_1^* + SC_1}\cdot\frac{SC_1 S\rho_f(1-\lambda_f)}{S^2\rho_f^2(1-\lambda_f)^2} - \frac{S\rho_f(1-\lambda_f)}{C_1^* + SC_1}\cdot\frac{(C_1^* + SC_1)\cdot\frac{d}{d\ln S}\left[S\rho_f(1-\lambda_f)\right]}{S^2\rho_f^2(1-\lambda_f)^2}$$

$$= \frac{SC_1}{C_1^* + SC_1} - \frac{\frac{d}{d\ln S}\left[S\rho_f(1-\lambda_f)\right]}{S\rho_f(1-\lambda_f)} = \gamma - \frac{1}{S\rho_f(1-\lambda_f)}\cdot\frac{d\left[e^{\ln S}\rho_f(1-\lambda_f)\right]}{d\ln S}$$

$$= \gamma_{f1} - \frac{1}{S\rho_f(1-\lambda_f)}\cdot\left[S\rho_f(1-\lambda_f) + S\rho_f\frac{d(1-\lambda_f)}{d\ln S}\right]$$

$$= \gamma_{f1} - \frac{1}{S\rho_f(1-\lambda_f)}\cdot\left[S\rho_f(1-\lambda_f) - S\rho_f\frac{d\lambda_f}{d\ln S}\right]$$

$$= \gamma_{f1} - \frac{1}{S\rho_f(1-\lambda_f)}\cdot\left[S\rho_f(1-\lambda_f) - S\rho_f\cdot\lambda_f\cdot(1-\lambda_f)\rho_f\cdot\left[(1-\gamma_{f1})\gamma_{f2} - \gamma_{f1}(1-\gamma_{f2})\right]\right]$$

$$= (\gamma_{f1} - 1) + \lambda_f\rho_f\left[(1-\gamma_{f1})\gamma_{f2} - \gamma_{f1}(1-\gamma_{f2})\right]$$

B.2 The Import-Competing Firm

We derive the pass-through by first keeping the setting of the BDM model, and later adjusting for the fact that we need to consider an import-competing firm in the country of the exporter in order to be able to combine both into one global firm. Pass-through is the derivative of output price with regards to the exchange rate. Differentiating the output price of the import-competing firm (P_2) with respect to the natural logarithm of the exchange rate (defined as above in foreign currency relative to domestic currency from the perspective of the exporter) yields

$$
\frac{d\ln P_2}{d\ln S} = \frac{d\ln}{d\ln S}\left[\frac{\frac{C_2^*}{S}+C_2}{\rho_f \lambda_f}\right] = \frac{\rho_f \lambda_f}{\frac{C_2^*}{S}+C_2}\cdot\frac{d}{d\ln S}\left[\frac{\frac{C_2^*}{S}+C_2}{\rho_f \lambda_f}\right]
$$

$$
= \frac{\rho_f \lambda_f}{\frac{C_2^*}{S}+C_2}\cdot\frac{d}{d\ln S}\left[\frac{C_2^* e^{-\ln S}+C_2}{\rho_f \lambda_f}\right]
$$

$$
= \frac{\rho_f \lambda_f}{\frac{C_2^*}{S}+C_2}\left[\frac{\frac{-C_2^*\rho_f \lambda_f}{S}-\left(\frac{C_2^*}{S}+C_2\right)\frac{d}{d\ln S}\left[\rho_f \lambda_f\right]}{\rho_f^2 \lambda_f^2}\right]
$$

$$
= \frac{\rho_f \lambda_f}{\frac{C_2^*}{S}+C_2}\cdot\frac{\frac{-C_2^*\rho_f \lambda_f}{S}}{\rho_f^2 \lambda_f^2}-\left[\frac{\rho_f \lambda_f}{\frac{C_2^*}{S}+C_2}\cdot\frac{\frac{C_2^*}{S}+C_2}{\rho_f^2 \lambda_f^2}\cdot \rho_f\cdot\frac{d\lambda_f}{d\ln S}\right]
$$

$$
= \frac{1}{\frac{C_2^*}{S}+C_2}\cdot\frac{\frac{-C_2^*\rho_f \lambda_f}{S}}{\rho_f \lambda_f}-\left[\frac{1}{\lambda_f}\cdot\frac{d\lambda_f}{d\ln S}\right]
$$

$$
= \frac{-C_2^*}{C_2^*+SC_2}-\frac{1}{\lambda_f}\cdot\lambda_f\cdot(1-\lambda_f)\rho_f\cdot\left[(1-\gamma_{f1})\gamma_{f2}-\gamma_{f1}(1-\gamma_{f2})\right]
$$

$$
= -(1-\gamma_{f2})-(1-\lambda_f)\rho_f\left[(1-\gamma_{f1})\gamma_{f2}-\gamma_{f1}(1-\gamma_{f2})\right]
$$

B.3 The Global Firm

Total pass-through for the global firm (η) is defined as the foreign sales-weighted average of pass-through from foreign operations (η_f) and domestic operations (η_d) so that

$$\eta = \phi\eta_f + (1-\phi)\eta_d.$$

In particular, we interpret the pass-through from foreign operations (η_f) as the pass-through of a firm that produces domestically and abroad, but sells all of its output abroad (exporter). Similarly, we interpret the pass-through from domestic operations (η_d) as the pass-through of a firm that produces domestically and abroad, but sells all of its output at home (import-competing firm).

      While we can take the pass-through of the exporter as derived above, we need to consider an import-competing firm *located in the country of the exporter,* in order to be able to combine both to form the global firm. I.e., we want to analyze an import-competing firm, but from the currency perspective of the exporting firm above, in order to have the same currency perspective. This is like looking at an import-competing firm located in the country of the exporter. It is still the pass-through of a firm that produces domestically and abroad, but sells all of its output domestically (import-competing firm) under quantity competition. In order to be able to combine the pass-through of the exporter with that of the import-competing firm, we need to make the following adjustments to the above pass-through of the import-competing firm:

- The sign of the pass-through has to be changed since the currency perspective is opposite.
- $(1-\lambda_f)$ is the market share of the import-competing firm in the foreign market. Therefore, we replace this with λ_d which we define as the market share of the import-competing firm in its local market.
- Replace ρ_f with ρ_d.
- γ_{f1} is the exporter's share of cost in foreign currency (due to foreign currency inputs or foreign production). We replace γ_{f1} with γ_{d1}, which is the fraction of domestic cost of foreign firms exporting into the local market and the fraction of domestic cost of local competing firms
- γ_{f2} is the import-competing firm's share of cost in foreign currency. We replace γ_{f2} with γ_{d2}, which is the fraction of domestic cost of the import-competing firm.

$$\eta_d = (1-\gamma_{d2}) + \lambda_d\rho_d\left[(1-\gamma_{d1})\gamma_{d2} - \gamma_{d1}(1-\gamma_{d2})\right]$$

Thus:

$$\eta = \phi\left[\left(\gamma_{f1}-1\right)+\lambda_f\rho_f\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right]\right]$$
$$+\left(1-\phi\right)\left[\left(1-\gamma_{d2}\right)+\lambda_d\rho_d\left[\left(1-\gamma_{d1}\right)\gamma_{d2}-\gamma_{d1}\left(1-\gamma_{d2}\right)\right]\right]$$

$$\eta = \phi\left[\left(\gamma_{f1}-1\right)+\lambda_f\rho_f\mu_f\right]+\left(1-\phi\right)\left[\left(1-\gamma_{d2}\right)+\lambda_d\rho_d\mu_d\right]$$

with

$$\mu_f =\left[\left(1-\gamma_{f1}\right)\gamma_{f2}-\gamma_{f1}\left(1-\gamma_{f2}\right)\right]$$

and

$$\mu_d =\left[\left(1-\gamma_{d1}\right)\gamma_{d2}-\gamma_{d1}\left(1-\gamma_{d2}\right)\right]$$

Note: In order to obtain the pass-through of the exporter in the BDM model, set $\phi=1$ and $\left(1-\gamma_{f2}\right)=0$, *i.e.* $\gamma_{f2}=1$, which means that the import-competing firm has only cost in the foreign country, i.e. its local market). Similarly, in order to obtain the pass-through of the import-competing firm in the BDM model, set $\phi=0$ and $\left(1-\gamma_{f2}\right)=0$, *i.e.* $\gamma_{f2}=1$, which means that the import-competing firm has only cost in the foreign country (i.e. its local market).

Figure 1: Residual and Actual Exposures

The graph shows the combinations of *Actual Exposures* of 16 automotive companies as estimated from stock returns and the corresponding *Residual Exposures* from the simple model by Bodnar and Marston (2002) after accounting for financial hedging with foreign currency debt and foreign exchange rate derivatives. The line represents the best fit of an OLS regression for the two variables.
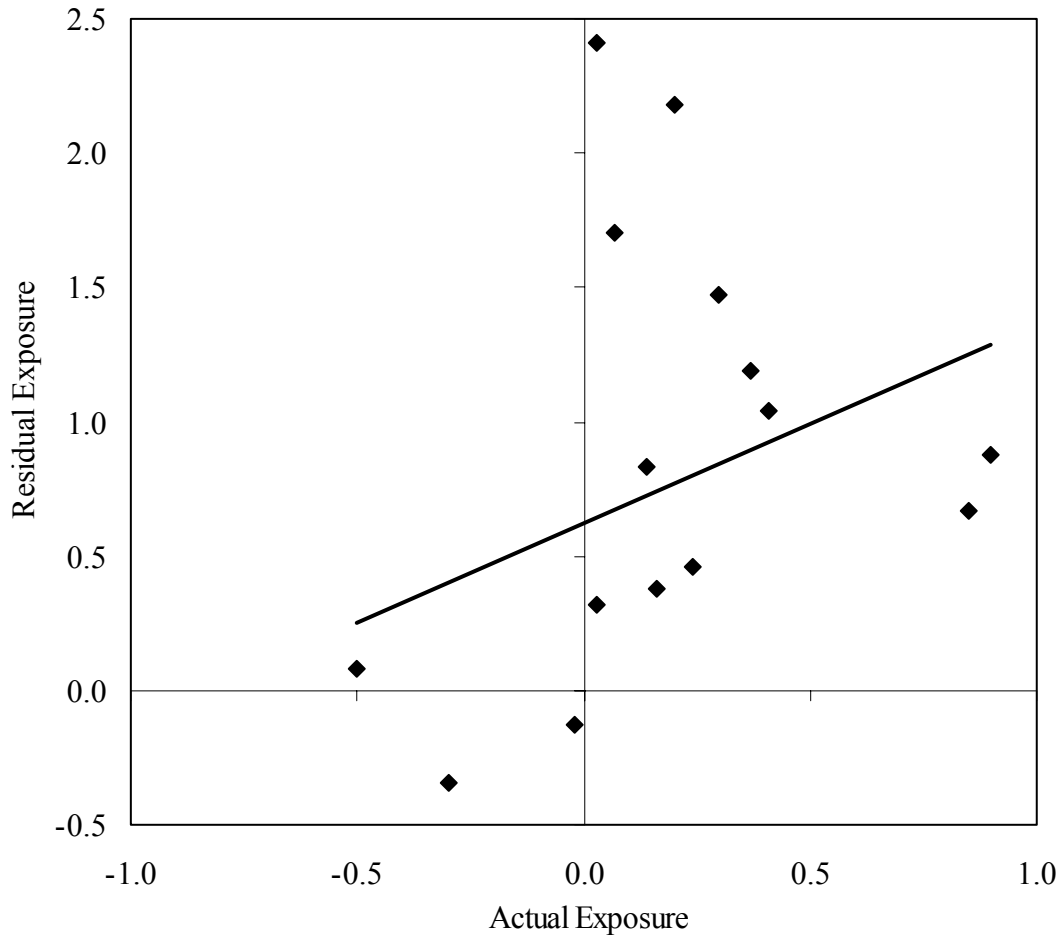
Figure 2: Feasible Exposures of BDM Model and Enhanced Model

The figure shows feasible exposures of the BDM model and the enhanced BDM model as a function of the degree of product substitutability ($\rho_f = \rho_d$).
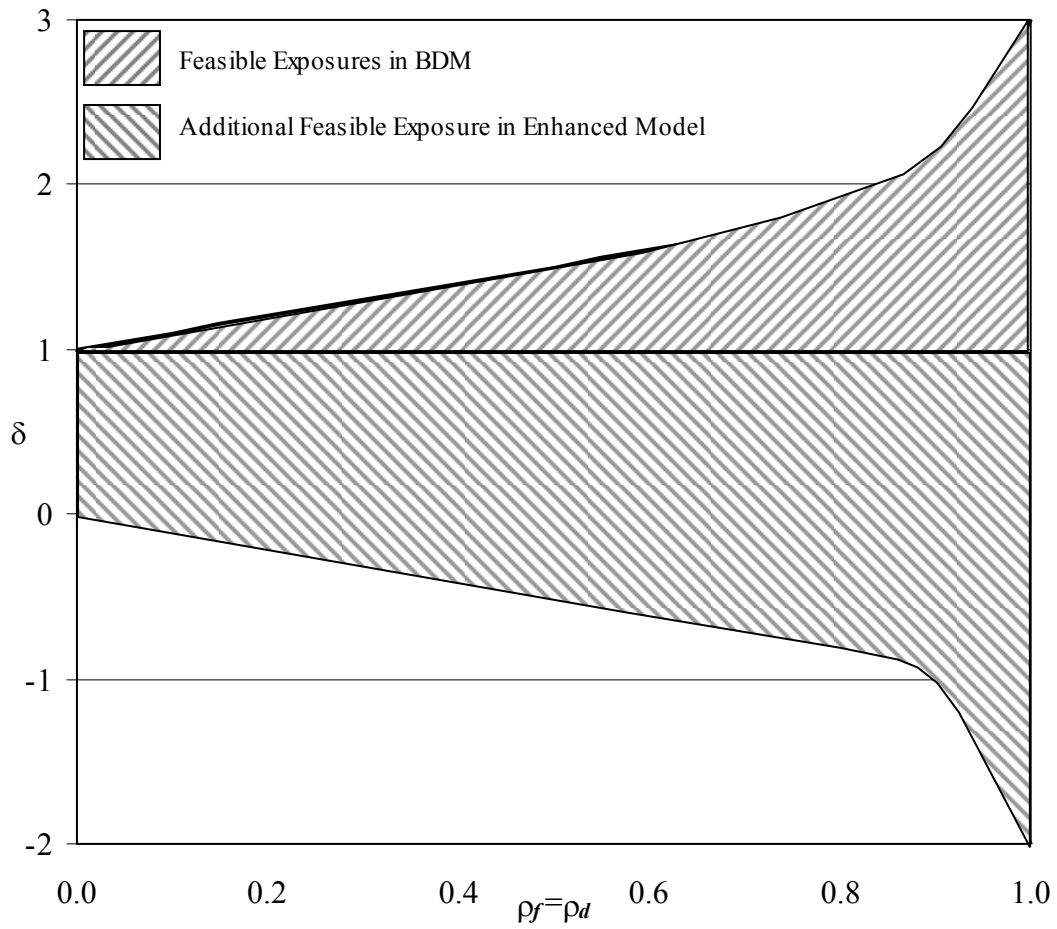
Figure 3: Actual Exposure of Automakers by Foreign Sales

The figure shows the actual exchange rate exposures of 16 global automakers as a function of their percentage of foreign sales. The graph also shows the maximum and minimum exposures allowed by the enhanced BDM model.
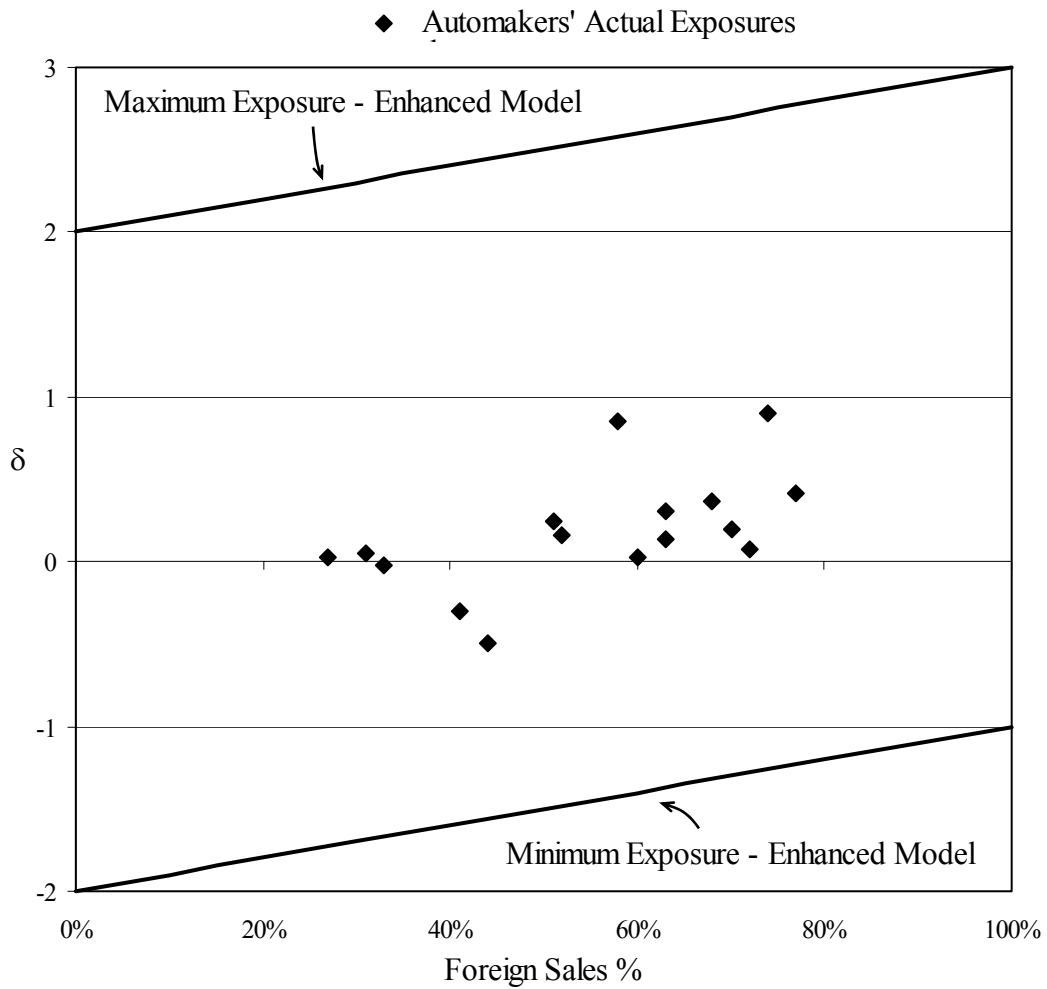
Figure 4: Comparative Static Analysis for Enhanced BDM Model Exposure

The figure plots exchange rate exposure values (δ) obtained from the Enhanced BDM model for various input parameter values. Parameter values for all variables except the one plotted on the horizontal axis are set to ϕ_f=0.5, γ_{f1}=0.3, γ_{d1}=0.6, γ_{f2}=0.6, ρ_f=ρ_d=0.7, λ_f=0.3, and λ_d=0.7.
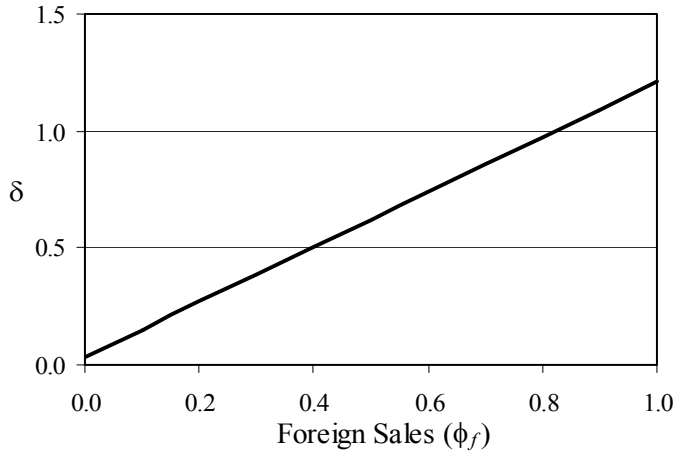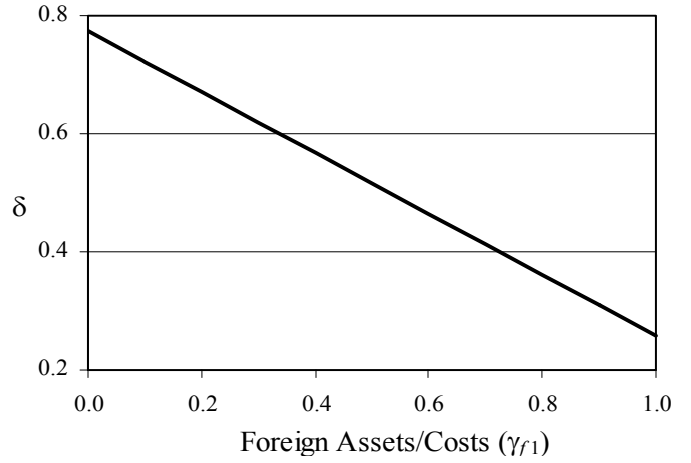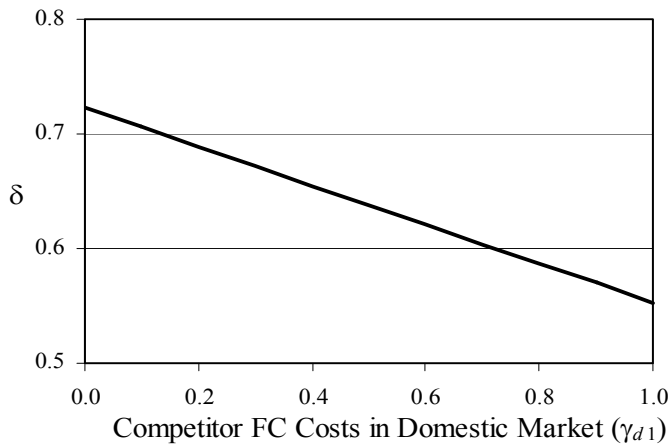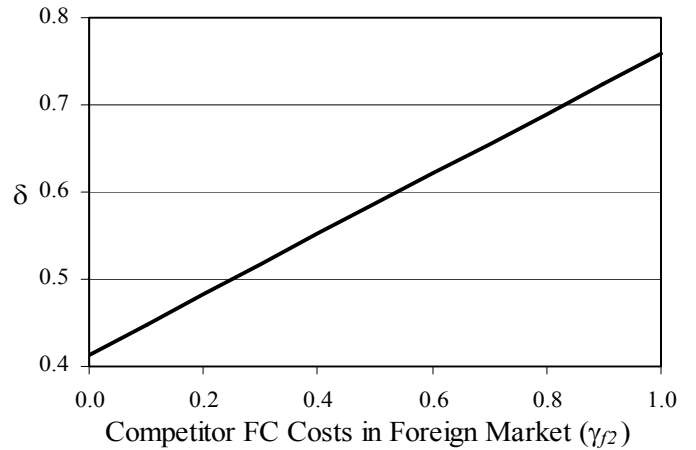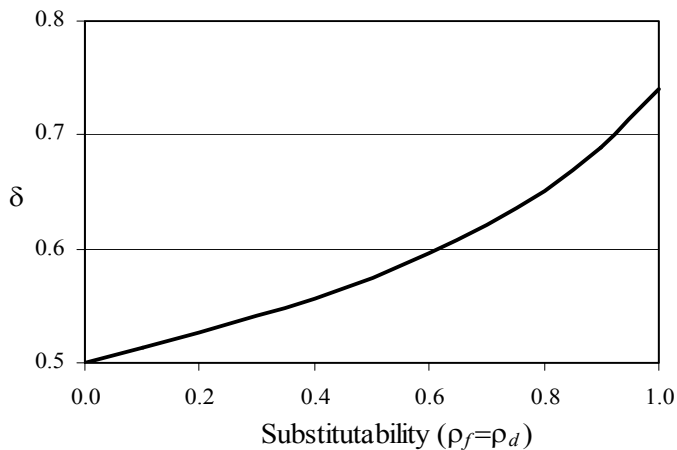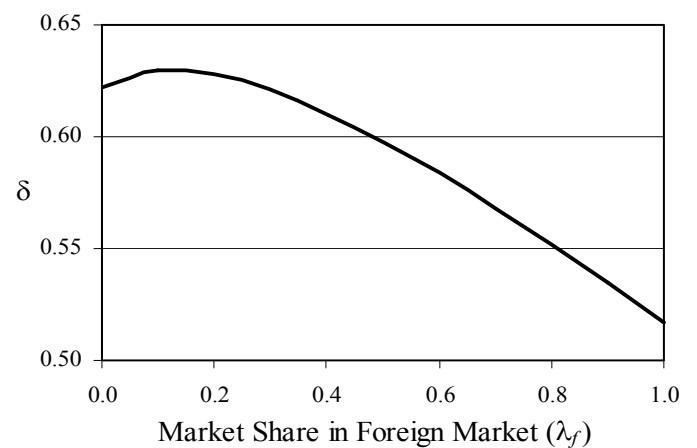
Figure 5: Exposure Estimates from the Enhanced BDM Model by Industry

This figure plots the relationship between exposure and average firm (or industry) characteristics for 27 global manufacturing industries. Detailed descriptions of each variable are provided in the main text and in Table A1 the appendix.

Panel A

Model Pass-through

$R^2 = 0.75$

Model Exposure

Panel B

Foreign Import Penetration

$R^2 = 0.18$

Model Exposure

Panel C

Foreign Assets

$R^2 = 0.15$

Model Exposure

Panel D

FC Debt or Derivatives

$R^2 = 0.54$

Model Exposure
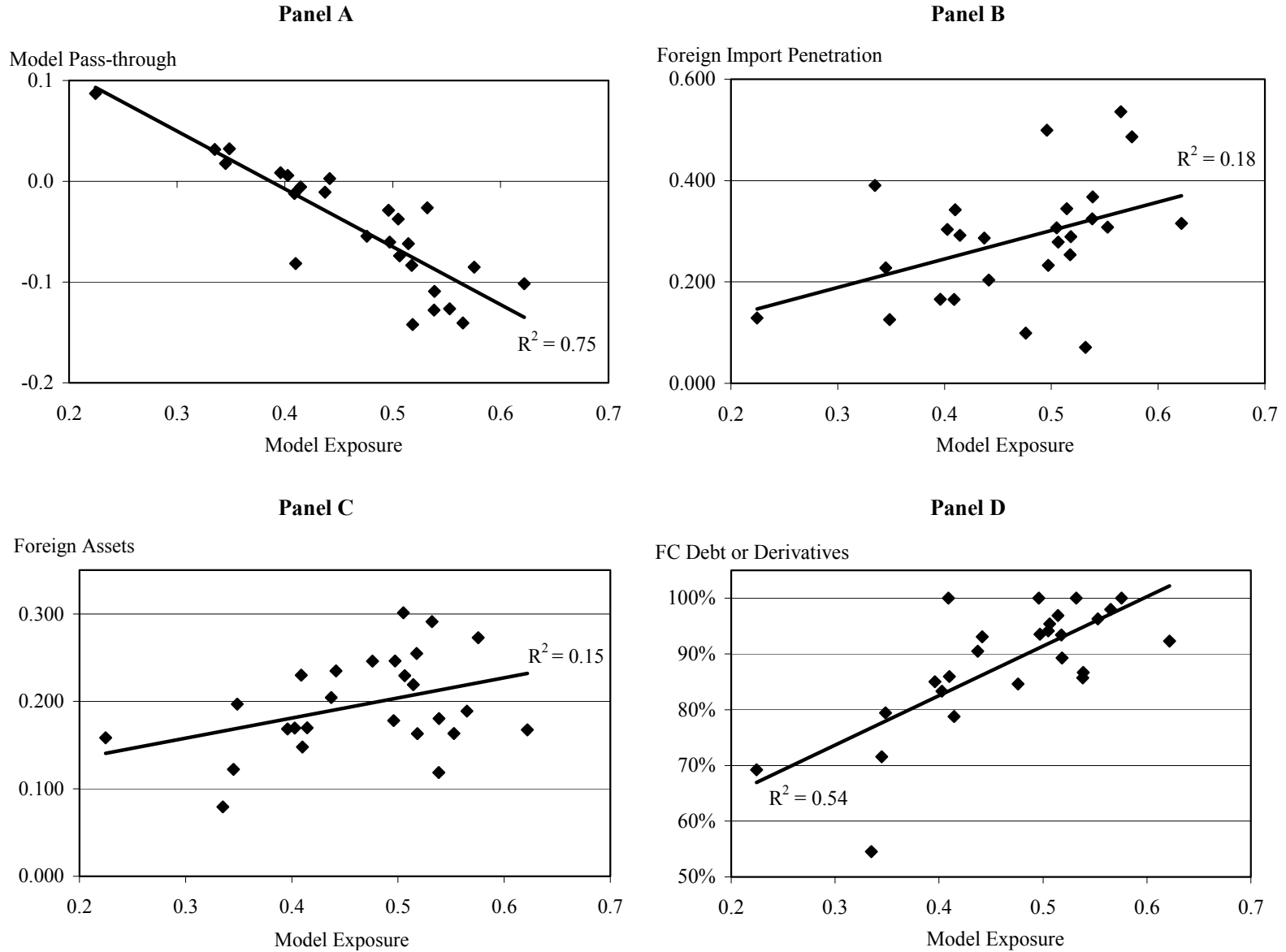
Table 1: Global Automotive Sales and Production

The table shows statistics on the sales and production of major automotive companies by major geographic region. In particular, Panel A refers to the percentage of total car sales, Panel B shows the percentage of total car production, and Panel C presents the difference in the percentages of sales and production. All data are for the year 2003. North-America includes the United States, Canada and Mexico. Source: WARD'S World Motor Vehicle Data Book (2003).

	Home Country	Europe	North America	Japan	Other
Panel A: Sales (%)					
Ford	United States	30.3	62.3	0.0	7.4
General Motors	United States	20.2	67.6	0.0	12.2
Hyundai	South Korea	17.5	31.1	0.0	51.4
Honda	Japan	7.5	54.8	25.6	12.1
Isuzu	Japan	1.8	14.0	27.8	56.4
Mazda	Japan	23.5	34.6	29.7	12.2
Mitsubishi	Japan	14.5	22.8	37.1	25.7
Nissan	Japan	18.8	40.2	31.5	9.5
Suzuki	Japan	14.2	4.5	41.9	39.4
Toyota	Japan	13.2	32.8	36.8	17.2
Fiat	Italy	80.1	0.0	0.0	19.8
BMW	Germany	64.6	30.6	0.0	4.9
DaimlerChrysler	Germany	28.4	68.4	0.0	3.2
Volkswagen	Germany	62.9	13.4	0.0	23.7
Peugeot	France	92.8	0.5	0.0	6.7
Renault	France	90.6	0.8	0.0	8.6
Panel B: Production (%)					
Ford	United States	35.2	56.1	0.0	8.7
General Motors	United States	24.2	64.5	0.0	11.3
Hyundai	South Korea	1.3	0.0	0.0	98.7
Honda	Japan	6.7	43.2	40.2	9.9
Isuzu	Japan	1.0	7.2	56.2	35.6
Mazda	Japan	0.0	16.9	80.2	2.9
Mitsubishi	Japan	6.0	10.7	64.6	18.6
Nissan	Japan	15.3	27.8	51.5	5.4
Suzuki	Japan	6.7	0.5	59.3	33.5
Toyota	Japan	6.9	18.8	62.6	11.6
Fiat	Italy	79.4	0.0	0.0	20.6
BMW	Germany	80.3	14.8	0.0	4.9
DaimlerChrysler	Germany	34.6	63.0	0.0	2.4
Volkswagen	Germany	68.1	5.8	0.0	26.1
Peugeot	France	94.3	0.0	0.0	5.7
Renault	France	95.7	0.8	0.0	3.6
Panel C: Sales (%) – Production (%)					
Ford	United States	-4.9	6.2	0.0	-1.3
General Motors	United States	-4.0	3.1	0.0	0.9
Hyundai	South Korea	16.2	31.1	0.0	-47.3
Honda	Japan	0.8	11.6	-14.6	2.1
Isuzu	Japan	0.8	6.8	-28.4	20.8
Mazda	Japan	23.5	17.8	-50.6	9.3
Mitsubishi	Japan	8.5	12.1	-27.6	7.1
Nissan	Japan	3.5	12.4	-20.0	4.0
Suzuki	Japan	7.5	4.0	-17.4	6.0
Toyota	Japan	6.3	14.0	-25.8	5.5
Fiat	Italy	0.7	0.0	0.0	-0.8
BMW	Germany	-15.7	15.7	0.0	0.0
DaimlerChrysler	Germany	-6.2	5.4	0.0	0.8
Volkswagen	Germany	-5.2	7.6	0.0	-2.3
Peugeot	France	-1.5	0.5	0.0	1.0
Renault	France	-5.1	0.1	0.0	5.0

Table 2: Theoretical and Empirical Foreign Exchange Rate Exposures of Automotive Companies

The table shows relevant firm characteristics and resulting theoretical foreign exchange rate exposures based on the model by Bodnar and Marston (2002), as well as estimated foreign exchange rate exposures. In particular, the columns show (from left to right) the name of the firm, the percentage of foreign sales (from WRDS), the Gross Profit Margin (3-year average), the resulting Gross Exposure, the percentage of foreign production (from WARDS), the resulting Model Exposure, the notional amount of foreign exchange rate derivatives relative to firm value (FX Derivatives), a proxy of the hedging effect of foreign currency debt relative to firm value (Foreign Currency Debt), and the resulting Residual Exposure. The last columns of the table show the foreign exchange rate exposure estimated from regressions of the excess return on the local stock market index and the trade-weighted exchange rate index on the excess stock return of automotive companies, adjusted for leverage (Actual Exposure), and the corresponding p-value (in brackets). All exchange rates are defined in local currency relative to (a basket of) foreign currency. The estimations are based on weekly data in local currency for the period 2000 – 2004.

Company	Foreign Sales	Gross Profit Margin	Gross Exposure	Foreign Production	Model Exposure	Financial Hedging		Residual Exposure	Actual Exposure	p-value
						FX Derivatives	Foreign Currency Debt			
Ford	0.44	0.22	1.99	0.53	0.14	0.04	0.02	0.08	-0.50	[0.12]
General Motors	0.41	0.21	1.93	0.53	-0.04	0.18	0.12	-0.34	-0.30	[0.20]
Hyundai	0.60	0.20	3.03	0.07	2.74	0.18	0.15	2.41	0.03	[0.76]
Honda	0.74	0.31	2.41	0.60	1.07	0.15	0.04	0.88	0.90	[0.00]
Isuzu	0.72	0.15	4.84	0.44	2.34	0.49	0.15	1.70	0.07	[0.39]
Mazda	0.70	0.23	3.10	0.20	2.43	0.15	0.09	2.18	0.20	[0.14]
Mitsubishi	0.63	0.16	3.86	0.35	2.05	1.01	0.21	0.83	0.14	[0.05]
Nissan	0.68	0.23	2.94	0.48	1.34	0.08	0.07	1.19	0.37	[0.00]
Suzuki	0.58	0.23	2.53	0.41	1.16	0.49	0.01	0.67	0.85	[0.00]
Toyota	0.63	0.22	2.82	0.37	1.53	0.02	0.03	1.47	0.30	[0.12]
Fiat	0.33	0.28	1.15	0.37	0.21	0.27	0.07	-0.13	-0.02	[0.90]
BMW	0.51	0.20	2.56	0.35	1.14	0.66	0.02	0.46	0.24	[0.14]
DaimlerChrysler	0.77	0.18	4.27	0.66	1.27	0.04	0.19	1.04	0.41	[0.02]
Volkswagen	0.52	0.16	3.29	0.42	1.02	0.46	0.18	0.38	0.16	[0.27]
Peugeot	0.27	0.25	1.08	0.13	0.69	0.33	0.04	0.32	0.03	[0.80]
Renault	0.31	0.21	1.46	0.11	1.06	1.97	0.10	-1.01	0.05	[0.73]
Mean	0.55	0.22	2.70	0.38	1.26	0.41	0.09	0.76	0.18	[0.29]
Median	0.59	0.22	2.69	0.39	1.15	0.23	0.08	0.75	0.15	[0.14]

Table 3: Selected Descriptive Statistics for Sample

The table shows descriptive sample statistics for selected variables. In particular, the table reports the mean, standard deviation and various percentiles of the variable distribution. Foreign exchange rate exposures are estimated using weekly time series in local currency of excess stock returns, excess stock market index returns and changes in trade-weighted exchange rate indices. N=1,161. All variables are defined in Table A1 in the appendix.

	Mean	StdDev	Percentiles				
			5th	25th	Median	75th	95th
Actual FX Exposure	0.071	1.945	-3.094	-0.806	0.148	1.058	3.147
Actual FX Exposure (unlevered)	0.019	1.606	-2.556	-0.552	0.086	0.743	2.512
Foreign Sales	34.5%	27.2%	0.0%	11.6%	31.9%	53.5%	85.4%
Foreign Assets	19.1%	21.7%	0.0%	2.2%	12.2%	27.7%	67.0%
Foreign Debt Dummy	0.871						
FX Derivatives Dummy	0.659						
Import Penetration	24.1%	17.3%	3.4%	11.9%	21.1%	32.8%	59.1%

Table 4: Definitions of Parameters of the Enhanced BDM Model

The table shows the variables, variable description and empirical counterpart for an enhanced exposure model derived from Bodnar, Dumas and Marston (2002). All empirical variables are defined in Table A1 in the appendix.

Variable	Variable Description	Empirical Counterpart (where domestic/foreign are relative to each company's country of incorporation)
ϕ	Foreign sales as a percent of total sales (FS)	Foreign sales as a percent of total sales (*FS*)
$(1-\phi)$	Domestic sales as a percent of total sales	1 - percentage of foreign sales as a percent of total sales (*FS*)

Exporting Firm
(domestic = country of exporter, foreign= country of import-competing firms)

γ_{f1}	Firm's fraction of marginal costs in foreign currency (due to foreign currency inputs or foreign production)	Percentage of foreign assets of firm
γ_{f2}	Import competing firms' fraction of marginal costs in the foreign market/currency(s) (i.e. their domestic market), also foreign currency costs of other exporting firms	Weighted average of the percentage of domestic assets of foreign firms and percentage of foreign assets of other domestic firms, i.e. weighted average of γ_{d2} for foreign firms, and γ_{f1} for domestic firms in the same industry (exporting also into the foreign market)
λ_f	Market share of firm in foreign markets	Rest-of-world GDP-weighted average of import penetration ratio

Import-Competing Firm
(domestic=country of import-competitor, foreign=country of exporting firms)

γ_{d1}	Exporters' fraction of marginal costs in the domestic market/currency (i.e. their foreign market), also domestic currency costs of other domestic, import-competing firms	Weighted average of the percentage of foreign assets of foreign firms and percentage of domestic assets of other domestic firms, i.e. weighted average of γ_{f1} for foreign firms, and γ_{d2} for domestic firms in the same industry (exporting also into the foreign market)
γ_{d2} $(=1-\gamma_{f1})$	Firm's fraction of marginal costs in the domestic currency	Percentage of domestic assets of firm (1 minus percentage of foreign assets)
λ_d	Market share of import competing firm in domestic market	1 - domestic market import penetration ratio
ρ_f, ρ_d	Degree of product substitutability in the foreign (*f*) and domestic (*d*) markets	Specified exogenously

Table 5: Summary Statistics of Parameters of the Enhanced BDM Model

The table shows summary statistics on the model parameters for the enhanced exposure model derived from Bodnar, Dumas and Marston (2002) with $\rho=0.7$. In particular, the table reports the mean, standard deviation, minimum, maximum and various percentiles of the variable distribution. N=1,161.

| Parameter | Mean | StdDev | Min | Percentiles | | | | | Max |
				5th	25th	Median	75th	95th	
Production costs									
γ_{f1}	0.191	0.217	0.000	0.000	0.022	0.122	0.277	0.670	0.944
γ_{d1}	0.631	0.170	0.000	0.286	0.548	0.675	0.741	0.846	0.945
γ_{f2}	0.662	0.135	0.122	0.432	0.573	0.672	0.751	0.876	1.000
γ_{d2}	0.809	0.217	0.056	0.330	0.723	0.878	0.978	1.000	1.000
Relative Costs									
μ_f	0.470	0.225	-0.514	0.028	0.359	0.507	0.632	0.772	1.000
μ_d	0.177	0.204	-0.766	-0.141	0.064	0.179	0.303	0.489	1.000
Import Competition									
λ_f	0.294	0.126	0.009	0.085	0.230	0.287	0.369	0.537	0.754
λ_d	0.759	0.173	0.000	0.409	0.672	0.789	0.881	0.966	0.998
Model Exposure									
$\rho_f=\rho_d=0.5$	0.428	0.296	-0.105	0.023	0.183	0.402	0.643	0.943	1.354
$\rho_f=\rho_d=0.7$	0.477	0.316	-0.169	0.036	0.222	0.451	0.705	1.035	1.577
$\rho_f=\rho_d=0.9$	0.549	0.355	-0.247	0.052	0.269	0.524	0.779	1.171	1.943
Model Pass-through									
$\rho_f=\rho_d=0.5$	-0.088	0.215	-0.916	-0.498	-0.218	-0.045	0.072	0.159	0.695
$\rho_f=\rho_d=0.7$	-0.061	0.218	-0.883	-0.470	-0.195	-0.028	0.096	0.203	0.695
$\rho_f=\rho_d=0.9$	-0.035	0.223	-0.850	-0.446	-0.174	-0.009	0.128	0.251	0.836

Table 6: Firm and Industry Characteristics by Level of Model Exposure

The table shows summary statistics on the model exposures and firm characteristics for the enhanced exposure model derived from Bodnar, Dumas and Marston (2002) with $\rho=0.7$. The table reports the mean, median and standard deviation of different variables for firms with above and below median model exposure (high and low). The last column presents p-values of Wilcoxon rank sum tests. N=1,161. All variables are defined in Table A1 in the Appendix.

Variable	High Model Exposure			Low Model Exposure			Wilcoxon
	Mean	Median	STD	Mean	Median	STD	*p*-value
Model FX Exposure	0.738	0.705	0.212	0.215	0.222	0.136	
Actual FX Exposure	0.196	0.229	1.867	-0.055	0.044	2.014	0.032
Actual FX Exposure (Unlevered)	0.128	0.148	1.505	-0.091	0.028	1.696	0.033
Foreign Debt	0.978	1.000	0.148	0.764	1.000	0.425	<0.001
FX Derivatives	0.799	1.000	0.401	0.519	1.000	0.500	<0.001
Import Penetration	0.289	0.246	0.192	0.193	0.160	0.136	<0.001
Foreign Import Penetration	0.295	0.287	0.127	0.293	0.288	0.125	0.474
Industry Herfindahl	0.152	0.103	0.151	0.140	0.102	0.125	0.151
Country-Industry Herfindahl	0.478	0.402	0.327	0.355	0.295	0.274	<0.001
Memo:							
Model Pass-through	-0.211	-0.191	0.192	0.088	0.091	0.117	<0.001

Table 7: Hedging Effects of Derivatives and Foreign Debt

The table shows empirical results of regressions of foreign debt and FX derivatives use on the difference between estimated foreign exchange rate exposures and theoretical model exposure. Theoretical exposures are obtained from an enhanced exposure model derived from Bodnar, Dumas and Marston (2002). The dependent variable is the difference between estimated (unlevered) actual exposure and model exposure. Results are presented separately for different degrees of product substitutability (ρ). For each regressor, the table shows the estimated coefficient and corresponding p-value (in brackets) as well as the number of observations. The models are estimated with data from 1,161 firms. All variables are defined in Table A1 in the appendix.

Panel A: Model Specification Test

	Intercept		FC Debt		FX Derivatives	
$\rho_f = \rho_d$	Coef.	p-value	Coef.	p-value	Coef.	p-value
0.5	-0.32	<0.01				
0.7	-0.37	<0.01				
0.9	-0.44	<0.01				
0.5	-0.06	0.51	-0.29	0.01		
0.7	-0.10	0.33	-0.31	<0.01		
0.9	-0.14	0.16	-0.35	<0.01		
0.5	-0.26	<0.01			-0.09	0.22
0.7	-0.30	<0.01			-0.10	0.17
0.9	-0.36	<0.01			-0.12	0.10
0.5	-0.06	0.52	-0.29	0.01	-0.00	0.97
0.7	-0.10	0.34	-0.30	0.01	-0.01	0.90
0.9	-0.14	0.17	-0.33	0.01	-0.02	0.78

Panel B: Results for Alternative Hedging Strategies

	Intercept		FC Debt Only		FX Derivative Only		Both	
$\rho_f = \rho_d$	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
0.5	-0.12	0.26	-0.21	0.11	0.42	0.15	-0.25	0.03
0.7	-0.15	0.16	-0.22	0.09	0.42	0.16	-0.27	0.02
0.9	-0.19	0.07	-0.25	0.06	0.42	0.16	-0.31	0.01

Table 8: Relative Importance of Mitigating Channels

This table calculates enhanced BDM model exposures to demonstrate the relative importance of different channels for exchange rate risk reduction. The first row considers an atomistic firm ($\lambda_f = \lambda_d = 0$ and therefore limited ability to pass-through exchange rate changes) with no operational hedging ($\gamma_{f1} = 0$, $\gamma_{d2} = 1$) and no financial hedging. The next row considers a firm with average market share in both the domestic and foreign markets ($\lambda_f = 0.294$, $\lambda_d = 0.759$) but still no operational or financial hedging. The third row considers a firm with average market share in both the domestic and foreign markets ($\lambda_f = 0.294$, $\lambda_d = 0.759$), the average level of foreign assets ($\gamma_{f1} = 0.191$, $\gamma_{d2} = 0.809$), but no financial hedging. The fourth row considers a firm with average market share in both the domestic and foreign markets ($\lambda_f = 0.294$, $\lambda_d = 0.759$), the average level of foreign assets ($\gamma_{f1} = 0.191$, $\gamma_{d2} = 0.809$), and a reduction in the hedge ratio consistent with the coefficient estimates for FC Debt and FX derivatives presented in Table 7 as measures of financial hedging. Results are presented separately for different degrees of product substitutability (ρ).

Scenario	$\rho_f = \rho_d = 0.5$		$\rho_f = \rho_d = 0.7$		$\rho_f = \rho_d = 0.9$	
	Exposure Estimate	Marginal Change (% of Base)	Exposure Estimate	Marginal Change (% of Base)	Exposure Estimate	Marginal Change (% of Base)
Base Case Low Pass-through ($\lambda_f = \lambda_d = 0$), No Operational Hedging ($\gamma_{f1} = 0$, $\gamma_{d2} = 1$), No Financial Hedging	0.580		0.674		0.768	
Pass-through ($\lambda_f = 0.294$, $\lambda_d = 0.759$), No Operational Hedging ($\gamma_{f1} = 0$, $\gamma_{d2} = 1$), No Financial Hedging	0.486	-16.3%	0.571	-15.3%	0.694	-9.7%
Pass-through ($\lambda_f = 0.294$, $\lambda_d = 0.759$), Operational Hedging ($\gamma_{f1} = 0.191$, $\gamma_{d2} = 0.809$), No Financial Risk Management	0.436	-8.6%	0.490	-11.9%	0.571	-16.0%
Pass-through ($\lambda_f = 0.294$, $\lambda_d = 0.759$), Operational Hedging ($\gamma_{f1} = 0.191$, $\gamma_{d2} = 0.809$), Financial Hedging	0.146	-50.0%	0.180	-46.0%	0.221	-45.6%
Total Reduction in Exposure		-74.9%		-73.3%		-71.3%

Table 9: Analysis of Additional Firm-Specific Variables

The table reports the results of regressions of additional firm characteristics on exposure residuals that are obtained from regressions of foreign debt and FX derivatives use on the difference between unlevered estimated foreign exchange rate exposures (actual exposures) and theoretical model exposure. Column (1) shows results using the enhanced exposure model derived from Bodnar, Dumas and Marston (2002) with $\rho=0.7$, while column (2) shows results using the theoretical exposures from the model by Bodnar and Marston (2002). Regressions also include industry dummy variables. For each regressor, the table shows the estimated coefficient and corresponding p-value. The table also shows the number of observations used in the regression and the adjusted R^2. All variables are defined in Table A1 in the appendix.

| | (1) | | (2) | |
| | Enhanced BDM | | Bodnar-Marston (2002) | |
	Coef.	*p*-value	Coef.	*p*-value
Intercept	0.42	0.19	0.96	<0.01
Size (log)	-0.03	0.28	-0.05	0.03
Gross Profit Margin	-0.35	0.06	0.16	0.30
Tangible Assets	-0.17	0.51	-0.47	0.03
Number of Industry Segments	0.02	0.50	0.00	0.96
Leverage	0.03	0.86	0.08	0.66
Debt Maturity	-0.01	0.97	-0.20	0.12
Dividend Dummy	0.13	0.17	0.11	0.20
Cash and Short-term Investments	0.17	0.56	-1.18	<0.01
Industry Dummy Variables	Yes		Yes	
Observations	978		2,234	
Adjusted R^2	0.02		0.04	

Table A1: Variable Definitions

The table reports the variables of the study and their definition. Panel A refers to firm characteristics and Panel B to industry-specific and country-specific variables.

Variable	Definition
Panel A: Firm Characteristics	
Foreign Sales	International Sales / Net Sales or Revenues
Foreign Assets	International Assets / Total Assets
Foreign Production	International Production / Total Production (from WARDS) for Automakers
Actual Exposure	Foreign exchange rate exposure from a regression of changes in the local stock market index in excess of the risk-free rate and changes in a trade-weighted foreign exchange rate index (in local currency relative to foreign currency) on stock returns in excess of the risk-free rate
Actual Exposure (Unlevered)	Leverage-adjusted value of Actual Exposure
FX Derivatives	Dummy variable with value 1 if firm uses FX derivatives; 0 otherwise
Foreign Debt	Dummy variable with value 1 if any foreign debt is reported; 0 otherwise
Size (log)	Natural logarithm of the sum of market capitalization, total debt and preferred stock
Gross Profit Margin	Gross Income / Net Sales or Revenues (3 year average)
Tangible Assets	(Total Assets - Intangibles) / Total Assets. Intangibles assets include items such as goodwill cost in excess of net assets purchased, Patents, Copyrights, Trademarks, etc.
Number of Industry Segments	Number of business segments (4-digit SIC codes) that make up the company's revenue (between 1 and 8)
Leverage	Total Debt / sum of market capitalization, total debt and preferred stock
Debt Maturity	Total Long-Term Debt / Total Debt. Long-term debt represents debt obligations due more than one year from the company's balance sheet date or due after the current operating cycle
Dividend	Dummy variable with value 1 if dividend yield, dividend payout or dividend per share is positive; 0 otherwise
Cash and Short-term Investments	Sum of cash and short term investments / Total Assets

Panel B: Industry and Country Characteristics	
Average Margin	Average of Gross Profit Margin for firms in the same industry
Import Penetration	Industry Imports / (Industry Production + Industry Imports)
Foreign Import Penetration	GDP-weighted average of Import Penetration for the same industry in all foreign countries
Country-Industry Herfindahl	Herfindahl index based on sales by country and industry
Industry Herfindahl	Herfindahl index based on sales by industry