

## DISCUSSION PAPER SERIES

No. 9266

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EVALUATE RISKY PROJECTS, WITH  
AN APPLICATION TO AUTOMOBILE  
PRODUCTION**

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# HOW TO USE DEMAND SYSTEMS TO EVALUATE RISKY PROJECTS, WITH AN APPLICATION TO AUTOMOBILE PRODUCTION

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Discussion Paper No. 9266  
December 2012

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## ABSTRACT

### How to use demand systems to evaluate risky projects, with an application to automobile production\*

This article introduces a method to quantify the effect of a firm's strategic choices on the risk profile of its profits at different horizons. We combine a demand system for differentiated products with counterfactual paths of risk factors. Prices, costs and quantities respond endogenously to the counterfactual state of the world. The draws on risk factors are generated using copulas, in a way that flexibly can be adapted to the risks faced in various industries. We illustrate the method by studying how the US operations of German carmakers BMW and Porsche are affected by the decision to relocate production, i.e. operational hedging. We find that for plausible costs of building a plant, production in the US is attractive for BMW, but not for Porsche.

JEL Classification: F23, L16 and L62

Keywords: demand estimation, exchange rate exposure, operational hedging and risk management

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\*We are grateful to the Swedish Research Council (VR) and Jan Wallanders and Tom Hedelius Stiftelse for financial support. We thank Elisa Alonso, Marcus Asplund, Johannes van Biesebroeck, Carlos Noton, Rickard Sandberg and seminar audiences at CEMFI, the CEPR/JIE workshop in Applied IO in Tel Aviv, EARIE in Istanbul, ESSEC, Foro de Finanzas in Elche, HECER, Lund, Stockholm School of Economics, Uppsala and Queen Mary for valuable comments.

Submitted 10 December 2012

## **Introduction**

The future profits of a firm depend on the realized values of risk factors that affect its costs and demand. Profits also depend on the strategic choices made by the firm itself and by its competitors. Furthermore, the strategic choices and the risk factors interact in possibly complex ways: locating production abroad or repositioning a brand to a premium segment will, for instance, alter the way that an exchange rate change affects costs and the profit maximizing price.

How can a manager contemplating different strategic choices gauge the effect of those choices on the risk profile of profits? This is the motivating question of this paper. Our methodological contribution is to show how to combine a demand system and risk factors to evaluate strategic choices at different horizons. Examples of strategic choices that we have in mind concern the scale of operations, production locations, product line length and brand positioning. Our starting point is that if we want to examine firm profits under different choices, in different states of the world, we desire a fully worked out structural model that relates demand to prices and to strategic choices. In recent years, following Berry, Levinsohn and Pakes (1995, BLP hereafter), structural models of demand have been developed in the field of Industrial Organization. These models have, with one exception, not been applied to the study of risk and typically consider only one or a few counterfactual scenarios. Thus, models of demand similar to the one we use have been applied to evaluate mergers (Nevo (2000)), to measure the impact of trade policy (Berry, Levinsohn and Pakes (1999)), to quantify the welfare effects of entry (Petrin (2002)) and to address the sources of the declining market share of US auto manufacturers in Train and Winston (2007). These demand estimation methods have also been applied to marketing-related issues, see Chintagunta and Nair (2011) for an overview. Perhaps closest in spirit to us is Berry and Jia (2010), who provide an ex post analysis of the sources of profit changes in the US airline industry, using a model of demand similar to the one we propose to use in a forward looking manner.

Demand estimation techniques are one building block for the method we propose. Our other building block is a framework to generate counterfactual draws on the risk factors. Examples of risk factors that we envision are input prices, exchange rates and economy-wide shocks to demand. The estimations that are used to generate the counterfactual draws of the risk factors are separate from the demand modeling. This allows one to for instance use long time series of macroeconomic variables while only using shorter time series data for the product market. We use copulas to provide a flexible way of modeling the correlation of the draws of the risk factors (see Patton (2009) for an overview of the use of copulas in Finance or Danaher and Smith (2011) for applications in marketing). The final step in our methodology is to feed the random draws on risk factors into the demand system, letting all prices, costs and quantities respond to generate counterfactual distributions for cash flows. Comparing such distributions for different strategic choices, and their net present value, brings us to our goal.

While neither demand estimation nor modeling of risk factors is novel we hope to show that combining these tools in the way that we propose is a fruitful way of analyzing strategic choices for a firm. While our aim is to contribute to methodology, we illustrate how the methods can be applied by focusing on production location choices of German carmakers BMW and Porsche. German carmakers that have substantial sales in the US are exposed to changes in the exchange rate between the euro and the US dollar. One response from several carmakers has been to open up production facilities in the US. For instance, BMW produces a number of models in the US and states in its 2007 annual report (p 62) that “From a strategic point of view, i.e. in the medium and long term, the BMW Group endeavors to manage foreign exchange risks by ‘natural hedging’, in other words by increasing the volume of purchases denominated in foreign currency or increasing the volume of local production.”<sup>1</sup> Other carmakers have followed different strategies: despite obtaining 30-40 percent of its sales in North America, Porsche produces exclusively in the euro area. We quantify how the risk profiles of Porsche’s and BMW’s US sales depend on the production location.<sup>2</sup> We use data on prices, quantities and product characteristics for the top segments of the US auto market for 1995-2006 to estimate demand that serves as the main input in our counterfactuals. The data are at the national level and products are defined at the model line level (such as Porsche 911, Ford Explorer and so forth). We consider three risk factors: Two real exchange rates and a measure of the business cycle. To estimate the stochastic properties of the risk factors we rely on data from 1973 onwards.

In terms of methodology we relate to two broad literatures apart from the ones already mentioned. The first literature is rooted in Corporate Finance and Management where it has long been taught that a way to evaluate investment projects with risky cash flows is to consider profits under the different realizations of risk factors and weigh these realizations according to their likelihood. One selects a probability distribution for each of a set of variables that affect profits, such as price and market size, and then use these distributions to generate counterfactual profit distributions (see Hertz (1964) for an early proposition and textbook coverage in Brealey and Myers (2003), Mansfield et al (2009) or Damodaran (2010)). The method we propose applies the same logic but, by using a demand system, we circumvent several of the troublesome features of the approach that is associated with the literature since Hertz. Using structural estimates of demand allows us to deal with the fact that cash flows themselves are likely to be endogenous to the investment project under consideration in a straightforward manner. It also, in an economically sound way, introduces the correlation between endogenous variables such as quantities, costs and prices – of both the firm itself and its competitors.

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<sup>1</sup> The German carmaker Volkswagen also opened a US plant in 2011 and states in its annual report 2009 (p 188) that “Foreign currency risk is reduced primarily through natural hedging, i.e. by flexibly adapting our production capacity at our locations around the world, establishing new production facilities in the most important currency regions and also procuring a large percentage of components locally.”

<sup>2</sup> Indeed, Porsche is enough of a schoolbook case on exchange rate exposure that it is featured as mini cases in two of the leading textbooks in international finance (Eiteman, Stonehill and Moffett (2007, p 322) and Eun and Resnick (2007, p 236)) and a popular business school case: Porsche exposed (Moffet and Petitt (2004)).

Furthermore, rather than conjecturing probability distributions about variables such as sales (for which we often have short relevant time-series data) we can use longer time series to estimate probability distributions for many cost and demand shifters such as prices of raw materials and exchange rates. The discipline imposed by this should be especially valuable given the extensive evidence that humans are prone to behavioral biases when probabilities are involved (see for instance the seminal work of Tversky and Kahneman (1971) and the large literature that has followed).

The second literature that we relate to develops tools to estimate dynamic oligopoly games (see for instance Ericson and Pakes (1995), Bajari, Benkard, Levin (2007) or Akerberg et al (2006) and Aguirregabaria and Nevo (2012) for surveys). These papers are closely related to the present paper in that they develop tools to estimate structural models of demand and use them to examine industries over time, while allowing for strategic choices to affect the payoffs of competitors. However, when considering many strategies of several competitors the state space grows rapidly and computational costs are an important restriction. At the risk of oversimplifying, the papers in this literature have largely concentrated on inferring parameters or behavior that is hard to observe directly, such as the sunk costs of entry. Such information is of clear importance to a policymaker trying to for instance gauge the probability of entry following some policy change (for steps in the latter direction see Benkard, Bodoh-Creed and Lazarev (2010)). The assumptions on the type of shocks faced by firms are typically quite stylized (such as i.i.d. firm specific shocks to the sell-off value of the firm) and neither the time series properties of shocks, nor using the models in a forward looking manner, have been the focus of this literature. In contrast, the present paper puts the *future distribution of shocks* center stage – that is, it focuses on how should you value the profits associated with an investment when exogenous risks such as exchange rates or the business cycle are important. For many applications we ultimately wish to have a framework that is suited for both dealing with uncertainty that arises because of the strategic interaction and for dealing with the risks that stems from the stochastic nature of exogenous demand and cost shocks – see Besanko et al (2010) for such a combination in a stylized framework. For the time being we believe that is useful to complement work that focuses on the strategic interaction with work that focuses on how exogenous shocks feed through into profits – and how the impact of cost and demand shocks depends on strategic choices. The relation between the present work and research in finance and operations management is perhaps easier to appreciate after we have covered the model, and the penultimate section of the paper therefore spells out how our research informs research in these other fields.

In the next section we present the methodology for generating counterfactual draws on cost and demand shocks and for estimating demand and counterfactual profits. In Section 3 we present our empirical application and in Section 4 we show the results from demand estimation and from the generation of counterfactual macroeconomic conditions. The counterfactual profits are then presented

and analyzed in Section 5. We discuss further relation to the previous literature in Section 6 and conclude in Section 7.

## **2 How we generate counterfactual distributions of discounted cash flows.**

### *Overview*

The ultimate object of interest in our application is the probability distribution of profits, translated into euros, stemming from the US sales for BMW and Porsche. By producing a model locally in the US rather than in the euro area, the risk profile will be affected. We consider three risk factors: The real exchange rates between the dollar and the euro (usd/eur), between the dollar and the Japanese yen (usd/jpy) and the measure of consumer confidence published by the Conference Board. Consumer confidence is frequently mentioned in the industry as an important covariate for the demand for cars, as stressed by Ludvigson (2004). To estimate demand we use data on the products of BMW and Porsche, as well as of the products with which they compete.

We use Figure 1 to illustrate the methodology. The first stage concerns the joint modeling of risk factors, the second deals with the modeling of prices, costs and quantities sold, and the final stage consists of reporting the resulting profits and discounted cash flows. Importantly, although some risk factors may also feature in the demand estimation, *demand and risk factor modeling are completely separate*.<sup>3</sup> In corporate finance the term “cash flow” is frequently used to denote operating profits. In this paper we use operating profits and cash flows as synonyms – both measure the profits as price minus marginal costs times quantities (in our application we assume that marginal costs are independent of quantity produced).

[Figure 1 about here]

### *Risk factor modeling*

The first step is to choose the risk factors that are seen as potentially important and to generate counterfactual draws of these risk factors. Risk factors clearly vary with the business conducted by an enterprise. In the typical application we envision that firms would have views on the main potential risk factors. Consider the airline business for instance. On the demand side, airlines depend on economic activity in the economy and on the cost side, fuel costs are commonly seen as an important source of risk. By risk factors we mean variables that have an effect on profits and for which we can

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<sup>3</sup> This can be useful if we for instance want to include several business cycles to determine the stochastic properties of risk factors, but only use a shorter time period for the relevant output markets. As an example note that while oil prices from the 1980s may contain useful information on distribution of oil price shocks, demand estimates for mobile phones from the 1980s are not likely to be informative for today’s market for mobile phones.

estimate a probability distribution. Risk factors in our setting can thus for instance be market prices (such as exchange rates or prices of raw materials) or demand shocks (for instance captured by business cycle measures).

There are a number of ways one generate counterfactual draws on the risk factors. Intuitively, the idea is to capture the main features of the joint distribution of the risk factors and generate random draws based on it. Jointly modeling the factors, instead of assuming their independence, is important in a number of applications - for instance, in the hypothetical case where costs are subject to exchange rates and demand is subject to interest rate risk, the cost and demand risk factors are likely to be correlated. One could assume factors follow a parametric distribution. Alternatively, one could estimate a vector autoregressive model of factor returns.

In this paper we make use of copula methods. In recent years copulas have been used to model the interdependencies between asset prices (see for instance Jondeau and Rockinger (2006), Kole et al (2007)). The attractiveness of the copula approach is that it allows modeling of the univariate processes separately from their dependence. The core result with regard to copulas is due to Sklar (1959) who showed that any joint distribution of random variables can be decomposed into two parts: The marginal univariate distributions and a function, the copula function, which captures the dependency between the marginals. Consider three random variables  $X_1, X_2, X_3$ . The joint cumulative density function (cdf) is given by  $H(x_1, x_2, x_3) = Pr[X_1 \leq x_1, X_2 \leq x_2, X_3 \leq x_3]$ . For each  $X_i, i=1,2,3$ , the marginal cdf is given by  $F_i(x_i) = Pr[X_i \leq x_i]$ . Using  $C$  to denote the copula function we can thus write

$$H(x_1, x_2, x_3) = C(F_1(x_1), F_2(x_2), F_3(x_3)).$$

As detailed in Section 4.3, we model the marginal distributions for exchange rates and consumer confidence using GARCH processes. Our first step is thus to estimate the parameters from univariate GARCH processes and then estimating the copula relation between the residuals. We then use these estimated parameters to generate 200 random shocks for each future period in the forecast horizon and let the shocks in each period follow the GARCH and copula relations. We use counterfactual values 12, 24, 36 and 48 months ahead from the end date July 2006.

In general terms, the first step is thus the modeling of the joint distribution  $G(\cdot)$  of risk factors  $(f_1, \dots, f_k)$ . We denote one given set of simulated draws by  $f_{[s],t+n}$ , where  $s=1, \dots, S$  is the simulation draw and  $t+n$  denotes that the draw refers to  $n$  periods ahead.

### ***Model***

Figure 1 also illustrates how risk factors  $f_{[s],t+n}$  feed into costs, prices and quantities sold in the general case. To estimate the relation between the risk factors and demand one could in principle estimate product level demand curves – regressing quantities on prices of the own product, the prices of



competitors and demand shifters represented by (some of) the risk factors. A concern in many differentiated product industries is that product attributes and the set of competitors change over time which implies that we need to identify effects from short time series. Such problems are commonly faced in estimating demand for differentiated products and are the motivation for the estimation approach that we describe here.

We follow BLP (1995) who estimate a random-coefficients (RC) logit model for automobiles in the US market. We do not develop every detail of the model, but rather refer to previous treatments including, in particular, BLP (1995) and Berry (1994); Davis and Garcés (2010) provide an accessible discussion. The demand system builds on discrete choice modeling of individual choices, but only market level data are needed. The key assumption, that allows us to avoid directly estimating an infeasible number of cross-price elasticities, is that we model demand as dependent on product characteristics. Thus, when for instance buying a car in the BMW 3-series, the consumer purchases a combination of observable product characteristics. In our application to car demand we use price, size, horsepower/weight, brand and country of production. Any risk factors that affect demand should also be included in the specification. In our case, as already mentioned, we include consumer confidence as a measure of the state of the world which affects the utility of buying a car. By imposing a structural model of demand, the own- and cross price effects are found by using the estimated coefficients of the model in combination with the model structure. Modeling demand as dependent on characteristics also allows us to handle changing product characteristics and product introductions. Define the conditional utility for individual  $i$  when consuming product  $j$  from market  $m$  (where  $m$  can refer to both the time and geographical dimension) as:

$$u_{ijm} = \sum_{k=1}^K x_{jmk} \beta_{ik} + \zeta_{jm} + \varepsilon_{ijm}, \quad i = 1, \dots, I; j = 1, \dots, J; m = 1, \dots, M$$

where  $x_{jmk}$  are observed product characteristics and  $\zeta_{jm}$  represent unobserved (by the econometrician) product characteristics but that are assumed to be observed by all consumers. Different consumers are allowed to have different valuation of the various characteristics. Following the literature, we decompose the individual coefficients

$$\beta_{ik} = \bar{\beta}_k + \sigma_k v_{ki}$$

where  $\bar{\beta}_k$  is common across individuals,  $v_{ki}$  is an individual-specific random determinant of the taste for characteristic  $k$ , which we assume to be Normally distributed and  $\sigma_k$  measures the impact of  $v$  on characteristic  $k$ . Finally,  $\varepsilon_{ijm}$  is an individual and option-specific idiosyncratic component of

preferences, assumed to be a mean zero Type I Extreme Value random variable independent from both the consumer attributes and the product characteristics. The specification of the demand system is completed with the introduction of an outside good with conditional indirect utility  $u_{i0} = \xi_{0m} + \sigma_0 + v_i + \varepsilon_{i0}$ , since some consumers decide not to buy any car.

Risk factors may also have a direct impact on the cost of production. We focus on marginal costs and follow BLP (1995) and others in this literature and assume that marginal costs are constant. In our case the exchange rates affect the marginal cost of car production in the euro area and in Japan relative to the US market, and we can view exchange rates as marginal cost shifters. Via the effect on prices, this marginal cost shock will feed through into demand as well. If a firm were to use these methods to evaluate projects, it would use own internal calculations to model the link between costs and input prices or other cost shocks such as exchange rates. We lack this detailed data and therefore make an assumption of Bertrand competition by multi-product firms to back out the marginal costs that are implied by this form of competition when coupled with the demand specification that we use. This is the way that marginal costs have typically been estimated in the previous literature that applies these demand estimation methods.

Demand will also depend on prices, which will endogenously depend on the realizations of the risk factors. If used by the firm itself, with knowledge of internal costs and pricing rules, it can operationalize these pricing rules in the simulations. If the firm applies a fixed markup on costs for instance, the relation between price and costs will be given by this relation in the counterfactual simulations. To model prices of competing products under different scenarios the firm may also use historical data, and regress prices on realizations of risk factors and product fixed effects. Using the point estimates from such hedonic regressions, it is then straightforward to use the estimated coefficients to generate counterfactual prices that reflect the draws of the risk factors in each counterfactual scenario. Alternatively, one can use an assumption of all firms setting prices in a static Nash-Bertrand fashion. Note however while the type of models that we build on are generally seen as giving a plausible representation of substitution patterns on the part of consumers, static Nash-Bertrand pricing may overestimate the degree of price adjustment in many cases. In her study of the US car market, using similar tools as we do, Goldberg (1995, p. 937) for instance notes that “After 1985, the model predicts a significant increase in German import prices as a consequence of a dramatic dollar depreciation which is not matched by the data. In fact, the prices of German imports remained fairly constant during 1986 and 1987.” That consumer prices are stable by assumption, but quantities vary over the business cycle is a central feature in much of macroeconomic modeling for instance.<sup>4</sup> Nakamura and Zeron (2010) and Goldberg and Hellerstein (2012) introduce dynamic price

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<sup>4</sup> See Okun (1981) for a seminal reference. Copeland and Hall (2011) use transaction prices for the big three US carmakers and show that demand shocks have a small impact on price and are absorbed almost entirely by sales and production decisions.

adjustment in a framework similar to ours. Including dynamic price adjustment with a large number of counterfactual demand and cost shocks would be very computationally demanding and we therefore opted for hedonic price regressions to yield counterfactual prices in a straightforward manner.<sup>5</sup>

### *Outcome*

We have thus outlined how the random draws of the risk factors can be modeled to affect prices, costs and demand. The final outcome of a set of n-period-ahead simulation draws  $f_{[s],t+n}$  is the profit function  $\pi_{[s],t+n}$ . By repeating this iteration S times one can approximate the distribution function of the profits of firm with their empirical counterpart. It is worth emphasizing again that the empirical distribution of profits is also conditional on a strategy, e.g. having the entire production chain located in the home market as opposed to consumer market, or stabilizing prices in the currency of the market rather than passing through costs. Discounting future cash flows under the different scenarios allows comparing the outcomes of different strategies. We can discount future cash flows along each of the simulated paths of the risk factors. Therefore we can use the framework not only to examine expected profits but also consider differences in the tails of the profit distribution, which may be of central interest for risk management purposes and for evaluating the effect of different strategic choices on the risk profile of a firm.

For each set of draws of exchange rates and consumer confidence we generate operating profits at the product level for all firms, but given our focus will report them only for BMW and Porsche. At the producer level, total cash flows from US sales equal the sum of cash flows from all products controlled by the firm in question and translated into the home currency. Cash flows for a product that is produced in the euro area by a firm based in the euro area at period  $t+n$ , for a set of counterfactual draws  $s$ , is therefore given by

$$\Pi_{s,t+n}^{EU} = \left( \left( \frac{eur}{usd} \right)_{s,t+n} \hat{p}_{s,t+n} - \hat{c}_{s,t+n}^{EU} \right) \hat{q}_{s,t+n}(\hat{c}_{s,t+n}, \hat{p}_{s,t+n}(e)). \quad (1)$$

The eur/usd exchange rate here is one draw from a counterfactual distribution. The price  $\hat{p}$  reflects the counterfactual vector of draws of exchange rates. Counterfactual demand,  $\hat{q}$ , depends on the vector of counterfactual prices for all producers  $\hat{p}$ , and on the counterfactual realization of  $\hat{c}$ , the consumer confidence. The marginal cost  $\hat{c}$  is assumed to be independent of volume and fixed in the currency of the production location. The last period for which we estimate demand is model year 2005-2006 and we simulate counterfactual predictions looking ahead from this date. In the case where production of a model is in the euro area, we take this marginal cost for each car model to be fixed in euros in the forward looking scenarios. Similarly, *marginal* costs of cars produced in other currency areas are

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<sup>5</sup> Our motivation here is somewhat related to the estimation of policy functions that form the first stage in Bajari, Benkard and Levin (2007).

assumed to be fixed in the currency of production location. As quantities vary in the simulations total costs will vary across the simulation draws. Furthermore, the marginal costs of cars produced outside the US will shift, when expressed in US dollars, reflecting the draws from the exchange rate distributions.

For a BMW or Porsche model that is counterfactually produced in the US we assume that the marginal cost, in US dollars, is fixed at its 2006 level. Assuming marginal costs fixed in either the home or the market currency is a simple way to capture two polar cases regarding the correlation between exchange rates and marginal costs. In using the backed out marginal costs from 2006 the counterfactual simulations for BMW and Porsche start from a situation where marginal costs are equal in EU and US. We thus tone down any level differences in costs as a motivation for producing abroad, which we would argue is a reasonable simplification in this case. For BMW and Porsche we compare production in Germany with production in the US. Average differences in factor prices are limited between these two countries. For instance, over 1992 to 2005 wages in manufacturing are on average 6.8 percent higher in US than in Germany.<sup>6</sup> The swings in exchange rates are, for these production locations and a given technology, likely to overwhelm level differences in production costs. For example, the usd/eur exchange rate fell from 1.4 in 1996-7 to 0.88 in 2001-2 and then rose again to 1.22 by 2005-6. Inflation is low in both countries during this time so such changes translate into cost differences of production. Like most of the literature that applies these kind of demand models (such as BLP) we do not have access to detailed marginal cost information – we therefore opted for these simple and transparent assumptions on marginal costs rather than ad-hoc assumptions about for instance supplier networks in Germany and US affect marginal costs. As we use the empirical exercise as an example meant to illustrate how the methodology can be used – and the ultimate goal is to provide a tool that will be useful to decision makers in firms (or consultants with access to firm level data) rather than competition authorities we do not believe that this is not an important weakness. Alternative assumptions on marginal costs are straightforward to implement, should one wish to do so.

If a producer located in the euro area (EU) instead produces a model locally in the US, the cash flow from that model is

$$\Pi_{s,t+n}^{US} = \left(\frac{eur}{usd}\right)_{s,t+n} (\hat{p}_{s,t+n} - \hat{c}_{s,t+n}^{US}) \hat{q}_{s,t+n}(\hat{c}_{s,t+n}, \hat{p}_{s,t+n}(e)). \quad (2)$$

When production is in the EU, as in equation (1), costs are thus stable in euro whereas the exchange rate has a large effect on revenue. In contrast, in (2) costs and revenue are in the same currency and it is only the net profit that is affected by the exchange rate.

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<sup>6</sup> Source: OECD, labor compensation per employee in manufacturing, expressed in USD using PPP-adjusted exchange rates.

To produce cars targeted to the US market locally in the US can be seen as operational hedging. An alternative for a risk-averse owner is to use financial hedging and we note that a possible application for a manager is to also include cash flows from various financial hedges at this stage of the simulations.

To calculate the net present value (NPV) of the different production locations we need three ingredients: A set of future profits as outlined above, an appropriate discount rate, and initial outlays. We do not aim to make a methodological contribution on how to establish the appropriate discount factor.<sup>7</sup> We therefore use standard assumptions from corporate finance and discount cash flows using the weighted average cost of capital (WACC). We take the profit distribution 4 years ahead as reflecting the long run distribution in the calculation of NPV. We thus calculate the NPV of each of the 200 streams of cash flows. As initial outlays we take back-of-the-envelope calculations of the cost of establishing a new production facility.

### **3 The empirical application**

#### *Data*

We use quantity sold, recommended dealer price and product characteristics for all cars sold in the luxury, sport, SUV (sports utility vehicles) and CUV (cross over utility vehicles) segments in the US. The main source of data is WARDS who supplied us with a panel of monthly sales by model line (BMW 3 series, Porsche 911 etc). We examine the period from August 1995 to July 2006. In our regression analysis we aggregate sales to 12-month periods, but rather than use calendar years we note that new models, and a new recommended dealer price, appear in late summer each year.<sup>8</sup> Our time unit of analysis therefore runs from August to July the following year and we use the term model-year.

In Table 1 below we show some descriptive statistics for our set of cars. We examine the upper segments of the car market and the mean real price is roughly stable at 35 000 dollars. The lowest price is for a Pontiac G5 and the highest is for a Porsche Carrera GT. On average some 30 000 to 40 000 cars are sold per model in a given model-year. The largest selling name plate in the data is the Ford Explorer. The number of models in the data increases substantially over the period, mainly reflecting growth in the CUV and SUV segments.

[Table 1 about here]

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<sup>7</sup> See Cochrane (2011) for an overview of current research on discount rates.

<sup>8</sup> We use the recommended dealer price as our measure of price -- a simplification that we share with previous work examining the car market at this level. In practice dealers buy from the manufacturer and rebates on the car are given, either in the form of lower prices, discounted financing or buy-in's of the customers' old car: see Busse, Silva-Risso and Zettelmayer (2006) for an analysis of pricing at a sample of Californian retailers.

The dollar appreciated against the euro and yen up until the middle of the period, after that it depreciated against the euro but remained rather stable against the yen. The consumer confidence measure of the business cycle shows substantial variability as well.

### ***The US market for BMW and Porsche***

German-based BMW is one of the ten largest car manufacturers in the world. Over the period, on average, 23.7 percent of BMW deliveries of cars are in North America.<sup>9</sup> Compared to other auto manufacturers the accounting figures point to BMW as a profitable firm with high margins: its' return on assets is on average 5.3 percent and the profit margin is 15.6 percent (EBITDA operating margin before interest, taxes, depreciation and amortization).<sup>10</sup> The main products for BMW over this period are the luxury cars in the 3, 5 and 7 series. At the start of the period it also sells the luxury sports car Z3. BMW further controlled the Land Rover and Range Rover lines that were produced in the UK. In 2000 Ford Motor Company took control of these brands. Since 1999 BMW has production capacity in a US factory in Spartanburg. In 2005-2006 the luxury sports car Z4, as well X3 and X5, that are classified as middle luxury CUVs are produced in this plant. All other products are produced in the euro area, apart from the Mini, which is produced in the UK. We therefore expect a potentially important role for the usd/euro exchange rate on BMW profits. Indeed the annual report for 2005 (p. 56) notes that "Of all the currencies in which the BMW group does business, the US dollar represents the main single source of risk; fluctuations in the value of the US dollar have a major impact on reported revenues and earnings."

Turning now to Porsche, the North American market accounted for an average of 35 percent of its sales revenue. During this period all production of Porsche cars is located in Europe. During the time period that we examine, accounting profitability and operating margins are high at Porsche: the return on assets is on average 19.7 percent and the operating margin is 24.7 percent. Porsche's main product over the period is the 911 - a name plate that was introduced in 1963 and still accounts for almost half of Porsche's US revenues at the end of the sample period. At the start the 911 is the only model marketed by Porsche in the US. The small roadster Boxster is then introduced in late 1996. The Cayenne is introduced in 2003 (identified as a middle luxury CUV by WARDS) and the sports car Cayman in 2005. In 2004 Porsche adds the top of the line sports car Carrera GT. After only having had assembly in Germany, Porsche starts production of its Boxster in Finland in 1997 (under an agreement with Finnish producer Valmet). Since 2005 also the Cayman model is produced in Finland which, like Germany, is part of the euro zone.

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<sup>9</sup> Source. BMW Annual reports 2005 and 2000.

<sup>10</sup> Average over August 1999 to July 2006. Corresponding return on assets for Daimler (1.5%), Ford (-0.4%), Toyota (6.8%) and Volkswagen (2.4%). Corresponding EBIDTA margins for Daimler (8.1%), Ford (6.8%), Toyota (13.9%) and Volkswagen (10.5%). Source for this and the statistics that follow for Porsche: Orbis.

## 4. The estimated model

### 4.1 Demand Estimates

Table 2 reports estimates of two RC logit specifications for the US car market. Both use price, engine power (HP), size and whether non-manual transmission is included in the baseline model as observable product characteristics. We model price as a random coefficient with a mean effect of price on utility and individuals' coefficients on price follow a distribution as outlined in Section 2. Both specifications also include time (model-year), country of origin, and brand fixed-effects. We treat price as endogenous in our demand specification. To estimate our model, besides the exogenous characteristics, we use the BLP instruments (following BLP (1995)), a set of polynomial basis functions of exogenous variables exploiting the three-way panel structure of the data, consisting of the number of firms operating in the market, the number of other products of the same firm and the sum of characteristics of products produced by rival firms. As documented in the literature (Berry 1994, BLP 1995), not accounting for the endogeneity of prices results in an attenuation bias, that is, the price coefficient is biased towards zero, and this is what our findings also suggest: the uninstrumented version of Specification I has a price coefficient of -0.002, well below the instrumented ones at -0.021. Besides the tenfold increase in the slope of the demand curve, at 27.52 (and significant at the one percent level), the F-statistic of the first-stage regression of price on the exogenous regressors is well above the rule-of-thumb value of 10 suggested by Staiger and Stock (1997). This suggests that instruments are not weak and that there is no evidence that the instrumented price coefficient is biased towards the uninstrumented one. Instruments are also not rejected when computing tests of overidentifying restrictions, as reported in Table 2.

[Table 2 about here]

The stance in which Specifications I and II differ is in the treatment of consumer confidence and market segment variables. Specification I uses consumer confidence and separate fixed-effects for market segments. In contrast, Specification II uses interactions of market segments and consumer confidence. Specification II thus allows asymmetric responses in market shares according to the market segment a model belongs to, according to which economic outlook consumers expect to prevail. Both specifications have significant coefficients for the mean and for the dispersion of price coefficients, whereas the remaining characteristics are usually not significant. In fact, most of the explanatory power for market shares tends to come from brand and market segment fixed-effects.

The (own) price elasticities (equivalently, markups) of the models in Specification II are in the range 3.7-7.3 with an average elasticity 6.0, thus broadly in line with previous studies of the car industry, notably Petrin's (2002) RC logit estimates using micro data (see, for instance, column 6

of his Table 9).<sup>11</sup> Interestingly, the estimates for Specification II suggest an intuitive "pecking order" effect of the interaction terms. For instance, demand for the "Upper Luxury" segment tends to be more sensitive to consumer confidence than that of the "Middle Luxury" segment, which in turn is more sensitive than that of the "Lower Luxury" segment. We interpret these results as evidence that, conditional on buying a car, consumers are more likely to purchase models from high-end segments the more confident they are about the economic outlook.

## 4.2 Price setting

Demand will depend on prices, which will endogenously depend on the realizations of the risk factors. When faced with the task of estimating prices of a new equilibrium, e.g. following a merger between two firms, economists typically assume a form of conduct, say Bertrand-Nash, and compute the new equilibrium following the change in product ownership due to the merger. Recently, Nakamura and Zeron (2010) and Goldberg and Hellerstein (2012) introduce dynamic price adjustment to account for pass-through in a framework similar to ours. While increases in computing speed may make this the preferred scenario in future work, we have instead opted for hedonic price regressions as a straightforward way to generate empirically plausible counterfactual prices (since we perform equilibrium calculations based on joint realizations for a high number simulations in order to approximate the empirical distribution of firm profits under each scenario). For managerial applications we see this as an attractive solution awaiting further improvements in computing speed.

We use the coefficients from hedonic regressions to generate counterfactual prices. We regress real prices on forward exchange rates interacted with country of origin, product characteristics (HP, size, transmission) and product fixed effects. To gauge if the results are reasonable we report the elasticities in Table 3. The exchange rate pass-through in this regression is 0.146 for the euro exchange rate and 0.116 for the Yen.<sup>12</sup> Both are significant at the 5 percent level. Comparing to other estimates, they are somewhat on the low side. A number of studies examine pass-through in import prices (see Goldberg and Knetter (1997) for an early survey) and find pass-through elasticities that are frequently equal to about one half. Note however that pass-through at the border is typically substantially higher than measured pass-through at the retail level. We can also compare to another non-structural estimate for the US auto market, Hellerstein and Villas-Boas (2010). The 24 models in their study exhibit an average pass-through of exchange rates into transaction prices of around 38 percent, but with large standard deviations.

[Table 3 about here]

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<sup>11</sup> Goldberg (1995) finds elasticities in the range 1.1-6.2 across specifications and market segments, using data from 1983-1987.

<sup>12</sup> The elasticity with respect to horsepower is 0.166 and significant at the 1 percent level. Size and transmission are not significant, but the car model fixed-effects capture much of the variation that could identify these elasticities; the adjusted R-square for this regression is 0.986.



### 4.3 Counterfactual shocks

We use bimonthly data for consumer confidence and the real exchange rates for the period January 1973 to July 2006 to estimate the statistical properties of these variables, which we then use to generate our counterfactual draws. We use a multivariate t-copula to model the dependence between our three stochastic variables of interest. Define  $F_i(x_i) \equiv u_i$ . The t-copula is then defined by

$$C(u_1, u_2, u_3; \rho, \nu) = T_{\nu, \rho}(t_\nu^{-1}(u_1), t_\nu^{-1}(u_2), t_\nu^{-1}(u_3))$$

where  $T_{\nu, \rho}$  is the cdf of the multivariate Student's t-distribution with correlation matrix  $\rho$  and degrees of freedom  $\nu$ . The cdf of the univariate student's t-distribution with  $\nu$  degrees of freedom is denoted by  $t_\nu$ . An attractive feature of the t-copula is that it allows for a higher dependence between extreme events than for instance the Gaussian copula.

We use GARCH(1,1) models to estimate the exchange rate processes. Use  $y_{it}$  to denote the logarithmic returns (first-differences of logarithmic series) in the real usd/eur and real usd/jpy respectively between time  $t$  and  $t-1$ . We assume that the process followed by  $y_{it}$  is given by

$$y_{it} = c_i + \eta_{it}$$

$$\sigma_{it}^2 = \kappa_i + \alpha_{i1}\sigma_{it-1}^2 + \alpha_{i2}\eta_{it-1}^2.$$

That is, today's realization is equal to the last period's value plus a possible drift term and a random shock. The error term  $\eta$  is assumed to follow a t-distribution with mean zero. We allow the shocks to have time varying volatility.

We model the process followed by consumer confidence in first differences, such that  $y_{it}$  is the difference in consumer confidence between time  $t$  and  $t-1$ .<sup>13</sup>

$$y_{it} = c_i + \eta_{it}$$

The decreases in consumer confidence are greater than increases. To capture this asymmetry we model the shocks using an exponential GARCH model, EGARCH(1,1). Again, let the error term  $\eta$  follow a t-distribution with mean zero and define  $z = \eta/\sigma$ . Following Nelson (1991) we then assume that volatility can be modeled as

$$\ln(\sigma_{it}^2) = \kappa_i + \alpha_{i1}\ln(\sigma_{it-1}^2) + \alpha_{i2}z_{t-1} + \gamma(|z_{t-1}| - E|z_{t-1}|).$$

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<sup>13</sup> As opposed to exchange rates, consumer confidence is not a traded asset. Moreover, anecdotal evidence suggests that individuals and firms focus on the levels and, more importantly, at the changes of this factor, thus the use of first differences in this case.

If  $\gamma$  is negative, the conditional volatility will be greater for negative shocks than for positive shocks. We fit a Student's t-copula to the residuals that we estimate by the GARCH and EGARCH processes. The estimation output for the marginal distributions is given in Table 4. The significant coefficient on lagged volatility in the usd/eur relation points to that volatility is indeed time-varying at this frequency. The process for consumer confidence reflects a pattern where the typical change is an upward drift but that negative shocks are associated with greater volatility (captured by the negative coefficient on the leverage term).

[Table 4 about here]

The degrees of freedom for the t-copula are estimated to be 21.65. The estimated correlation coefficients using the t-copula are -0.085 between usd/eur and consumer confidence, 0.063 between usd/jpy and consumer confidence and 0.522 between usd/eur and usd/jpy. Combining these estimates allows us to generate counterfactual shocks where the marginal distributions follow the GARCH processes and the co-dependence follows a t-copula in each period. Adding the succession of these shocks to the starting values in July 2006 then gives us counterfactual paths of the exchange rates and consumer confidence. As an example of our results, Figure 2 shows the distributions for counterfactual draws for these three variables 12 months ahead from July 2006. The histograms show the densities for the respective variable and the scatter plots the relation for each bilateral comparison. The scatter plot in the lower left hand corner for instance plots counterfactual draws of usd/eur against counterfactual draws of usd/jpy.

[Figure 2 about here]

As seen, the draws reflect substantial dispersion for all three variables. The skewness of consumer confidence is visible. The starting value in July 2006 is 134 and we see predictions for 12 months ahead centered at this level (median across the draws is 146, mean 139) but a long tail of weaker realizations. As seen in the scatter plots in the middle row, the relation between consumer confidence and the exchange rates is weak. The positive relation between the two exchange rates on the other hand is clearly visible in the scatter plots in the upper right and lower left corner. These then are the counterfactual levels of macro variables that are fed into the demand system when we consider the 12 month horizon ahead. Note that by the additive nature of the shocks we can view our results as simulating 200 possible paths of the underlying variables. As we expand the forecast horizon some of the paths for consumer confidence are predicted to be too low, or even negative. In these cases we replace the value with a hypothesized lower threshold of 10. The lowest level in the time period covered by our data is 15.8 (December 1982).

## 5. Simulation Results

We now turn to a presentation of the simulation results, feeding the counterfactual shocks into demand and costs and letting all prices respond. We compare different production scenarios as to what models are produced locally in the US – first in terms of per period profits and then in terms of NPV. It deserves to be emphasized that we examine only profits from the US market, thus considering the project of whether to set up production in the US as a stand-alone project.

### **5.1 Per period distributions of profits**

First we consider predicted profits up to 4 years ahead. In generating these counterfactuals we use data up to July 2006 only so the counterfactual profits for 2007 is one year out and, for 2010, 4 years out. A useful way of presenting simulated cash flows is to examine their frequency distribution. In Figure 3a we graph kernel density estimates of simulated cash flows for BMW at different horizons. As is to be expected, the further ahead, the more dispersed is the distribution. In 3a we present simulated profits for the case where the CUV's X3, X5, X6 and the roadster Z4 are produced in the US. This corresponds to the actual production locations in July 2006. In 3b we compare simulated profits under the current production locations with a counterfactual where there is only production in the EU (3 years ahead). As seen, average profits are similar and there is considerable dispersion in both scenarios. By having more production in the US, BMW makes cash flows less sensitive to the usd/euro exchange rate such that the probability distribution has a higher peak – a testament to that producing in the US can be seen as operational hedging. Also note that the lower tail of the profit distribution is shifted inwards. Conversely, the right tail is somewhat heavier when producing only in the EU.

[Figure 3 about here]

### **5.2 Net present value of different production locations**

The previous section illustrated one use for the simulation tools that we develop, namely to generate probability distributions for cash flows that we can use to examine risk at different horizons and under different scenarios. In the present section we use the counterfactual values to examine the choice of production locations. Using standard methods to calculate the WACC, the resulting discount rates are 5.66 for BMW and 5.93 for Porsche.<sup>14</sup> We use these discount rates to calculate the NPV of each of the 200 streams of cash flows and report summary statistics on these streams in Table 5.

[Table 5 about here]

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<sup>14</sup> For details on the WACC calculation see for instance Damodaran (2010). As risk free rate we use the 10 year German bund (interest rate of 4.05 in July 2006). Betas are 1.087 for BMW and 1.251 for Porsche (calculated on monthly data using DAX 1988:10 to 2006:6). The balance sheet information are based on the annual reports for 2005 (BMW) and 2005-2006 (Porsche).

To avoid clutter we report the discounted profit streams only in Table 5 and discuss separately what plant investments these might motivate. For simplicity we take the production capacity in EU to be in place and treat it as a sunk cost. The cost of building a plant in the US will depend on a large number of assumptions. To have a rough estimate of the cost of establishing a new plant we note that the cost of establishing Volkswagen's new plant in Chattanooga is reported to be 1 billion USD (equivalent to about 0.7 billion euros at the prevailing exchange rate in January 2010).<sup>15</sup> BMW opened a new plant in Leipzig, Germany, in 2005. A total of 1.3 billion euro had been invested in this plant prior to its opening (Annual report 2005, p 19).

Consider first the differences in the mean NPV and compare BMW's NPV in the current scenario with that of a case where all production is in the EU. The difference in mean NPV between the two scenarios is around 0.8 billion euro. The difference is of the same magnitude as the cost of establishing a new plant and from this perspective we would expect BMW to be roughly indifferent between the two. Producing all models locally in the US would increase the mean NPV by around 2.5 billion euro. We expect that the greater the flexibility that BMW has in switching production locations, the more will a US plant be worth. Indeed, in our simulations the NPV when production is perfectly flexible between the EU and the US is some 12.2 billion euro higher than when production is in the EU only.

Now turn to differences in mean NPV for Porsche. The ranking of scenarios is the same as for BMW, but differences are lower in absolute terms. Say that Porsche would want to follow BMW and produce their CUV, the Cayenne, in the US. The difference in mean NPV between that scenario and the current one is only 0.14 billion euro. This is much lower than the back-of-the-envelope costs of a new plant mentioned for BMW and Volkswagen. Also in the extreme case of perfectly flexible production, the increase in mean NPV is only 1.3 billion relative to the current scenario. These numbers stress that Porsche operates on a much smaller scale than BMW. For the model-year 2005-6 for instance BMW sold 73,800 cars of the models that it produces in the US. In the same period only 12,500 of Porsche's Cayenne were sold in the US. Porsche's total US sales for the same time period are 34,800. If the minimum efficient scale for an auto plant is rather high, it can clearly make sense for BMW to make the investment but not for Porsche. For comparison we can turn to Hall's (2000) study of minimum efficient scale using data from 14 North American plants operated by Chrysler. He finds a minimum efficient scale of around 3,000 cars per week (his Figure 6) and that the average plant operated 83 percent of the weeks. The yearly minimum efficient scale would thus be around 130,000 cars. There can clearly be important differences across time and manufacturers. Nevertheless the evidence presented here points to that limited incentives for Porsche from the

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<sup>15</sup> New York Times, "Students See a Creek and Imagine a Bridge for VW", Jan 26 2010.

revenue side, coupled with differences in scale, as a plausible explanation for why Porsche has not pursued the strategy of starting production in the US.

Let us also consider the full distribution of NPV's. Again examine BMW first. We see from Table 5 that the lower tail of cash flows is shifted inwards by producing some models in the US. The worst path implies a negative NPV of around -8.7 billion euro with the current set of locations rather than a negative value of -25.4 billion euro in the case where all production is in the EU. Now compare the first percentile of the NPV for different scenarios: with the current production locations, it is a modest negative value of -0.9 billion euros rather than -15.9 billion euros for the case where all production is in the EU. Moving all production to the US is associated with a drastic shrinking of the standard deviation of NPV. The logic is the same as that illustrated in figure 4b above: If only net revenue is affected by the exchange rate, the variability of cash flows is much lower. Differences in mean profits are slight across scenarios. This reflects the assumption that marginal costs of production are the same in the final pre-simulation period. Patterns for Porsche are similar to those for BMW, but NPV is much lower reflecting Porsches smaller scale of operation. How the firm should weigh these figures depends on risk preferences and on the value attached to avoiding negative outcomes. Compare the case of current locations for BMW with the counterfactual of having all production in the EU. The shrinking of the tails in the NPV distribution is then roughly symmetric. The difference between NPV's at the first percentile is roughly 15 billion euro, which is close to the difference in NPV's at the 99<sup>th</sup> percentile. The difference at the 5<sup>th</sup> percentile is also close to the difference at the 95<sup>th</sup> percentile and the difference at the 10<sup>th</sup> percentile is greater than that at the 90<sup>th</sup> percentile. For a decision maker that attaches a larger weight to outcomes in the lower tail of the distribution, natural hedging appears attractive in this case.

## **6. Further relation to the literature**

Before concluding let us relate to some further literatures that study investment under risk. One contribution is to generate estimates of profit flows that can be used to evaluate natural and operational hedging strategies. Natural hedging is typically taken to describe a situation where the firm tries to match the currency of revenue and costs. Operational hedging is a broader concept and also captures other operating strategies that aim to modify the risk profile of firms. There is a rich theoretical literature in Operations Research examining operational flexibility as a way to modify the risk profile of a firm's operations (see for instance Huchzermeier and Cohen (1996), Chen and Yano (2010) or Chod, Rudi and Van Mieghem (2010)). Much of this work contains quantitative illustrations but do not directly aid us in our aim – to quantitatively evaluate the risk profiles using data from a particular market. There is some descriptive work establishing that operational hedging lowers variability: Jin and Jorion (2006) examine the natural gas industry and Hankins (2011) studies financial firms. Interestingly, in their wide ranging questionnaire on risk management practices, Bodnar et al (2011)

find that, for non-financial firms, operational hedging is reported as being more important than financial hedging as a way of managing foreign exchange exposure. One aim of the present project has indeed been to quantify the value of being able to engage in operational hedging – in our case shifting production locations.

Our method is also related to the valuation of investments using real options. Establishing production facilities in several locations can be seen as the purchase of a real option. Mello, Parson and Triantis (1995) examine the hedging and production decisions of a firm that can produce a fixed output in any of two locations - the price of the output is fixed but the attractiveness of producing in the different locations varies with the exchange rate. They show how the value, of the real option to produce in different locations, increases with the volatility of the exchange rate. In the present paper we want to give empirical content to such a stylized model. Most empirical applications of real options analysis have considered resource extracting industries such as mining (see for instance Slade (2001) or Moel and Tufano (2002)). An exogenous output price that follows a Brownian motion is typically the principal source of risk in real option applications. While these assumptions may be appropriate for the gold mining industry, they are clearly less satisfying for price setting oligopolistic firms.

Finally, we relate to work in financial economics that attempts to measure exchange rate exposure and macroeconomic exposure more broadly.<sup>16</sup> A number of papers relate historical stock market valuation to changes in exchange rates (see for instance Jorion (1990) or Dominguez and Tesar (2006)). This strand of the literature has concluded that exporters tend to be positively affected by a depreciation of the exchange rate, but that coefficients tend to be unstable. The closest precursor to the present paper, Friberg and Ganslandt (2007), uses a structural model of demand to examine exchange rate exposure. This is the only previous paper that we are aware of that uses draws from distributions of risk factors combined with a demand system for differentiated products to generate frequency distributions for profits. While Friberg and Ganslandt (2007) introduced this way of quantifying exposure, several building blocks that make the method a useful tool for decision makers in firms are introduced in the present paper. Most importantly, we show how to apply the method to evaluate different strategic choices. Our use of copulas to model the risk factors allows us to handle several risk factors in a flexible way – in contrast Friberg and Ganslandt (2007) used only a bivariate normal distribution for shocks. Compared to Friberg and Ganslandt (2007), we use a functional form of demand that is typically seen as generating more compelling estimates of substitution patterns between

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<sup>16</sup> The modeling of risk factors also relates to a burgeoning field that examines return distributions using value at risk (VaR) methods (see for instance Jorion (2006) for an overview). VaR methods have also been applied to generate cash flow distributions for non-financial firms as in Stein et al (2001) and in this particular setting are sometimes called cash-flow at risk (C-FaR). A fundamental difficulty in the application of C-FaR lies in generating profit distributions from a short time series. Stein et al (2001) advocate matching firms based on a few observables, such as market capitalization, to generate a larger number of realizations of shocks that can be used to create a probability distribution. While potentially useful from the perspective of a financial investor the results do not lend themselves to evaluate counterfactual strategic scenarios at the firm level.

products – a random coefficients logit model rather than a nested logit model. It deserves to be mentioned that in the current paper we disregard the why's, the when's and the how's of financial hedges. These are important issues, but we focus on the relation between profits and risk factors, a relation that will be dependent on the choices made by firms with respect to for instance production locations and pricing strategy. This is a prerequisite step before taking a view on if, and why, financial or operational hedges should be used (see Stulz (2002) for an overview of the arguments for why a firm would want to use financial instruments to manage risks).

## **7. Concluding comments**

This paper proposes a structural model to quantify the exposure of firms to risk factors affecting their profits. In our illustrative application, we show that, under our assumptions, a decision to produce in the US is easily motivated for BMW but not for Porsche. The key insight of the paper is that by feeding draws from the distribution of risk factors through a demand system, rather than having them directly affect sales or market size, many of the weaknesses of Monte Carlo methods to evaluate risky investments are muted.

We have made a number of simplifying assumptions, most of which for convenience. We only considered the US market for instance and assumed a simple cost structure. Time and resource constraints hindered us from assembling similar quality data for BMW's and Porsche's other markets. Conveniently, the method can be implemented by using data that are typically available for purchase, such as sales, prices and characteristics of products. Using more detailed information – typically available to firms, but not researchers – is bound to increase the accuracy of any such exercise. For instance if a firm were to perform calculations such as these for itself, it would want to make use of its knowledge of the cost structure.

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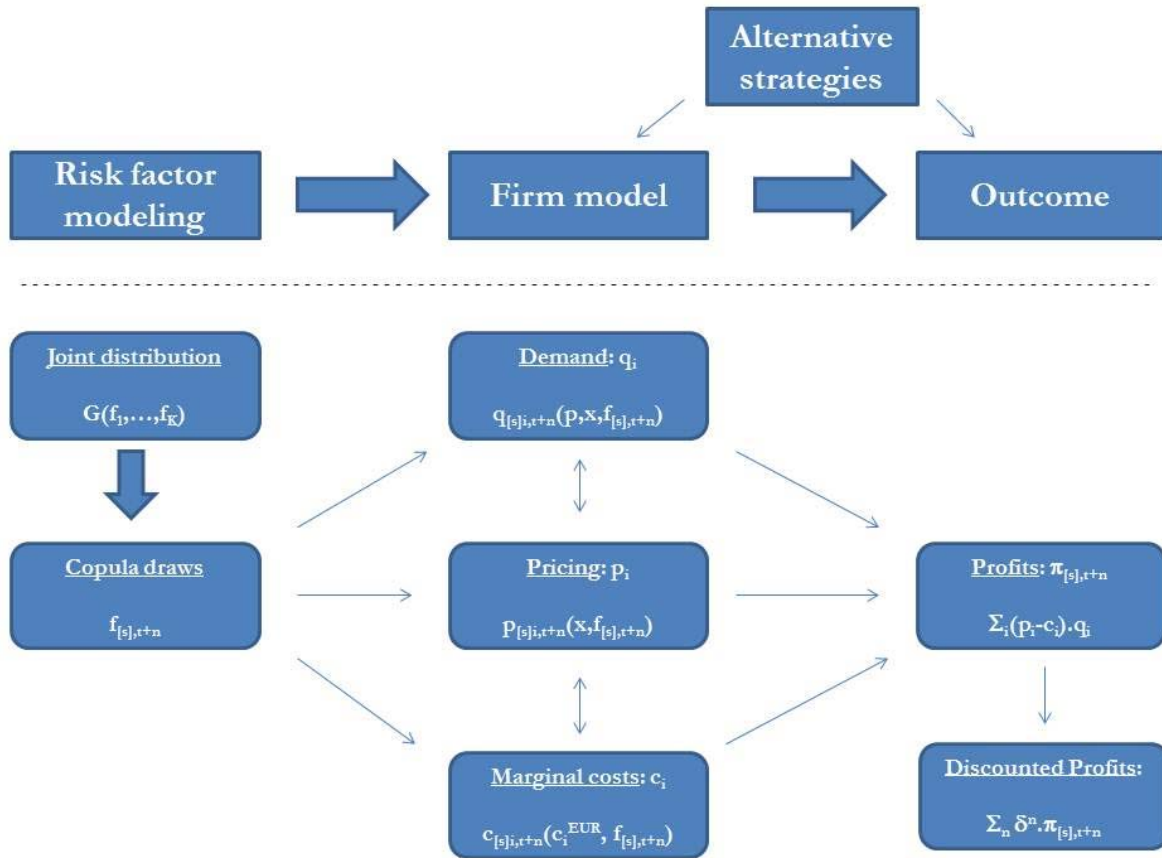


Figure 1. Illustration of the algorithm used to generate counterfactual profits.

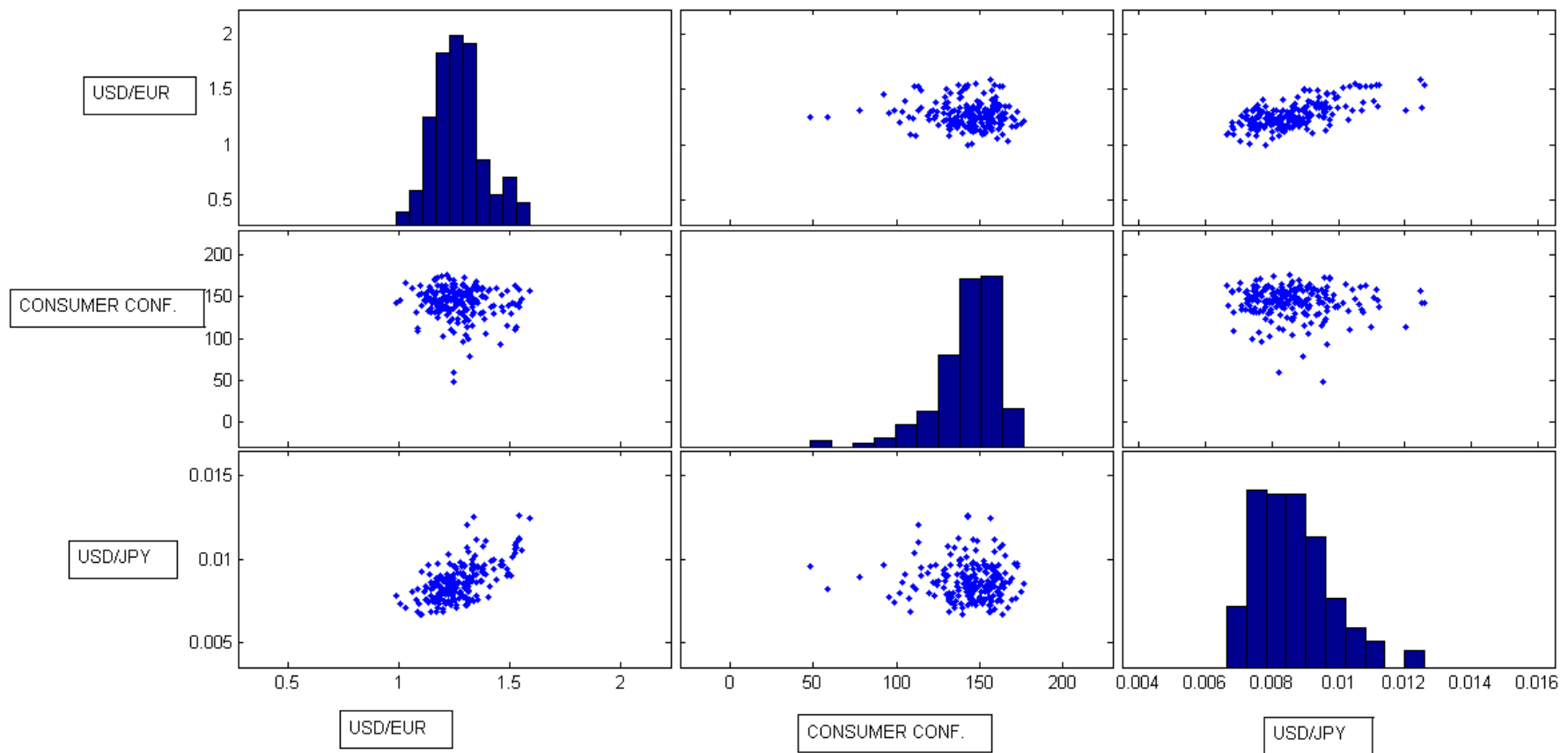


Figure 2. Counterfactual values of exchange rates and consumer confidence at the 12 month forecast horizon using July 2006 as start date.

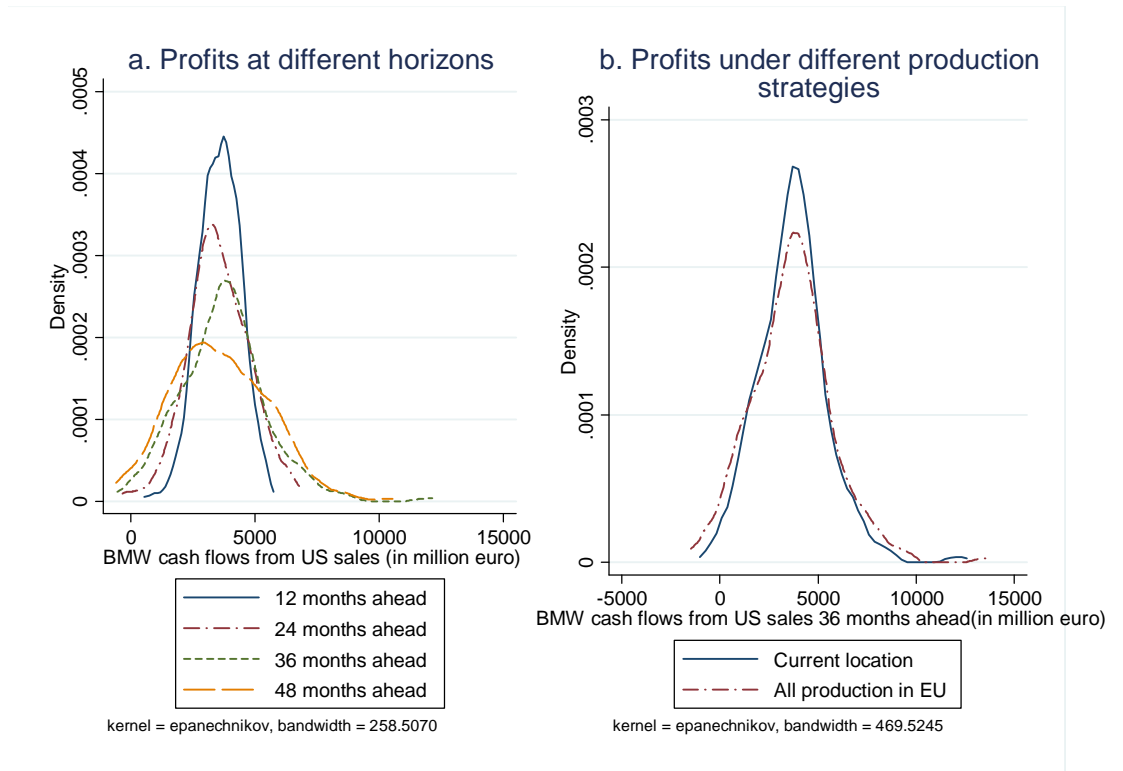


Figure 3. Counterfactual distributions of cash flows for BMW. Figure a, current production locations (X3, X5, X6 and Z4 in US and others in EU) at different horizons. Figure b, current production structure vs. all production in the EU at the 36 month ahead horizon.

Table 1. Descriptive statistics, top segments of the US car market 1995-2006.

Model year	Price per model				Number of cars sold per model		# models	usd/euro	usd/jpy*100	Consumer Confidence
	Mean	SD	Min	Max	Mean	SD				
1995-6	38041.75	18481.03	12708.33	87966.01	31530.07	57075.50	82	1.3970	1.0522	112.88
1996-7	37403.57	17539.10	14269.31	90906.66	32092.60	55076.02	94	1.2591	.9289	140.65
1997-8	37171.44	17072.26	14260.55	89372.36	34396.79	56395.09	102	1.1342	.8355	164.11
1998-9	35899.63	16201.52	13965.91	87525.82	38519.35	62108.20	102	1.1461	.8701	173.16
1999-0	35634.01	16255.59	13478.56	85887.34	40980.89	61989.83	112	1.0056	.9495	180.08
2000-1	35608.50	17303.36	13074.47	124516.40	39472.35	54538.38	122	.8797	.8466	168.76
2001-2	34669.26	17604.04	12924.47	124899.60	43623.14	58616.76	121	.8985	.7599	108.28
2002-3	35099.71	17904.43	14149.53	123546.70	41264.77	56876.86	136	1.0422	.7754	73.05
2003-4	37679.09	34669.60	13738.66	399968.30	40191.50	54702.66	148	1.1687	.8213	82.72
2004-5	36959.30	34023.86	12330.40	390308.40	39729.80	51515.50	155	1.2204	.8185	109.13
2005-6	35935.96	31963.93	12563.45	374788.50	34188.75	40637.60	168	1.1487	.7331	125.42

Descriptive statistics is over models per 12 month period running from August to July. Prices in real 2000 dollars.

Table 2. Demand estimates, US car market 1995-2006. Random-coefficients logit model.

Variables	I	II	Examples	
Price	<b>-0.021</b> [-2.804]	<b>-0.030</b> [-4.475]		
HP	0.002 [0.247]	0.010 [1.394]		
Size	0.067 [1.360]	0.049 [0.790]		
Transmission	0.000 [.367]	0.000 [-0.754]		
Sigma price	<b>0.008</b> [4.844]	<b>0.009</b> [5.345]		
CONS. CONF.	0.016 [1.145]	-		
CONS. CONF. x Upper Luxury	-	<b>0.029</b> [2.428]	Audi A8	BMW 7 Series
CONS. CONF. x Middle Luxury	-	<b>0.020</b> [2.383]	Audi A6	BMW 5 Series
CONS. CONF. x Lower Luxury	-	<b>0.011</b> [1.737]	Audi A4	BMW 3 Series
CONS. CONF. x Luxury Sport	-	<b>0.020</b> [1.843]	Mercedes SLK	Porsche 911
CONS. CONF. x Luxury Specialty	-	0.013 [1.457]	Lexus SC430	Mercedes CLK
CONS. CONF. x Small Specialty	-	0.001 [0.079]	Mini Cooper	VW Beetle
CONS. CONF. x Large Luxury CUV	-	<b>0.016</b> [2.166]	Acura MDX	Cadillac Escalade
CONS. CONF. x Middle Luxury CUV	-	<b>0.015</b> [2.108]	Lexus RX330	Porsche Cayenne
CONS. CONF. x Large CUV	-	<b>0.020</b> [2.274]	Chrysler Pacifica	Honda Pilot
CONS. CONF. x Middle CUV	-	0.012 [1.524]	Ford Escape	Hyundai Santa Fe
CONS. CONF. x Small CUV	-	0.005 [0.623]	Mitsub. Outlander	Toyota RAV4
CONS. CONF. x Large Luxury SUV	-	<b>0.030</b> [2.319]	Cadillac Escalade	Range Rover
CONS. CONF. x Middle Luxury SUV	-	<b>0.016</b> [1.854]	Land Rover Discovery	Lexus GX470



CONS. CONF. x Large SUV	-	<b>0.017</b> [1.953]	Chevrolet Tahoe	Chevy Suburban
CONS. CONF. x Middle SUV	-	<b>0.015</b> [1.930]	Land Rover Freelander	Nissan Xterra
CONS. CONF. x Small SUV	-	-0.004 [-0.531]	Chevrolet Tracker	Jeep Wrangler
<u>Elasticities</u>				
Min	-5.0	-7.3		
Mean	-3.9	-6.0		
Max	-2.5	-3.7		

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Coefficients in bold denote significance at 5% level. T-stats in brackets. All specifications include time, country of origin and brand fixed effects. Specification I also includes segment fixed effects. When testing for overidentifying restrictions the tests statistics are 1.615 and 1.125 for Specifications I and II, respectively. The associated p-values are 0.656 and 0.771. The degrees of freedom in both cases is three.

Table 3. Hedonic regression elasticity estimates, US car market 1995-2006.

Variables	Estimates
<u>Characteristics</u>	
HP	<b>0.166</b> [8.67]
Size	0.028 [0.88]
Transmission	0.000 [0.56]
<u>Exchange rates</u>	
USD/EUR	<b>0.146</b> [3.10]
USD/JPY	<b>0.116</b> [1.99]
<u>Fixed-effects</u>	
Model	Yes

The table reports elasticities and associated t-statistics for the hedonic regression of real prices on product characteristics, real exchange rates and model fixed-effects. Parameters in bold are significant at the 5% significance level.

Table 4. Univariate processes for exchange rates and consumer confidence, Jan 1973-July 2006 bimonthly data.

	usd/eur	Consumer confidence	usd/jpy
Estimation	GARCH(1,1)	E-GARCH(1,1)	GARCH(1,1)
C	0.0003 [0.09]	<b>1.5170</b> [2.70]	0.0004 [0.11]
$\kappa$	0.0004 [0.80]	<b>2.0786</b> [2.84]	0.0011 [0.50]
$\alpha_1$ "GARCH"	<b>0.7392</b> [2.40]	<b>0.5033</b> [2.94]	0.5263 [0.62]
$\alpha_2$ "ARCH"	0.0960 [1.09]	<b>0.4531</b> [2.54]	0.0549 [0.68]
$\gamma$ "Leverage"		<b>-0.3759</b> [-3.26]	
Degrees of freedom	200	18.17	16.37
Log-likelihood	324.1647	-712.1135	309.1884

Regressions run on bimonthly data 1973:1 to 1996:6. T-stats in brackets. Coefficients in bold are significant at the 5% level.

Table 5. Net present value of cash flows under different production scenarios. Summary statistics over each of 200 simulated paths of exchange rates and consumer confidence.

Scenario (in EU unless stated)	Mean	SD	Min	p1	p5	p10	p50	p90	p95	p99	Max
BMW current production	66855.73	33035.98	-8757.34	-868.53	12832.64	27285.23	65230.56	107530.5	120723.8	146332.4	187041.5
BMW all in EU	66030.74	39677.0	-25389.7	-15891.3	1834.71	18491.26	64042.04	114141.8	131106.6	161588	210517.3
BMW all in US	69363.49	13232.33	40852.35	43184.86	47700.07	53559.51	68370.25	87052.16	91848.57	101463.8	118353.9
BMW flexible between EU and US	79062.57	27194.84	40852.35	43184.86	47700.07	53559.51	69520.16	114834.9	131106.6	161609.1	210517.3
Porsche current all in EU	1897.94	3728.70	-7475.31	-6652.55	-4079.24	-2452.23	1756.18	6442.18	7934.54	11078.23	15948.99
Porsche Cayenne in US	2044.99	2532.16	-4514.81	-3994.55	-1952.53	-839.8	1956.57	5286.83	6219.31	8331.30	11729.64
Porsche all in US	2344.86	464.34	1445.76	1474.16	1615.62	1751.25	2310.67	3001.04	3162.45	3571.10	4138.73
Porsche flexible between EU and US	3509.35	2246.67	1445.76	1474.16	1615.62	1767.92	2437.59	6518.42	7934.54	11081.14	15948.99

The table reports profits for simulations using 200 simulated paths of real usd/eur, usd/jpy and consumer confidence as described in the text. The set of models is the same as 2006. Financial hedge constructed such that the entire expected inflow in US dollars is sold forward.