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Exchange Rates and Cash Flows in Differentiated Product Industries: A Simulation Approach

RICHARD FRIBERG and MATTIAS GANSLANDT*

ABSTRACT

How do exchange rate changes impact firms' cash flows? We extend a simulation method developed in industrial organization to answer this question. We use prices, quantities, and product characteristics for differentiated products, coupled with a discrete choice framework and an assumption of price competition, to estimate marginal costs for all producers. Using a Monte Carlo approach we generate counterfactual prices and profits for different levels of exchange rates. We illustrate the method using the market for bottled water. Our results stress that even in a relatively simple market such as this one, different brands face very different exchange rate risks.

CONSIDER A FIRM THAT PRODUCES a good in France, using mainly local inputs, and sells it abroad in locations that have a floating exchange rate vis-à-vis the euro. Profits, and in turn the value of the firm, are potentially exposed to exchange rate changes. If the euro appreciates, profits when measured in euros are likely to decrease. How large is the decrease in profits? Similarly, what is the impact of such an exchange rate change on the profits of an import-competing firm? These are the questions that a large literature on exchange rate exposure attempts to answer.

The classic treatment on exchange rate exposure is that of Adler and Dumas (1984), who show that exposure can be defined as the regression coefficient on the exchange rate in a linear regression of the value of the firm. In their paper, Adler and Dumas are not very explicit about how to implement the methodology. In particular, should we use historical data (as a number of papers that we describe below do) or should we use simulated data? Sercu and Uppal (1995, p. 495) consider the latter approach and note that "The simulation requires that we come up with a number of possible future values for the spot exchange rate and compute the value, in home currency, of the cash flows for each possible future exchange rate value." In the present paper we use a set of tools recently developed in industrial organization to perform such simulations. To the best of our knowledge we are the first to apply these simulation tools to exchange rate exposure and to use them to gauge exchange rate risk. We do so using data for a simple differentiated products market, bottled water. In industrial organization

*Richard Friberg is at Stockholm School of Economics and CEPR. Mattias Ganslandt is at Research Institute of Industrial Economics. We thank Joel Reneby, Fredrik Wilander, an anonymous referee, and seminar participants at Stockholm University, Uppsala University, and the Finance workshop at Stockholm School of Economics for valuable comments.

the methods we propose have been used, for instance, to examine the impact of the introduction of new goods on prices, profits, and welfare (the minivan in Petrin (2002), direct broadcast satellites in Goolsbee and Petrin (2004)), and to simulate the impact on prices and profits of a merger between two firms (Nevo (2000a), Ivaldi and Verboven (2005)). More closely related work uses similar methods to examine exchange rate pass-through (Goldberg (1995)) or evaluate the effects of trade policies (Berry, Levinsohn, and Pakes (1999)).

The use of these simulation methods sets us apart from previous work on exchange rate exposure. Taking Adler and Dumas (1984) as a starting point, a large number of empirical studies note that we may view time-series data as reflecting different states of nature and regress the actual stock market value of firms on exchange rates. In this way researchers examine the exposure of individual firms (He and Ng (1998) for Japanese multinationals or Williamson (2001) for car manufacturers), the exposure of individual firms set in relation to their hedging strategies (Allayannis, Ihrig, and Weston (2001)), asymmetric exposure between depreciations and appreciations using data from several sectors and countries (Koutmos and Martin (2003)), exposure at different time horizons (Bartov and Bodnar (1994)), the sensitivity to inclusion of market portfolios as controls (Bodnar and Wong (2003)) and links between the responsiveness of goods' prices to exchange rates and exchange rate exposure (Bodnar, Dumas, and Marston (2002)). Overall, these studies find that exporters are more likely to face significant exchange rate exposure than purely domestic firms but that these effects are not very strong. Parallel to this literature are several theoretical investigations of exchange rate exposure; see, for example, Ware and Winter (1988), von Ungern-Sternberg and von Weizsäcker (1990), or Marston (2001). It is well known that while transaction exposure[1] and translation exposure[2] are relatively easy to identify and hedge if one so wishes, the broader economic exposure that Adler and Dumas (1984) set out to measure is very complex. Economic exposure boils down to how firms' cash flows are affected by changes in costs, demand and the prices of competing products.

The remainder of the paper is organized as follows. Section I presents a brief theoretical analysis. Section II describes the supply simulations and presents an application of the simulations using data from the market for bottled water. Section III describes the market. Section IV discusses the sensitivity of profits to one exchange rate and Section V reports results from Monte Carlo simulations in which all relevant exchange rates are allowed to move. Section VI concludes

[1] Transaction exposure refers to the effect of exchange rate changes on the home currency value of contractual cash flows that are denominated in foreign currency. A typical example would be an exporter that has made a sale in foreign currency but has offered 90 days trade credit to the buyer. Transaction exposure is sometimes referred to as contractual exposure; see, for instance, Eun and Resnick (2001) for a discussion.

[2] Translation exposure concerns the impact of exchange rate changes on the consolidated financial reports of a multinational firm. Translation exposure arises since financial statements of foreign subsidiaries are typically maintained in terms of foreign currency. It is also referred to as accounting exposure, and in contrast to transaction exposure there are no direct cash flow effects of translation exposure; again, see Eun and Resnick (2001) for a discussion.

and discusses the relation between the current simulations and other ways of estimating exchange rate-related risks for nonfinancial firms.

I. Exchange Rate Exposure under Bertrand Competition

To fix ideas we follow Marston (2001) and sketch exchange rate exposure in a model of Bertrand competition (Marston examines exchange rate exposure for some other forms of competition). Assume that we can express the value of a firm as the discounted present value of a stream of profits, that is, as

$$V = \sum_{t=1}^{\infty} \frac{\Pi(e_j)_t}{(1+\rho)^t}, \tag{1}$$

where Π_t denotes after-tax profits, ρ denotes the discount rate, and e_j is the home currency price of foreign currency. It is clear that the exchange rate exposure, dV/de_j, is proportional do $d\Pi/de_j$. Indeed, if we assume constant cash flows over time, then we have

$$V = \frac{\Pi}{\rho} \Rightarrow \frac{dV}{de_j} = \frac{1}{\rho}\frac{d\Pi}{de_j}. \tag{2}$$

A firm may produce several brands. For now we focus on a firm that produces one brand only, which we denote *j*. Assume that only domestic inputs are used and all sales of brand *j* are on one foreign market. Profits for brand *j* (disregarding any hedging positions and fixed costs) are then given by

$$\Pi_j = e_j p_j s_j \left(p_j, \sum_{k \neq j} p_k\right) M - c_j s_j \left(p_j, \sum_{k \neq j} p_k\right) M \tag{3}$$

where p_k are the prices of competing brands, s_j is the market share of brand *j,* and M is the size of the total market. Prices are expressed in the currency of the market in which the goods are sold. We assume that marginal costs (c_j) are constant and we express them in the currency of the producer. Totally differentiating equation (3) and rewriting, we obtain the following expression for how per period profits are affected by an exchange rate change:

$$\frac{d\Pi_j}{de_j} = \frac{\partial \Pi_j}{\partial p_j}\frac{dp_j}{de_j} + \sum_{k \neq j} \frac{\partial \Pi_j}{\partial p_k}\frac{dp_k}{de_j} + \frac{\partial \Pi_j}{\partial e_j}. \tag{4}$$

The first term equals zero for small changes in the exchange rate since by the first-order condition for profit maximization the price is set such that the partial derivative of profits with respect to the own price is zero (this follows from the envelope theorem). The second set of terms captures the effects of competitors' prices on the firm's profits. These terms are negative under price competition when goods are substitutes, tending to lower exposure.[3] This implies that domestic firms with no direct exchange rate exposure can be affected through foreign competitors' price changes—the closer substitutes these products are, and the more their prices change in response to changes in the exchange rate, the larger the effect will be. The last term in equation (4) captures the direct effect. This term reflects that foreign currency revenue is translated into home currency at a more favorable rate.[4] Marston (2001) notes that in a number of market structures exchange rate exposure reduces to the direct effect. This is most clearly seen in the case of monopoly, since in this case there are no competitors and the envelope theorem implies that if we evaluate the profit function at the optimally chosen price small changes in price will have no first-order effect on profits. This result is important because it takes us from the observation that exchange rate exposure is a complex animal depending on everything but the kitchen sink, to the observation that in some cases it simply reduces to revenue measured in foreign currency. However, if we consider price competition with differentiated goods we are not so fortunate, as exposure will depend on the closeness of substitutes and their price responses. Also, if we are interested in larger changes in the exchange rate we cannot rely on the envelope theorem. How, then, can we say something about the exposure of firms in such industries? That is the question we turn to next.

II. Exchange Rates and Profits in a Structural Model

Above we establish that the impact of changes in exchange rates on profits hinges on how prices respond to exchange rate changes and on how sales respond to changes in the own price as well as the prices of competitors. An empirically grounded measure of own- and cross-price elasticities is therefore important for any simulations. In principle we could estimate own- and cross-price elasticities simply by regressing the quantity sold for each product and using all prices in the market as explanatory variables (together with demand shifters such as income). In practice this is seldom feasible since we typically need to estimate a very large number of cross-price elasticities.[5]

Let us instead follow a number of recent papers that use structural models of demand to estimate markups and conduct simulations in differentiated goods markets. Central papers in this field are Berry (1994) and Berry et al. (1995); see Reiss and Wolak (2006) for a survey or Nevo (2000b) for a hands-on discussion.

[3] To see this first note that the first term is positive, that is, lower prices of competitors' products will lower firm j's profits. To see that the second term is negative rewrite $\frac{dp_k}{de_j} = \frac{\partial p_k}{\partial p_j}\frac{\partial p_j}{\partial e_j}$ for the case in which there is only one competitor (from the country where sales take place). A depreciation of the home currency leads firm j to lower its price on the export market (so $\partial p_j / \partial e_j$ is negative). Since goods are strategic complements, if firms produce substitutes and compete in prices, a lower price of one firm will be associated with a lower price for the other firm as well, making dp_k / de_j negative.

[4] If input prices change with the exchange rate and there is a direct effect on profits that would also enter here, for simplicity we let marginal costs in the producer's currency be fixed.

[5] For instance, if there are 10 brands we need to estimate 100 elasticities.

Feenstra (2003) contains a textbook treatment as well as a discussion of some of the applications in international economics. In the following we describe how these models can be applied to the estimation of exchange rate exposure.

Using a discrete choice framework, we suppose that the demand for a particular product is a function of observable product characteristics. To apply the methods we need market-level prices and quantities for all brands of a product sold as well as the product characteristics of these brands. For instance, say that we are interested in the U.S. auto market. Our data set would then include a panel of yearly observations on prices and quantities of all brands sold on the U.S. market. Such data are easily acquired for many differentiated goods markets from industry journals or from marketing companies (for instance AC Nielsen, GfK, or Information Resources Inc).[6] In addition, our data would include a set of observable product characteristics (in the case of cars these might contain a measure of fuel efficiency, the number of doors, and top speed). These represent the minimal data requirements. Additional data on, for instance, marketing expenditures or input prices may also be valuable. In Appendix A we describe in some detail how the data just described can be used to estimate a demand system for a particular market. However, since estimation of the demand is not the focus of this paper, we now turn to the simulation of counterfactual prices and profits.

A. Simulations of Supply

We assume that firms compete by setting prices noncooperatively in each period. One firm may operate several brands. Applying equation (3), let firm f, which controls the set F of brands, set prices to maximize the following:

$$\Pi_f = \sum_{j \in F} e_j p_j s_j \left(p_j, \sum_{k \neq j} p_k \right) M - c_j s_j \left(p_j, \sum_{k \neq j} p_k \right) M. \tag{5}$$

As is common in the literature on exchange rate pass-through we divide the maximization problem by e_j so that we consider the equivalent problem of maximizing profits in the currency of the market. A pure strategy Nash equilibrium in prices has to fulfill the following set of first-order conditions:

$$s_j(p) + \sum_{k \in F_f} (p_k - c_k/e_k) \frac{\partial s_k(p)}{\partial p_j} = 0. \tag{6}$$

If products k and j are produced by different firms $\partial s_k/\partial p_j$, the conjectured response is zero if firms compete à la Bertrand (i.e., by noncooperatively setting prices in a static game). If they are produced by the same firm, the cross-price effect depends on how close substitutes the two products are. We define the

[6] To see that these data are easily available, the interested reader can go to www.acnielsen.com, www.infores.com, or www.gfk.com.

$J \times J$ matrix Ω of cross- and own-price effects where row j and column k are given by $-\partial s_k/\partial p_j$. We can then express the system of first-order conditions as

$$s(p) - \Omega(p)(p - c/e) = 0, \tag{7}$$

where $s(p)$ is a $J \times 1$ vector of market shares, p a $J \times 1$ vector of prices, and c/e a $J \times 1$ vector of marginal costs expressed in the currency of the market (e is a $J \times 1$ vector of exchange rates). If we have some expression for $\partial s_k/\partial p_j$ it is straightforward to solve the system of equations to give us an estimate of $(\hat{c}/e)$, the marginal cost expressed in the currency of the market country:

$$(\hat{c}/e) = p - \Omega(p)^{-1}s(p). \tag{8}$$

Multiplying row j of the vector $(\hat{c}/e)$ by e_j gives us the marginal cost expressed in the producer's currency, $\hat{c}$. We are interested in how the prices respond to exchange rate changes. Let us examine a counterfactual vector of exchange rates, e'. For instance, this can be a vector in which we let currency e_j depreciate by 10% while keeping the other currencies unchanged. Alternatively, we can generate random draws of several exchange rates in a large number of counterfactual vectors e' and let the variance matrix between different exchange rates correspond to the historical variance matrix. Given our cross-price effects, an estimate of $\hat{c}$ and the exchange rates vector e', we can solve the nonlinear optimization problem in equation (9) for the vector of optimal counterfactual prices, p^*:

$$p^* - \frac{\hat{c}}{e'} = \Omega(p^*)^{-1}s(p^*). \tag{9}$$

These counterfactual prices can then be used to calculate counterfactual quantities and in turn profits. Thus, we have a link between counterfactual exchange rates and simulated profits. The market shares as well as the prices that we need in order to estimate marginal costs are observed directly in the data. The cross-price effects, however, need to be estimated. We turn to this issue next.

III. The Market for Bottled Water

We now show how the above simulation methods can be applied. In particular we apply these methods to the market for bottled water in Sweden. While bottled water in Sweden may not keep many financial managers awake at night, this market has few complexities, which makes it well suited as a first case to illustrate the potential usefulness of the approach. For instance, the production process is very simple—water is put in bottles at the source and then transported to retailers. This means that all production costs arise in the source country. The structure of the market is also quite simple in that only two exchange rates have the potential to be of interest for more than just the exporting firm, namely, the exchange rate vis-à-vis the euro and that vis-à-vis Norwegian kronor. We express both these exchange rates as the units of the exporters' currency needed to buy one Swedish krona and denote them *Eursek* and *Noksek*, respectively.

We use an unbalanced panel of monthly observations on prices and quantities of all brands of bottled water sold in grocery stores in Sweden over the 35 months from November 1999 to September 2001 to estimate demand. The data are from AC Nielsen and cover all of Sweden (split into six regions). Although we use the full period to estimate demand, we simplify the exposition by reporting simulations for one representative month only, May 2001. In the following all descriptive statistics are given for this month.

An interesting feature of the Swedish market for bottled water is that it provides a stark illustration of one of the strengths of the present framework—how to achieve a measure of exchange rate exposure when exposure differs across firms. At first blush this would appear to be an industry in which Swedish brands face negligible exchange rate exposure; essentially all costs are borne in domestic currency and the share of imports in the volume of bottled water is only 3.9%. Competing products such as carbonated soft drinks are also almost exclusively produced in Sweden.[7] Imported brands, on the other hand, would be expected to face important exchange rate exposure given that costs are borne in foreign currency. Given that firms have comparatively similar production techniques and they sell products that to the casual observer appear to be very close substitutes, one would expect different imported brands to face quite similar exchange rate exposure. However, as we discuss below, even in a simple setting such as this there are large differences across the exchange rate exposures of different brands as some firms are in relatively close competition with foreign brands whereas others are only in distant competition. In particular, we can view bottled water as comprising two segments: still water and sparkling water. In Sweden the sparkling segment is much larger than the still, with 97% of the bottled water sold in stores of the sparkling variety. In the sparkling segment only 1.9% of the volume is imported, whereas in the still segment 76.3% of the volume is imported. This suggests that domestic firms in the still segment could be quite exposed to exchange rate risk if they are indeed in relatively close competition with imports.

As with many differentiated product markets, there are a large number of different brands: In May 2001, 58 brands of bottled water were sold in Sweden, of which 20 were imported. Rather than try to directly estimate some 3,300 own- and cross-price elasticities (58 brands each with 58 elasticities) we use a discrete choice framework. We assume that consumers first choose which type of product to buy (sparkling, still, tap water) and then choose the brand that gives them the highest utility based on product characteristics, prices, and a random taste component that is specific to each consumer–product combination. The data set and demand estimation that underlie our present simulations have previously been used as input in a paper that examines the welfare effects

[7] It is also probable that these products are only in weak competition with bottled water. This is consistent with the findings in the frequently cited antitrust case involving Nestlé and Perrier, where it was found that bottled water was a separate market from other forms of beverages.

of trade in bottled water (Friberg and Ganslandt (2006)). The methodological foundations for the estimation and the results are presented in Appendix A. To summarize, we use what is known as a nested logit specification and estimate the linear equation (10) using instrumental variables for prices and market shares within segments (segments are known as nests in the literature that we build on):

$$\ln(s_j) - \ln(s_o) = x_j \beta - \alpha p_j + \sigma \ln(s_{j/g}) + \xi_j. \tag{10}$$

Here s_j is the market share of brand j, s_o the market share of the outside good (tap water), x_j a set of observable product characteristics (such as country of origin dummies and whether the water is classified as natural mineral water or not), p_j the price of brand j, $s_{j|g}$ the market share within the nest of brand j, and ξ brand-specific valuations that are not dependent on observable characteristics. This estimation yields coefficients for α and σ, as well as brand-specific valuations, which give us explicit forms for the own- and cross-price elasticities. In this case the own- and cross-price elasticities are given by

$$\frac{\partial s_k}{\partial p_j}\frac{p_j}{s_k} = \begin{cases} \alpha p_k \left(s_k + \dfrac{\sigma}{1-\sigma} s_{k|g} - \dfrac{1}{1-\sigma} \right) & \text{if } j = k \\ \alpha p_j \left(\dfrac{\sigma}{1-\sigma} s_{j|g} + s_j \right) & \text{if } j \neq k \text{ and } j,k \in \text{ same nest} \\ \alpha p_j s_j & \text{if } j \neq k \text{ and } j,k \in \text{ different nests.} \end{cases} \tag{11}$$

Other things equal a brand that has a higher price has a more elastic demand. The cross-price elasticity from changes in the price of brand j to the market share of brand k depends among other things on whether the two products belong to the same nest or not. Thus, if a particular brand of sparkling water lowers its price, then other sparkling brands will lose a larger proportion of their customers than the still water brands do. We simulate equilibrium prices and profits for all 58 brands under different exchange rates. Descriptive statistics on all the brands in the still segment and a subset of the sparkling brands are given in Table I.

The still water segment is dominated by four brands: Imsdal, Evian, Blåvitt, and Vittel. Imsdal is imported from Norway, and Evian and Vittel are imported from France, thus these three brands all clearly face exchange rate exposure. Blåvitt is the only domestic brand with a substantial market share in this segment. The sparkling segment is dominated by three domestic brands that each have about one-quarter of sales. To economize, in the following we present the exchange rate exposure of a small number of brands that are illustrative of different exposures. We present results for the four market leaders in the still segment. We also present results for Ramlösa (the largest brand in the sparkling segment) and Perrier (a high priced premium sparkling brand imported from France).

Table I

Descriptive Statistics for Selected Brands of Bottled Water, Sweden, May 2001

The table reports country of production, market share by volume, price, own- and cross-price elasticities, as well as estimated markups for selected brands on the Swedish market for bottled water. Cross-price elasticity is defined as the percentage change in demand of other brands in the segment to a percentage change in the price of the brand in the corresponding row. For instance a cross-price elasticity of 2.93 as in the case of Imsdal implies that other nonsparkling brands will see a decline in sales of 2.93% following a 1% price decrease by Imsdal. All variables are aggregated at the national level. Own- and cross-price elasticities and markups calculated by equation (11) using the estimated demand parameters we report in column 3 in Table AI. In addition to Perrier the following sparkling brands were imported: Harboe from Denmark; Kopparbergs and Premier from Germany; Irish Classic from Ireland; Acqua Paradiso, Beber, Verdiana, and Vittoria from Italy; Fyresdal, ICA, and Rimi (store brands) from Norway; Rogaska from Slovenia; and Fontana from the U.K.

Brand	Origin	Market Share in Segment	Price (Kronor per Liter)	Own-Price Elast	Cross-Price Elast	Estimated Markup (in Percent)
Nonsparkling Segment (All Brands)						
Imsdal	Norway	45.7	11.64	−6.27	2.93	16.5
Blåvitt	Sweden	20.7	6.14	−4.15	0.70	24.6
Evian	France	15.9	12.16	−8.55	1.07	12.1
Vittel	France	11.5	10.82	−7.87	0.68	12.8
Iceland Spring	Iceland	1.9	7.26	−5.67	0.07	18.4
Nedraby	Sweden	1.5	6.0	−4.69	0.05	23.2
Acqua Paradiso	Italy	1	5.95	−4.67	0.03	21.6
Edins	Sweden	0.8	6.3	−4.95	0.02	20.5
Stenkulla	Sweden	0.5	4.6	−3.62	0.01	27.9
Celtic	France	0.3	6.58	−5.19	0.01	19.6
Grebbestad	Sweden	0.09	8.61	−6.80	0.004	14.7
Olden	Norway	0.05	12.31	−9.73	0.003	10.3
Sparkling Segment (Selected Brands)						
Ramlösa	Sweden	25.5	7.40	−4.81	1.04	29.5
Vichy Nouveau	Sweden	25.0	7.53	−4.91	1.03	29.3
LOKA	Sweden	23.4	6.65	−4.40	0.86	24
Perrier	France	0.08	17.11	−13.52	0.01	7.4
Means for all other domestic sparkling brands (29 brands)	Sweden	1.26	7.57	−5.94	0.043	25.9
Means for all other imported nonsparkling brands (12 brands)	Various European, see notes	0.2	8.93	−7.05	0.007	20.2

IV. The Dependence of Profits on the Euro Exchange Rate

We now turn to simulations of the link between profits and the euro exchange rate, holding other factors constant. We simulate profits for *Eursek* exchange rates from 0.04 to 0.20, with increments of 0.00025. To illustrate the mechanisms as clearly as possible we consider a really wide spread of the exchange rate. For comparison note that in May 2001 the *Eursek* was 0.11 and the minimum level of the *Eursek* is 0.103 and the maximum is 0.121 over the period for which we have data on sales (the standard deviation is 0.0038). We keep marginal costs constant in the producer currency, let all other exchange rates be constant, and let the parameters of the demand system be constant. We then use equation (9) to solve for counterfactual prices under different values of the *Eursek* exchange rate. Market shares depend on prices following equation (A8) in the Appendix. Given the counterfactual prices, exchange rates, and market shares, it is straightforward to calculate profits of both domestic and foreign firms. Each exchange rate level is therefore associated with one set of equilibrium prices and profits. We express profits in the producers' currency. In Figure 1 we graph the relation between simulated profits and the *Eursek* exchange rate for the selected brands.

Evian, Vittel, and Perrier—all of which are exporters from the euro zone—show a positive relation between profits and the *Eursek*, as expected. A depreciation of the euro raises profits in euros. We also note that the relation is convex, so that greater variability of the exchange rate raises expected profits. The intuition for the convex relation between profits and exchange rates is the same as in Oi's (1961) examination of profits and variability of prices for a price-taking firm: By adjusting optimally firms make the best of good times and limit their damage when the euro is strong. [8] The convexity is stronger for Evian than for Vittel and even stronger for Perrier. To understand why Perrier exhibits the most pronounced convexity note that the sparkling segment is very much dominated by domestic brands. If the euro weakens it will be relatively attractive for Perrier to expand its quantities and take market share from the domestic firms. Evian and Vittel, on the other hand, are present in the still water segment, where an important share of the competing brands achieves similar cost reduction. The convexity is also related to the own-price elasticities for brands. For Perrier this is very high (see Table I), such that a price decrease has a large effect on quantities and therefore on revenue. Similarly, Evian is more expensive than Vittel in the benchmark equilibrium and has a greater own-price elasticity than Vittel (see Table I). The revenue effect of *Eursek* is therefore stronger for Evian and results in a more convex relationship.

We also graph "passive profits," the profits in the home currency that would result if all prices were kept still, in Figure 1. The profits of domestic firms are then unaffected and exporting firms are affected linearly, with changes in the

[8] Note that since we compare equilibria we assume that all prices change and disregard price rigidities. In a duopoly version of our model it can be shown theoretically that the relation between profits and exchange rates is convex as long as both firms are in the market with a nontrivial market share (available in an appendix available upon request from the authors).

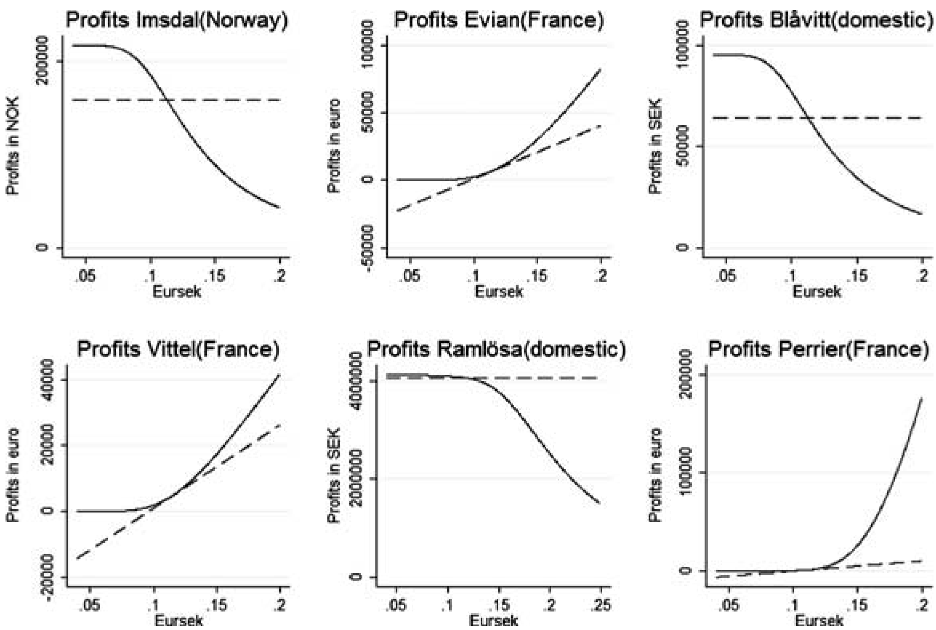

Figure 1. Counterfactual profits and *Eursek* exchange rate for selected brands. The figure shows simulated profits in the producer's currency for selected brands set in relation to the euro price of Swedish kronor (*Eursek*). Solid lines represent profits based on optimal prices (Bertrand equilibrium for differentiated goods) derived from the solution to the nonlinear problem in equation (9) for each corresponding level of the *Eursek*. Parameters set to $\alpha = 0.239$ and $\sigma = 0.698$ based on demand estimation as specified in Appendix A. All simulations are for May 2001. The dashed lines report profits as a function of the *Eursek* under the assumption that all prices faced by Swedish consumers are kept fixed at the actual observed prices in May 2001 (when the *Eursek* was equal to 0.11).

exchange rate affecting one-for-one the home currency value of foreign revenue if that revenue is fixed in foreign currency. The active policy is associated with higher profits for exporters than profits if all firms keep prices unchanged. We note that for small changes in the exchange rate passive profits are a good measure of economic exposure—the larger the change in the exchange rate, the greater is the difference between the two. This suggests that the intuition from Marston (2001) is a useful guide to measuring the exposure of exporting firms also in this more complex environment.

Figure 1 also shows that profits of Swedish and Norwegian competitors decrease when the euro is weaker. Two features are particularly noteworthy. First, given a sufficiently large euro appreciation, profits become insensitive to the euro exchange rate. Second, profits are convex as the euro depreciates (note that for Ramlösa we use simulations of *Eursek* up to 0.25 to show this clearly). One way to interpret the pattern on profits is therefore to say that for a sufficiently strong euro, profits of domestic firms are unrelated to the *Eursek*, but

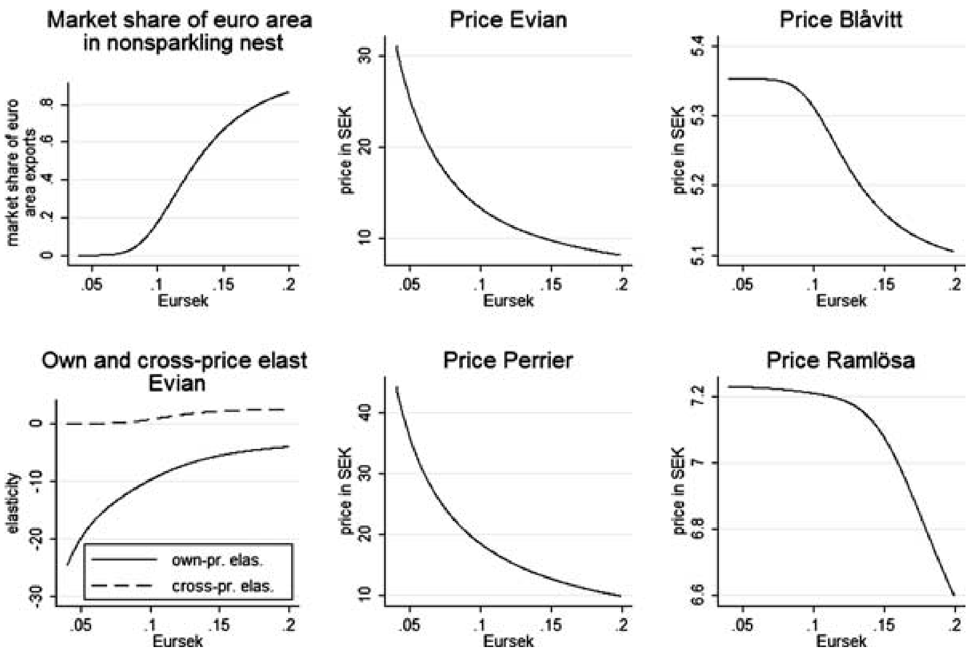

Figure 2. Market shares, prices, and elasticity of demand for selected brands. The figure shows simulated prices, market shares and own- and cross-price elasticities for selected brands set in relation to the euro price of Swedish kronor (*Eursek*). The prices represent the Bertrand equilibrium prices derived from the solution to the nonlinear problem in equation (9) for the respective level of the *Eursek*. Parameters set to $\alpha = 0.239$ and $\sigma = 0.698$ based on demand estimation as specified in Appendix A. The market share of euro-area producers is the share of the resulting equilibrium quantities that are imported from the euro area. The own-price (solid line) and cross-price elasticity (with respect to other nonsparkling brands, dashed line) of Evian are calculated using equation (11). All simulations are for May 2001.

for a weaker euro this relation becomes convex. The transition from a flat to a downward-sloping and convex section implies concavity over an interval.

To investigate the mechanisms that lie behind these curvatures we examine the prices and market shares of various brands in Figure 2. The price that a firm sets for a brand can be expressed as a markup over marginal costs. Changes in exchange rates shift the marginal costs of exporters, when expressed in the country of the market, and therefore they induce price changes. Domestic firms are affected via the cross-price effect: By lowering the prices of competitors a depreciation induces lower prices of domestic firms as well. The cross-price effects that we estimate are relatively weak and therefore the relation between prices and the *Eursek* is much more pronounced for euro-area exporters than for their competitors, as illustrated by the prices of Evian and Blåvitt. As the euro appreciates the Euroland producers essentially price themselves out of the market, which explains why domestic profits are unrelated to the *Eursek* for sufficiently strong *Eursek* in Figure 1. As the euro depreciates Euroland exporters take advantage of this change and lower their prices, taking market share from their competitors. As the euro depreciates around the current level, prices fall drastically but for further depreciation the price reductions taper off. As their market share increases exporters face successively weaker incentives to further lower price, much like the weaker incentives for a monopolist to lower prices compared to those facing an oligopolist. This is illustrated by the own- and cross-price elasticities of Evian. As demand becomes less sensitive to the own price the incentives to lower price following a depreciation weaken. As the market share of Evian increases and its price decreases, changes in the price of Evian also have a stronger impact on the prices of domestic firms.

We have thus characterized the slope of exposure to the *Eursek* exchange rate. But can we say more? For instance, how much is at risk? To examine this we turn to a Monte Carlo procedure that is an easy extension of the framework.

V. Exchange Rate Risk—A Monte Carlo Approach

The exporter's own exchange rate is only one variable of several that affect profits. In many situations other competitors will come from other currency zones. Accordingly, we also need to take account of covariances between different currencies. A sharp drop in the dollar vis-à-vis the euro, for instance, is likely to also be associated with a sharp drop against the yen. We would also like to take account of the fact that we are typically much more likely to observe exchange rate realizations that are closer to the mean of the exchange rate than a figure out in the tails. Thus, to say something about the exchange rate risk faced by different brands we need to incorporate exchange rate distributions in the framework—a question we turn to below.

As noted, in this particular case there are two exchange rates that are potentially important—the *Eursek* and the *Noksek*. Both of these currencies float freely against the Swedish krona. We generate 1,000 random draws on the *Eursek* and *Noksek* exchange rates, letting the means equal the values for the relevant month (May 2001). We assume that these exchange rates follow a bivariate normal distribution and let the covariance matrix for these random draws be given by the actual historical covariance matrix for the *Eursek* and *Noksek* exchange rates.[9] For each of these 1,000 draws we simulate counterfactual prices and calculate profits for all brands. In Figure 3 we present the distribution of these profits. The figures illustrate that different brands can face very different exchange rate risks. Evian, Perrier, and Vittel are exports from the euro zone and all have higher euro profits when the euro is weak. To some extent all three have a much higher upward potential in profits than downward, a reflection of the convexity of profits that we analyze in the previous section. Blåvitt and Imsdal have more symmetric exposure. At the other end of the spectrum is the major domestic brand Ramlösa, which has downside risk but little upside potential.

[9] We do so using monthly data for the period January 1980 through April 2001. We use the French Franc price of Swedish kronor as a proxy for *EURSEK* for the pre-1999 period.

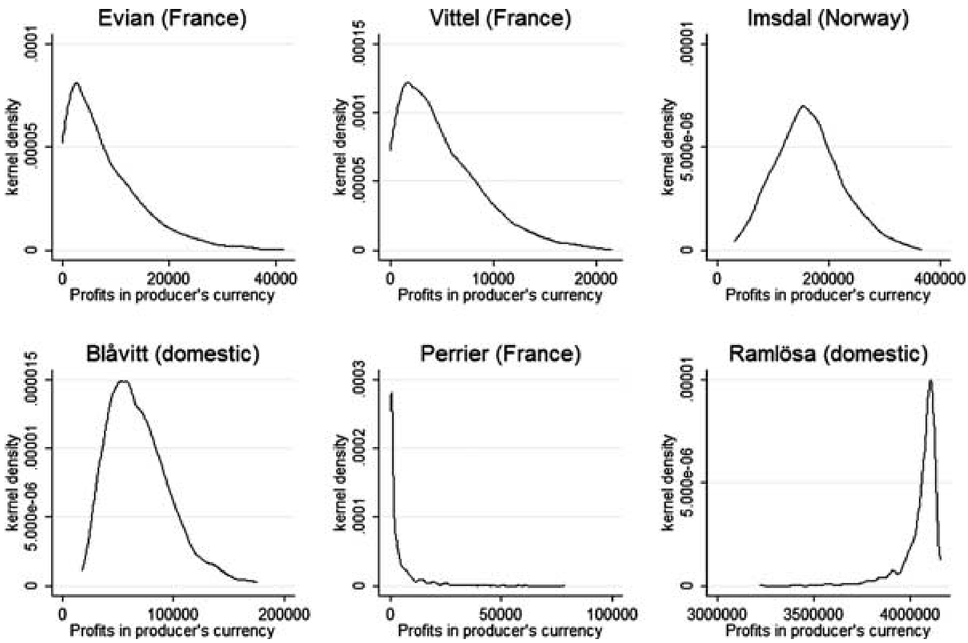

Figure 3. Density of profits in producer's currency for selected brands. Results from a Monte Carlo procedure with draws on euro and Norwegian krona exchange rates. The figure shows the distribution (kernel density) of brand-level profits for selected brands based on simulated profits generated by a Monte Carlo procedure with 1,000 draws on the euro/Swedish krona (*Eursek*) and Norwegian/Swedish krona (*Noksek*) exchange rates. For each draw, Bertrand equilibrium prices are calculated by solving the system in equation (9) and the resulting profits are calculated. Parameters in the nested logit demand system are set to $\alpha = 0.239$ and $\sigma = 0.698$ based on demand estimation as specified in Appendix A. All simulations are for May 2001.

Another way to examine the data is to look at points in the distribution as in Table II, where we normalize such that median profits are 100 for each brand to afford a starker illustration of differences across brands. The upward potential for the imported brands stands out. Blåvitt, with a market share in the nonsparkling segment of 20.7% is in close competition with a number of imported brands and is therefore significantly exposed to exchange rates.[10] For a major domestic brand facing mainly domestic competitors, the exchange rate risk is low; for Ramlösa profits at the 95th percentile are only 7% higher than profits at the 5th percentile.

We view the above demonstration of how one can quantify risk and generate a distribution of counterfactual profits as one key contribution of the paper. It may also be instructive to examine the links between exchange rates and profits using a standard exchange rate exposure regression on our simulated

[10] Of course, a difference between these figures is that when the Swedish krona is weak imported brands such as Imsdal will have low profits but domestic brands such as Blåvitt will have relatively high profits.

Table II

Estimated Distribution of Operating Monthly Profits in Producer Currency for Selected Brands

The table reports descriptive statistics on profits in the producer's currency of selected brands using simulated data from a Monte Carlo procedure with 1,000 draws on the euro/Swedish krona (*Eursek*) and Norwegian/Swedish krona (*Noksek*) exchange rates. For each draw, Bertrand equilibrium prices are calculated by solving the system in equation (9) and the resulting profits are calculated. Parameters in the nested logit demand system are set to $\alpha = 0.239$ and $\sigma = 0.698$ based on demand estimation as specified in Appendix A. Profits are normalized such that for each brand profits at the median are set to 100.

Percentile	Evian (France)	Vittel (France)	Imsdal (Norway)	Blåvitt (domestic)	Perrier (France)	Ramlösa (domestic)
1	0	1	25	36	0	88
5	4	5	43	48	0	94
10	12	15	55	56	2	97
50	100	100	100	100	100	100
90	302	261	153	164	1,127	101
95	380	326	169	189	1,961	101
99	541	437	201	235	4,263	101

data, as suggested by Adler and Dumas (1984). Table III below reports results from regressions of brand-level profits in the home currency on the *Eursek* and *Noksek* (exchange rate exposure). As is common in the empirical literature we run the regressions in logs, which makes it easy to compare exposures across the different brands.[11] The expected pattern is apparent, with euro exporters having a positive exposure to the *Eursek* and all brands except Norwegian Imsdal having a negative exposure to the *Noksek*. The relative magnitudes of the coefficients are consistent with intuition; for instance Ramlösa records the point estimates that are closest to zero.

The estimated exposure coefficients reported in time-series studies using stock market data are typically in the zero to one range and frequently not significantly different from zero.[12] To understand why the exposure coefficients

[11] However, as Adler and Dumas show, the actual exposure coefficient comes from a regression in levels. Since $dln\Pi/dlne$ approximately equals $(d\Pi/de)(e/\Pi)$, we can multiply the coefficient on lne from our regression in logs by Π and divide by e to back out the exposure measured in units of foreign currency.

[12] For instance, Dominguez and Tesar (2006) examine the exchange rate exposure of publicly traded firms in Chile, France, Germany, Italy, Japan, Netherlands, Thailand, and the U.K. using weekly data for 1980 to 1999 with on average 300 firms from each country included in the sample. Average exposure of firms with a significant positive exposure ranges from 0.38 to 2.02 with a median of the country averages of 0.63 (see their Table II). In He and Ng's (1998) study of 171 Japanese multinationals exposure coefficients are likewise mostly in the zero to one range with the highest exposures reaching 1.4. In Bodnar and Wong's (2003) study of 910 U.S. firms the mean exposure is 0.13 (Table I). Indeed, establishing whether exposure coefficients are significant at all has been a major focus of the studies based on U.S. data ever since Jorion (1990) found little evidence of significant exposure among U.S. multinationals.

Table III

Exchange Rate Exposure and Exchange Rate Pass-Through: OLS Regressions on Simulated Data

The top panel reports the estimated coefficients from brand-level ordinary least squares regressions of the natural log of simulated operating profits in the producer currency. Separate regressions are run for each brand. The simulated profits are generated by a Monte Carlo procedure with 1,000 draws on the euro/Swedish krona (*Eursek*) and Norwegian/Swedish krona (*Noksek*) exchange rates. For each draw, Bertrand equilibrium prices are calculated by solving the system in equation (9) and the resulting profits are calculated. Parameters in the nested logit demand system are set to $\alpha = 0.239$ and $\sigma = 0.698$ based on demand estimation as specified in Appendix A. As explanatory variables in the regressions reported below we use a constant, as well as the ln(*Eursek*) and ln(*Noksek*) exchange rates from the respective draws. The bottom panel reports the corresponding OLS regression in which the natural log of the (national average) price of the respective brand is the dependent variable. Standard errors are in parentheses. **denotes significance at the 1% level.

	Evian (France)	Vittel (France)	Imsdal (Norway)	Blåvitt (domestic)	Perrier (France)	Ramlösa (domestic)
Dep. Variable	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)
Ln(*Eursek*)	8.656**	7.878**	−1.156**	−1.312**	15.007**	−0.081**
	(0.094)	(0.086)	(0.023)	(0.021)	(0.121)	(0.004)
Ln(*Eursek*)	−2.694**	−2.703**	5.938**	−1.967**	−1.002**	−0.051**
	(0.195)	(0.179)	(0.047)	(0.042)	(0.251)	(0.009)
Dep. Variable	Ln(price)	Ln(price)	Ln(price)	Ln(price)	Ln(price)	Ln(price)
Ln(*Eursek*)	−0.852**	−0.846**	−0.106**	−0.066**	−0.932**	−0.012
	(0.008)	(0.003)	(0.009)	(0.013)	(0.013)	(0.009)
Ln(*Noksek*)	−0.021	−0.016**	−0.636**	−0.112**	0.004	−0.008
	(0.017)	(0.006)	(0.019)	(0.028)	(0.013)	(0.019)

that we find are so much higher, it may be useful to examine the exposure elasticity in some detail. For illustrative purposes consider an exporting firm and let q_j denote the quantity sold on exports, let p_j denote the foreign price (with p_d and q_d being the corresponding figures for domestic sales), let the marginal costs be constant, and let α denote the share of imported inputs. To bring out the intuition in its simplest form assume that the firm is a monopoly and use the envelope theorem to simplify the expression (the more general case, of course, is discussed in some detail in conjunction with equation (4)). The profits, exchange rate exposure, and exchange rate exposure elasticity of such a firm are then given by

$$\begin{aligned} \Pi_j &= ep_jq_j + pq_d - c(1-\alpha)(q_j+q_d) - e\alpha c(q_j+q_d) \\ \frac{d\Pi_j}{de} &= p_jq_j - \alpha c(q_j+q_d) \\ \frac{d\Pi_j}{de}\frac{e}{\Pi_j} &= \frac{e(p_jq_j - \alpha c(q_j+q_d))}{\Pi_j}. \end{aligned} \tag{12}$$

Closer examination of the exchange rate exposure elasticity points to several reasons why our estimates are higher than in the literature that examines the correlation between stock market valuations and exchange rates. First, the bottled water industry is quite unusual in that there are essentially no imported inputs, whereas in most industries there is an offsetting exposure as the price of inputs is correlated with the foreign currency revenue.[13] In terms of equation (12), α is set to zero for exporters in our application, which raises their exposure. Second, we examine exposure on the market and brand levels, whereas in almost all other cases sales from the domestic market form a large part of profits and therefore the percentage change in profits is much lower.[14] With no imported inputs the exposure coefficient is simply revenue from foreign sales over profits. Thus, the smaller the share of exports to one market in profits, the lower the exposure to that market's currency. Third, foreign exchange risks are hedged to a considerable extent, which should lower the contemporaneous correlation between stock prices and exchange rates.[15] Fourth, several of the stock market valuation studies include the market portfolio as a control, hence the reported exposure coefficients frequently have the interpretation of the exposure over and above that of the market. Since many national stock market indexes have a positive covariance with the price of foreign currency, the effect is to lower coefficients (see Bodnar and Wong (2003)).

Finally, our estimated markups are fairly low (markups range across brands from 5.4% to 60%, with a median markup of 21%), and thus the resulting low profits drive up the exposure when measured in percentage terms. As a comparison, we examine exposure coefficients from a counterfactual simulation in which we choose parameters such that median markups are almost three times as high (57%). Under this alternative scenario (reported in Appendix B), exposure is much lower, pass-through lower, and the distribution of profits less skewed.

The lower part of Table III reports regressions of (the log of) prices on (the log of) the relevant exchange rates (the *Eursek* and the *Noksek*) on our simulated data.[16] The imported brands tend to adjust prices by substantial amounts when

[13] In the survey of Bodnar, Hayt, and Marston (1998), for instance, 60% of firms report that they have a balance between foreign currency revenue and foreign currency expenses. Bodnar and Marston (2004) use questionnaire answers from that survey to gauge exposure elasticities. While the bulk of the elasticities are in the range between zero and one, a number of firms exhibit much higher elasticities with the most exposed having exposure elasticities close to 25 (see their Figure 2). The firms with the highest exposure are characterized by large net exports.

[14] That exposure is increasing in export intensity is largely confirmed by the literature; see, for instance, Dominguez and Tesar (2006).

[15] For evidence on the extent of hedging see for instance Bodnar and Gephardt (1999), or Bodnar et al. (1998). For evidence that hedging lowers the correlation between the hedged variable and stock prices, see Jin and Jorion (2006).

[16] Note that the brands that have a higher exposure also have higher pass-through coefficients. An intuitive explanation for this is that the exchange rate is particularly important for some brands—it has a large impact both on profits and on the optimal prices. It is worth noting that this feature will not hold in all possible models of imperfect competition. In some contrast to our results, Bodnar et al. (2002) show that higher (exogenous) elasticity of substitution in a duopoly

their home currency depreciates. Take Perrier, for instance. When the euro depreciates by 1% (thus lowering its marginal costs in terms of Swedish kronor) it lowers its price by 0.93%, which indicates close to full pass-through.[17] A domestic competitor in the same segment, such as Ramlösa, who is only affected by the exchange rate change through the prices of competing products, leaves its price essentially unchanged. Because Perrier has negligible market share, Perrier's lower price gives little incentive for Ramlösa to lower its price (the cross-price effect from Perrier to Ramlösa is close to zero at current prices). Given that less than 2% of sales in the sparkling segment are imported it is not surprising that a market leader in a differentiated products market with more than one-quarter of sales in its segment faces little incentive to adjust prices. In the nonsparkling segment the domestic brands face greater competitive pressures from imports with correspondingly higher correlation with exchange rates.

Simulations such as those above can of course be performed under a number of different assumptions: For instance, one can let volatility reflect different time horizons, one can let brands exit if they fall below a certain profit threshold, one can consider entry of new brands, or one can consider changes in ownership structure or changes in the price of inputs. In this paper we disregard tax concerns but they can also be easily incorporated. Similarly, we have not explicitly examined retail margins. To the extent that simulations such as these are performed by firms themselves, firms may naturally use additional information on costs rather than exclusively rely on the estimated marginal costs that are backed out of the estimation. However, the mechanics of the simulation would also remain the same in this case.

VI. Discussion

In this paper we show how tools from industrial organization can be applied to simulate exchange rate exposure and exchange rate risk. Focusing on one

is associated with lower pass-through and higher exposure. Thus, pass-through and exposure are negatively related. To understand why we obtain results that appear to contradict those of Bodnar et al. (2002), note that we are not performing comparative statics here; rather we are comparing the exposure and pass-through of a set of brands that differ across many dimensions such as own- and cross-price elasticities, marginal costs, and the location of production. In addition, as is well known, comparative statics results under imperfect competition are often sensitive to finer details of the setup.

[17] These pass-through coefficients may be surprisingly large given the finding in many empirical studies of low pass-through into import prices (Goldberg and Knetter (1997) report a median estimate of 50% pass-though to the United States with somewhat higher pass-through for smaller national markets) and even lower pass-through to consumer prices. An indication that a high pass-through of imported brands is reasonable in this setting is that in their study of pass-through to import prices Campa and Goldberg (2005) find that the short-run (quarterly) pass-through of exchange rate changes into import prices of food for Sweden was 0.68 (compared to 0.11 for the United States and an average of 0.46 across OECD countries, Table 1 in their Appendix). We also experiment with nonstructural regressions on the time series data that we do have, for instance, a simple OLS regression of the (log of) price of Perrier on the (log of) *Eursek* and *Noksek* yields a confidence interval on the coefficient on *Eursek* that ranges from –0.705 to –1.90. This is without inclusion of competitors' prices or instruments, issues that lead us to the structural model. Nevertheless, results such as these are consistent with a high pass-through of some brands.

industry, that of bottled water, we show that even in this simple market different brands are likely to face different risks. It would be interesting of course to apply this methodology to other differentiated product industries. These tools should be particularly appealing to import-competing firms for which data only have to be analyzed for one market. The methods we propose can also be used for simulating the effects of other risks, such as the impact of changes in gas prices on auto manufacturing firms' profits.

We now discuss the strengths and weaknesses of the methods above in relation to other ways of estimating exposure. As we note in the introduction, one frequent practice is to regress stock market valuation on changes in the exchange rate. While this is an easy-to-implement way of estimating exposure, for many purposes it is of limited value to the firm itself. First, if we do not understand what is driving results how can we trust that correlations of the past will hold in the future? Indeed, parameter estimates often are quite unstable over time (see, for instance, Dominguez and Tesar (2006)). The measure of exposure clearly also depends on past actions. For example, a firm that has hedged extensively in the past will not be able to say what its exposure is without hedging. Moreover, overall exposure measured in this way may also have little relation to the reasons a firm should hedge. This point is stressed by Froot (1994, p. 254), who writes "What I want to argue is that these methods [exposure measurement using stock market data]—whether good or bad as measures of exposure—cannot and should not be used to formulate hedging strategies .... Firms must investigate their exposure in cash flows and investment opportunities internally."[18]

The exposure coefficient also has another weakness as a measure of a firm's risk. While it does give a measure of what is at risk, for risk management purposes we are often more interested in worst-case scenarios, such as "What is the probability that my cash flows will fall below a certain threshold one year from now?" Such reasoning is the logic behind the value-at-risk (VAR) methodology that is commonly used by financial institutions. Stein et al. (2001) recently propose a similar methodology, cash-flow-at-risk (C-FaR), for nonfinancial firms. Their idea is to examine historical cash flow data to obtain a measure of the riskiness of a particular firm. A problem that one immediately encounters is that for any given firm we have few observations. The idea of Stein et al. (2001) is to identify a group of companies that are comparable in risk to the company of interest. The authors use historical cash flows to generate a large pool of forecast errors on cash flows (estimating the expected cash flow as a autoregressive process). They go on to categorize firms into different risk categories (based on market capitalization, profitability, the riskiness of industry cash flows, and stock price volatility) and using this classification to calculate a measure of the expected riskiness of a particular firm. As they themselves note, this "top-down" approach is somewhat of a black box and is of limited use in investigating the consequences of different strategies for firms. On the other hand, it

[18] See also Eun and Resnick (2001, pp. 324–325) for a discussion.

can be a very convenient way of putting some numbers on the riskiness of the business.

We propose a way of generating simulations in the spirit of Adler and Dumas (1984) that easily generates a large number of simulations that can be used to determine both exposure coefficients and a measure of C-FaR. Ours is a "bottom-up" approach that draws on both the previously mentioned approaches.[19] A particular strength of the method proposed in this paper is the ability to numerically investigate links between strategy and exchange rate exposure such as, "What is the effect of focusing on different brands or of making production more flexible?" Another strength lies in estimating exposure in industries that see a lot of change and for which we cannot rely on stable relations over many years. As with any calibrated model the accuracy of predictions depends on the fit of the model to the actual competition. Thus, as these methods are increasingly used and evaluated in other fields of economics, our confidence in the method will grow.

A final question is, of course, whether we really need any new measures of exchange rate exposure and exchange rate risk? We argue yes—even though many exchange rate exposure regressions yield low exposure coefficients, it is clear that the huge swings in exchange rates that we observe must have a profound impact on the competitive position and profitability of many firms. Furthermore, recent debates about a future adjustment of the U.S. current account deficit stress that we may witness large exchange rate shifts in the future. We note that firms indicate that they hedge exchange rate exposure to a large degree, with survey evidence in Bodnar and Gephardt (1999) for instance indicating that exchange rates are hedged to a greater extent than interest rates or commodity prices. At the same time, there are several indications that many firms are quite uncertain of their own exposure.[20] For instance, in a survey Loderer and Pichler (2000) find that many Swiss nonfinancial firms have only dim notions about their own currency exposure. Given that this is the case even in Switzerland—a small country with a floating exchange rate and well-developed financial markets—it seems that there is some utility to having additional tools in the toolbox.

[19] A paper related to ours is Andrén, Jankensgård, and Oxelheim (2005), who estimate the sensitivity of cash flows to various macroeconomic variables using historical data. They then use Monte Carlo simulations based on their parameter estimates to obtain a measure of downside risk to different macro variables and apply the methodology to a Norwegian industrial conglomerate. Their method is likely to be the most valuable when one examines a market that has been stable for a long time.

[20] A quite telling quote is from Belk and Glaum (1990, pp. 6–7): "Because of the complex nature of the topic and the great diversity of the companies interviewed, it is not surprising that the questions about the management of economic exposure and the longer term, strategic aspects of foreign exchange risk management produced very heterogeneous results. Some of the questions met with only hesitant replies, and at times the use of the term 'economic exposure' seemed to evoke a feeling of uncertainty and unease with the interview partner. The following gives a good instance of this[:]*Company A*: We do think about our economic exposures a lot, but it is difficult to say exactly what we do."

Appendix A: Estimation of Demand

This appendix details the estimation of demand that is an input for the simulations of supply outlined in Section II. We start with a description of demand estimation at a general level before turning to the case at hand. Assume that the utility that consumer i derives from buying a particular differentiated product depends on the characteristics of that product as well as the characteristics of the consumer according to

$$u_{ij} = \delta_j + \nu_{ij}. \tag{A1}$$

Here δ_j is the mean utility level for product j that is equal across all consumers and ν_{ij} is an error term that is specific to each individual–product match. The consumer buys the product that gives her the highest utility. We can make different assumptions about the error terms: One assumption is that the errors are randomly distributed across consumers and products following a generalized extreme value distribution, a situation known as the simple logit case. By construction this case does not allow for correlation across products. In reality we often believe that a consumer that has a high individual-specific valuation of one particular product also has a high valuation of similar products—if I have a high individual-specific valuation of a particular large Mercedes I am likely to also have a high individual-specific valuation of other large German cars. One way to capture this possibility is to allow the individual-specific errors to have correlations that depend on product characteristics in the spirit of Berry et al. (1995). Another way is to let products belong to different market segments or "nests," and to allow for a correlation of tastes within nests. This yields what is known as the nested logit form, which is popular in applied work because of its relative simplicity. We use the nested logit approach in this paper.[21]

Let products belong to one of several nests, G. Examples of nests are sparkling and still water on the bottled water market or lager, stout, keg ale, and real ale on the market for beer (Slade (2003)). One nest is the outside good, that is, the alternative to buying one of the products in the inside nests. A consequence of this is that if all the prices of the inside goods go up, the market share of the outside good increases. For instance, if the prices of all bottled waters go up the market share of tap water will increase.[22] Normalize the utility of consumption of the outside good to zero. The utility of consumer i if she purchases product j is defined as

$$u_{ij} = \delta_j + \zeta_{ig} + (1 - \sigma)\varepsilon_{ij}. \tag{A2}$$

[21] Of course one approach will not be perfect for all markets. In some industries it is quite easy to argue that there are a number of well-defined segments, in others the logit assumption will be reasonable, and in yet others it will be hard to get around the fact that we need to use computationally more demanding approaches.

[22] Often the outside good is defined by taking the number of potential consumers times a conceived maximum consumption. In Berrry, Levinsohn, and Pakes (1995), for instance, the total market is calculated as the total number of households in the U.S. times one car per household and year. The market share of the outside good is thus given as the total market minus total sales of new cars in that year.

Here δ_j is again the mean valuation for product j, ζ_{ig} is individual i's deviation from the mean valuation common to all goods in the nest, and ε_{ij} is individual i's good-specific deviation. Let $\zeta_{ig} + (1 - \sigma)\varepsilon_{ij}$ be distributed Type 1 extreme value. The correlation of tastes within groups, σ, lies between zero and one. The mean valuation is given by

$$\delta_j = x_j\beta - \alpha p_j + \xi_j. \tag{A3}$$

Here x_j is a matrix of product characteristics of product j, p_j is again the price, and ξ_j is a random component in the mean valuation that can be taken to be a measure of product quality that is not captured by the observable product characteristics. Under these assumptions Berry (1994) shows that the market share of product j can be written as

$$s_j = \underbrace{\frac{\exp(\delta_j/(1-\sigma))}{D_g}}_{s_{j|g}} \underbrace{\frac{D_g^{1-\sigma}}{1 + \sum_{g=1}^{G} D_g^{1-\sigma}}}_{s_g}, \tag{A4}$$

where $s_{j|g}$ is the market share within the nest and

$$D_g = \sum_{k \in G_g} \exp(\delta_k/(1-\sigma)). \tag{A5}$$

We can now take logs of market shares and rewrite to arrive at an estimating equation that allows us to estimate a linear equation to identify the parameters of interest, α and σ, which govern the own- and cross-price elasticities:

$$\ln(s_j) - \ln(s_o) = x_j\beta - \alpha p_j + \sigma \ln(s_{j/g}) + \xi_j. \tag{A6}$$

This gives us a demand equation that is linear in the error term that we estimate using instruments for the prices and market share within nests. Referring back to the sensitivity of demand, note that under the present assumptions each element of Ω (see equation (7)) takes on a value according to the following (these price effects are found by partial differentiation of equation (A4) with respect to prices):

$$\Omega_{k,j} = -\frac{\partial s_k}{\partial p_j}$$
$$= \begin{cases} \alpha s_j \left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma} s_{j|g} - s_j \right) & \text{if } j = k \\ -\alpha s_k \left(\frac{\sigma}{1-\sigma} s_{j\,|\,g} + s_j \right) & \text{if } j \neq k \text{ and } j,k \in \text{ same nest, same firm} \\ -\alpha s_k s_j & \text{if } j \neq k \text{ and } j,k \in \text{ different nests, same firm} \\ 0 & \text{otherwise} \end{cases} \tag{A7}$$

The estimates of α and σ that we find by estimating equation (A6) can thus be used together with observations on market shares and prices to solve for marginal costs using equation (8). The counterfactual simulations that we perform will clearly imply changes in quantities, and counterfactual market shares are given by

$$s_j(p^*) = \underbrace{\frac{\exp\left(\delta\left(p_j^*\right)/(1-\sigma)\right)}{D_g(p^*)}}_{s_{j|g}^*} \underbrace{\frac{D(p^*)_g^{1-\sigma}}{1+\sum_{g=1}^{G} D(p^*)_g^{1-\sigma}}}_{s_g^*}. \tag{A8}$$

Table AI

Demand Estimation, the Swedish Market for Bottled Water

The table reports results from the regression of

$$\ln(s_{jrt}) - \ln(s_{ort}) = x_{jrt}\beta - \alpha p_{jrt} + \sigma \ln(s_{jrt/g}) + \xi_{jrt}$$

using pooled ordinary least squares, ordinary least squares, and generalized method of moments, respectively. The dependent variable is thus the log of the market share of brand j in region r at time t minus the corresponding market share for the outside good. We assume that the total market is given by a consumption of 9.025 liters per person per month. The explanatory variables are price per liter in Swedish kronor of brand j in region r at time t, marketing expenditures of brand j at time t, regional dummies, a dummy for the high demand months of summer, the log of the market share within the nest (sparkling or nonsparkling) of brand j in region r at time t, a constant, and product characteristics. The product characteristics that we use are country of origin dummies, a dummy for Premium products and a dummy for natural mineral waters. The instruments we use are a brand- and location-specific cost shifter (the change in the diesel price times the distance from producer to market) and two sets of variables affecting markups, population in region r at time t and the number of competing products in region r at time t. The regression is estimated using monthly data from six Swedish regions for the period November 1999 to September 2001. Standard errors are in parentheses. All reported coefficients are significant at the 1% level.

Variable	Pooled OLS	OLS	GMM
Price	−0.209	−0.085	−0.239
	(0.006)	(0.005)	(0.081)
Ln(market share within nest)		0.704	0.698
		(0.007)	(0.101)
Brand characteristics		Advert. exp.	Advert. exp.
		Country effects	Country effects
		Premium dummy	Premium dummy
		Natural min w.	Natural min w.
Other explanatory variables	Summer	Summer	Summer
	Constant	Regional dummies	Regional dummies
		Constant	Constant
Instruments	No	No	Yes
Adjusted R^2	0.25	0.8	
Root MSE	2.31	1.17	1.3
Number of observations	6,786	6,552	6,387

We now briefly describe demand estimation in this particular case. The data is described in more detail in Friberg and Ganslandt (2006), who use the same data set. We estimate equation (A6) by generalized method of moments and use instruments for price and market share within nests (still, sparkling, outside good). The dependent variable is thus the log of the market share of brand j in region r at time t minus the corresponding market share for the outside good. We assume that the total market is given by a consumption of 9.025 liters per person per month. The explanatory variables are price per liter in Swedish kronor of brand j in region r at time t, marketing expenditures of brand j at time t, regional dummies, a dummy for the high demand months of summer, the log of market share within the nest (sparkling or nonsparkling) of brand j in region r at time t, a constant, and product characteristics. The product characteristics that we use are country of origin dummies, a dummy for Premium products and a dummy for natural mineral waters. The instruments we use are a brand- and location-specific cost shifter (the change in the diesel price times the distance from producer to market) and two sets of variables affecting markups, namely population in region r at time t and the number of competing products in region r at time t. The central input from demand estimation for the simulations are the mean valuations for each product j (δ_j), and the estimated coefficients on price and market share within nests, α and σ, respectively. Table AI presents the results from estimation of demand (more specifications are reported in Friberg and Ganslandt (2006).

Appendix B: A Specification with Higher Markups

In this appendix we report results under an alternative specification with median markups of 57%, almost three times as high as under the preferred specification. A comparison between Table BI and Table III shows that the higher markups are associated with much lower exposures. We may also examine the exposure profiles under this alternative parameterization, as we do in Figure B1. The same qualitative results as in Figure 3 are apparent with long upward tails for imported brands such as Perrier and Evian and a long downward tail for a major domestic brand in the sparkling segment such as Ramlösa. This alternative parameterization is associated with lower own- and cross-price elasticities, however, which tends to raise profits and limit the percentage effects on profits of changes in exchange rates (or equivalently of asymmetric shocks to marginal costs), implying distributions that have a higher mean and that are much less skewed than their counterparts in Figure 3.

Table BI

Exchange Rate Exposure and Exchange Rate Pass-Through: OLS Regressions on Simulated Data with Higher (Counterfactual) Markup

The top panel reports the estimated coefficients from brand-level ordinary least squares regression of the natural log of simulated operating profits in producer currency. Separate regressions are run for each brand. The simulated profits are generated by a Monte Carlo procedure with 1,000 draws on the euro/Swedish krona (*Eursek*) and Norwegian/Swedish krona (*Noksek*) exchange rates. For each draw, Bertrand equilibrium prices are calculated by solving the system in equation (9) and the resulting profits are calculated. The parameterization below corresponds to a counterfactual specification with $\alpha = 0.085$ and $\sigma = 0.704$. As explanatory variables we use a constant, as well as the ln(*Eursek*) and ln(*Noksek*) exchange rates from the respective draws. The bottom panel reports the corresponding ordinary least squares regression in which the natural log of the (national average) price of the respective brand is the dependent variable. Standard errors are in parentheses. * denotes significance at the 5% level and ** at the 1% level.

	Evian (France)	Vittel (France)	Imsdal (Norway)	Blåvitt (domestic)	Perrier (France)	Ramlösa (domestic)
Dep. Variable	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)	Ln(prof)
Ln(*Eursek*)	3.008**	2.764**	−0.387**	−0.447**	5.436**	−0.012**
	(0.018)	(0.016)	(0.002)	(0.001)	(0.033)	(0.000)
Ln(*Noksek*)	−0.602**	−0.607**	2.18**	−0.451**	−0.239**	−0.004**
	(0.039)	(0.035)	(0.004)	(0.002)	(0.069)	(0.000)
Dep. Variable	Ln(price)	Ln(price)	Ln(price)	Ln(price)	Ln(price)	Ln(price)
Ln(*Eursek*)	−0.683**	0.640**	−0.106**	−0.061**	−0.816**	−0.005
	(0.007)	(0.003)	(0.009)	(0.012)	(0.006)	(0.009)
Ln(*Noksek*)	−0.009	−0.006	−0.391**	−0.067*	0.007	−0.002
	(0.016)	(0.006)	(0.019)	(0.026)	(0.012)	(0.019)

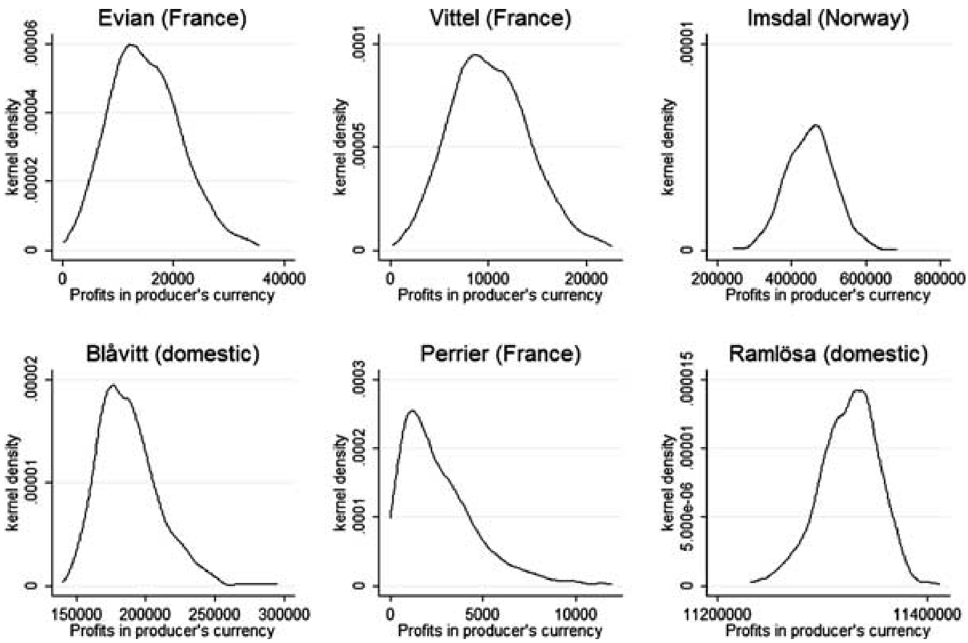

Figure BI. Kernel density of profits in producer currency with variability in exchange rate vis-à-vis euro and Norwegian kronor. High markup parameterization. The figure shows the distribution (kernel density) of brand-level profits for selected brands based on simulated profits generated by a Monte Carlo procedure with 1,000 draws on the euro/Swedish krona (*Eursek*) and Norwegian/Swedish krona (*Noksek*) exchange rates. For each draw, Bertrand equilibrium prices are calculated by solving the system in equation (9) and the resulting profits are calculated. The parameterization corresponds to a counterfactual specification with $\alpha = 0.085$ and $\sigma = 0.704$. All simulations are for May 2001.

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