Hedging and Product Market Decisions

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Abstract

In this article hedging adds value to firms in imperfect product and capital markets. First, hedging protects the firm against volatility in the need for more costly external financing. Second, it gives a firm a strategic advantage relative to its rivals, which is of special importance when rivals become financially constrained and the firm is able to get ahead. We find that when firms hedge, the net amount of their hedges can be less than the amount of hedging done if the sole motive for hedging was to reduce exchange rate risk exposure. The difference between this purely hedging motive and the actual hedge is a speculative component. If it works out on a change in the exchange rate it gives the firm an advantage when the rivals are financially constrained. The speculative component is therefore strategic and is optimal for a firm that does not like exchange rate volatility. The optimal hedge implies that, in equilibrium, (a) rival firms choose to hedge in differently, the greater the product-market effect is relative to the costs of getting outside funds, (b) an important part of the motivation behind firms’ hedging decisions is to increase profit relative to their competitors (benchmark) rather than to reduce volatility, (c) it is the relative financial position of the rivals and not relative location that justifies passing changes in exchange rates into production schedules and prices, (d) the magnitude of the impact of exchange rate on equity values depend on the firm’s and industry behavior, and (e) the equilibrium degree of hedging is increasing in the level of debt and in the degree of exchange-rate volatility.

JEL: L1, F3, G3

Keywords: Industry competition, financial hedging, exchange rates

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Abstract
In this article hedging adds value to firms in imperfect product and capital markets. First, hedging protects the firm against volatility in the need for more costly external financing. Second, it gives a firm a strategic advantage relative to its rivals, which is of special importance when rivals become financially constrained and the firm is able to get ahead. We find that when firms hedge, the net amount of their hedges can be less than the amount of hedging done if the sole motive for hedging was to reduce exchange rate risk exposure. The difference between this purely hedging motive and the actual hedge is a speculative component. If it works out on a change in the exchange rate it gives the firm an advantage when the rivals are financially constrained. The speculative component is therefore strategic and is optimal for a firm that does not like exchange rate volatility. The optimal hedge implies that, in equilibrium, (a) rival firms choose to hedge in differently, the greater the product-market effect is relative to the costs of getting outside funds, (b) an important part of the motivation behind firms’ hedging decisions is to increase profit relative to their competitors (benchmark) rather than to reduce volatility, (c) it is the relative financial position of the rivals and not relative location that justifies passing changes in exchange rates into production schedules and prices, (d) the magnitude of the impact of exchange rate on equity values depend on the firm’s and industry behavior, and (e) the equilibrium degree of hedging is increasing in the level of debt and in the degree of exchange-rate volatility.
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For many multinational corporations exchange rates are the single largest factor affecting their performance. The most recent Wharton survey of derivatives use by non-financial US firms reveals that 40% of the firms report that either their revenues or their expenses are exposed to foreign currency changes, and almost 60% report that they have a balance between total foreign currency revenues and expenses. The adjustments made to deal with volatile exchange rates range from re-arranging the international allocation of production and changing pricing policies, to redesigning the hedging strategies. Often, these decisions are not done assuming that the firm operates in isolation, but after detailed analysis of the industry’s situation and careful observation of the rivals’ actions. Any of these decisions affects and is in turn affected by the others, and as a result must all be taken simultaneously in responding to exchange rate changes. For example, exposure affects production and pricing decisions, but production and pricing also determine the exposure of the firm’s profits to exchange rates. Also, the degree of exposure impacts the firm’s hedging decision, and hedging affects the firm’s profitability and its value. If capital markets are imperfect and external sources of finance are more costly than internally generated funds, the cash generated from hedging can at times make a difference as to whether a firm gets ahead of its rivals, and therefore has important consequences to the production and pricing decisions of all the firms in the industry. This implies that when product and capital markets are both less than perfect, it is not possible to maximize firm value by separating operating and hedging decisions. Operating decisions and hedging decisions determine the degree of a firm’s exposure, as much as they are determined by the firm’s exposure.

This article analyzes the process by which firms operating in imperfect product and capital markets make decisions when dealing with exchange rate uncertainty. In so doing, it seeks to address a number of related questions. First, what is role hedging plays in firms’ competitive strategies? Does hedging affect, and if so by what channels, the production decision of firms? How is the possibility of hedging related to the degree of industry rivalry? How is hedging related to the extent to which firms pass through the change in exchange rates into the prices charged in international markets. Do firms use hedging to support production decisions and if so in what way? Second, when firms make operating decisions paying attention to their rivals’ actions, does rivalry also influences the firms’ hedging decisions? Should firms in the same industry try to copy their rivals or try to differ from their rivals when deciding their hedging strategies?

We attempt to answer these questions. To do so we present a simple model that illustrates the ways in which hedging interacts with product market considerations. In general, we show that firms have a strong incentive to incorporate in their hedging the possibility of gaining advantage over their rivals, given that their rivals are financially weaker. This is different from trying to
grab leadership at all cost, and also differs from minimizing exchange rate volatility. The answer flows from the insight that in a financially constrained setting, financial hedging can create value if done with a bit of speculation, but only when the firm is more likely to win a stronger position in the product market than to lose and fall behind its rivals. Firms which are close in financial strength are more interested in pursuing hedging strategies with a grain of speculation which can potentially make them stronger than their rivals. By focusing on the elimination of costly lower tail outcomes, the firm might ignore the opportunity that larger gains emerge as a result of being wealthier when rival firms are financially constrained. Such upside potential created by a decrease in competition induces firms to uncorrelate their hedging strategies. On the other hand, firms closer to the opposite ends of the spectrum, either already enjoying a robust financial advantage over their rivals, or, conversely, significantly more financially dependent than their relatively unconstrained rivals, prefer to take fewer risks and follow conservative hedging strategies. In equilibrium, the trade-off between the costs of own financial constraints and the gains from the competitors’ financial constraints determines the degree of hedging across rival firms. Whatever the outcome, it would be inappropriate to separate hedging decisions from product market decisions when these are interrelated to each other in their contribution to the value of the firm. In this respect this article raises questions over the work in corporate risk management that does not take into account how the firm’s production decisions affect the design of its hedge and vice versa. A notable exception is the insight first spelled out in Froot, Scharfstein and Stein (1993): "... when Firm 2’s cash flows are less than I∗, Firm 2 invests only what it has, while Firm 1 (which has hedged) gets to invest more ... the additional investment that hedging makes possible is particularly attractive to Firm 1 in these states: Firm 2 is not investing much; prices are high; and so are the marginal returns to the investment. Thus Firm 1 is clearly better off hedging.” (pp. 1651). The authors’ hint claims that, due to strategic product market considerations, firms may want to make hedging decisions different from their rivals is developed and extended in this article.

A topic that has received considerable attention in international corporate strategy is that relating firms’ exposure to exchange rates, and the extent to which adverse changes in exchange rates are incorporated into the prices charged by firms in foreign markets. It is right to take production policies into account when evaluating exposures, because production affect profits, and as Bodnar, Dumas and Marston (2002) point out ”the exposure of a firm’s profits to exchange rates should be governed by many of the same firm and industry characteristics that determine pricing behavior” (pp. 199). In this article we follow the same line of reasoning towards hedging decisions. Hedging determines exposure, as well as how a firm faces its competitors, and exposure determines how much hedging a firm needs to do, as well how it behaves in the product markets. Many researchers seem to find that exposures seem exceedingly small compared to the risks at
stake. To pass a judgement on this assertion, it is critical to look together with exposures at the product and financial policies of the firm.

We are not the first to show that a firm’s need for hedging must incorporate its production plan, as much as production determines hedging. Froot, Scharfstein and Stein (1993) point out that hedging creates value if it ensures that the firm can take advantage of good investment opportunities. The ability to guarantee sufficient funds when these are needed by hedging is important if external sources of finance are more costly to firms than internally retained funds, a condition of capital market imperfection that we also use. Their work is done under conditions of perfect competition in product markets and therefore, it does not evaluate the strategic implications that hedging has on the degree of rivalry in the product markets. However, as noted before, Froot, Scharfstein and Stein briefly comment on the effects of an imperfect market setting. Most of their intuition is correct. Here we provide a model that turns their conjecture into a more formal analysis and extend their insights in additional directions. Adler (1993) also considers the implications of product market competition for the hedging policy of the firm, but focuses on a single hedging strategy, variance minimization with linear payoff contracts, which may not be optimal. He also leaves unanswered the question of whether firms can design hedges separately from their production plans and their market values. We are able to show how a firm’s optimal hedging strategy depends on the nature of the rivalry in the product market and on the costs of raising funds externally. Two models that explicitly incorporate industry rivalry in an international setting are those by Marston (1998) and by von Ungern-Sternberg and von Weizsäcker (1990). Their motivation is similar to ours and is at the heart of Marston conclusion that the key determinant of exposure is the competitive structure of the industry. von Ungern-Sternberg and von Weizsäcker sound a similar theme: "if one wishes to advise companies on how to insure against exchange rate risks it is insufficient to know only the relevant financial theory. It is just as important to have a good understanding of the competitive environment in which the company acts" (pp.382). Firms in their model maximize profits from a single period production function, not value, and hedge myopically by separating hedging, which occurs before the exchange rate has changed, from production, which takes place after exchange rates are known and is fully financed with equity. Unfortunately, firms' hedging decisions are not done separately from production and investment decisions. Their model thus differs from ours in that they ignore any strategic effects that arise from and also feedback into the financial condition of the firm, as well how these relate to the firm’s competitive behavior.

This article is also along the line of research that links the capital structure of the firm to its competitive strategy in the product market. Capital structure decisions are strategic devices observable by rival firms, which then rationally anticipate its effect on subsequent investment and production decisions taken by the firm. The models in this literature differ somewhat in
their types. Models such as Brander and Lewis (1986) and Showalter (1995, 1999) show that more leveraged firms have incentives to commit to a certain product market behavior, usually aggressive, to gain a strategic advantage. A second type of models such as Fudenberg and Tirole (1986), Bolton and Scharfstein (1990) and Chevalier and Scharfstein (1995) emphasize the predatory behavior of financially unconstrained firms that have the incentive to be aggressive in an attempt to exhaust the financially weaker rival and drive it out of the market. Finally, models such as Phillips (1992, 1995) show how leveraged firms tend to either decrease or increase their investment levels. In the former case, the decrease in the investment level is because an increase in debt level means that the percentage of cash flow to be paid out each period is increased, resulting in less cash flow available to invest; in the latter case, debt leads to more production due to the limited liability effect, which raises the marginal benefit of a low marginal cost firm and thus the firm wants to increase investment. Almost all these models channel toward two main results. First, models that predict that leverage will cause firms to behave more aggressively under certain conditions, which makes competition tougher, such as Maksimovic (1988), Rotemberg and Scharfstein (1990), Showalter (1995, 1999), among others. Second, models in which debt commits the leveraged firms to behave less aggressively under certain conditions, which makes competition softer, such as Bolton and Scharfstein (1990), Glazer (1994), Chevalier (1995a, 1995b), among others. All these models show how output market behavior can be affected by the firms’ financial situation. On the other hand, the link can also be solved backwards. Rational, foresighted firms can anticipate output market consequences of financial decisions, and output market conditions will as a result influence the firm’s financial structure. This reverse link is especially evident in the models of Brander and Lewis (1986), Maksimovic (1988), Bolton and Scharfstein (1990) and Povel and Raith (2001).

The remainder of the article is organized as follows. Section I lays out a simple model of production and hedging of two multinational firms, with production and sales in two countries. It shows how the benefit from becoming stronger than the rival pushes a firm to take risks in a controlled way. Increasing rivalry in an attempt to get ahead can be better achieved by financial means, through hedging, than by real means, through production. When the firm uses financial means to improve its relative position, it chooses to hedge less than what it would if there were no strategic interaction between rival firms. In Section II the effects of hedging on the degree of industry rivalry are analyzed. In Section III the logic of the model is extended to analyze firms producing in different countries. Producing in segmented markets has effects on the industry by changing the degree of rivalry, as well as the optimal amount of hedging. The questions of how much ‘pass-through’ should the firms attempt to incorporate in their product market strategies and what is the role of hedging in the degree of pass-through are analyzed. Section IV presents and analyzes several extensions, and Section V discusses empirical and practical implications. Section VI concludes and makes a few remarks.
I A Simple Model of Global Production and Hedging

A. Assumptions

We begin by considering two rival firms, $i$ and $j$, that produce and sell an homogenous product in two countries for two periods. To start out, the firms have both half of their costs and revenues in each country. Later this even distribution of the firms’ operations is relaxed and each firm produces in a different location. The exchange rate between the two currencies fluctuates randomly. Specifically, each period the exchange rate can move up or down with equal probability by an amount $\hat{\varepsilon} \in \{-\varepsilon, +\varepsilon\}$. Most empirical research finds that exchange rates follow a random walk, but it would be simple to incorporate a different process in the model. Profits for both firms are denominated in a simple average of the individual currencies.

Each firm must decide how much it wants to produce, the external financing needed to fund production, and also how much it hedges the exchange rate risk posed by their operations. Firm’s operating revenues are represented by a Cournot-type function, with linear demand and linear cost. So for firm $i$, the profits are simply $(\theta - x_i - x_j)x_i - cx_i$, where $\theta > 0$ and the constant marginal cost denominated in the average currency is $c > 0$. All producers employ the same production technology. Variables $x_i \geq 0$ and $x_j \geq 0$ are the quantities produced by the two rival firms in period 1, and $(\theta - x_i - x_j)$ is the resulting market price. The specific form of the demand function is chosen for brevity. It is straightforward to extend the analysis to other more general classes of demand functions, but the results will not change in a significant manner.1 Each period, production takes place before sales are realized and revenues collected. Production is financed preferably with retained earnings, but outside debt is issued when internal funds are not sufficient. If firm $i$ has internal equity funds of $w_{i0}$ at $t = 0$, it needs to borrow the amount $d_i = cx_i - w_{i0}$ in the capital markets. We assume that each firm does not have sufficient equity to fund production, $d_i > 0$. The use of outside debt imposes a financial cost in addition to the production cost. For example, this financial cost could come from the choice of less profitable tangible assets over intangible assets in other divisions, resulting from the need to satisfy collateral requirements. The cost of external debt finance are assumed to be borne in period 2, when the firm, as a result of borrowing in the past, pays the price of being financially constrained. Adding an explicit interest cost in period 1 simply adds another term, but does not alter the results. To represent the negative effect of increasing financial constraints, we assume that at the margin, the costs of external finance increase with the amount borrowed. That is, the more the firm relies on outside debt, the lower its expected profits are in the future. This makes the firm averse to the risk posed by the use of external funds.

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1 As noted before by many others, this setup can be also understood as a model of price competition with costly capacity build-up (see Kreps and Scheinkman, 1983).
The firms decide on the level of hedging by choosing the currency denomination of their debts. Other ways of hedging are also possible, such as using forward contracts and swaps. Later we will also consider the use of currency options. Ignoring the differences in the accounting treatment of the hedges, hedging with currency debt is essentially equivalent to hedging with currency forward contracts and currency swaps. The use of currency debt to hedge exchange rate exposures is a common technique and is reported in many corporate risk management surveys. \(^2\)

The level of hedging is represented by \(h_i\). If a firm borrows all its external funds in one currency, \(h_i = 1\), and if it borrows all in the other currency, then \(h_i = -1\). Since the firms have half of their costs and revenues in each currency, they can eliminate all currency risk by borrowing half of the debt in one currency and the other half in the other currency. Therefore, firms are completely hedged when they set the amount \(h_i = 0\).

At the end of period 1, a firm has equity funds measured in the (simple) average (of the individual) currencies of

\[
\check{w}_{i1} = w_{i0} + (\theta - x_i - x_j)x_i - cx_i + h_i d_i \hat{\varepsilon}
\]

It starts out with a given initial amount of equity \(w_{i0}\), it makes a profit of \((\theta - x_i - x_j)x_i - cx_i\) from selling its product, and it marks to market the value of the debt outstanding due to changes in the exchange rate, \(h_i d_i \hat{\varepsilon}\). Rather than modelling explicitly product market interaction in period 2, we assume that the expected value of firm’s \(i\) equity at the end of this period is represented by the reduced form, \(E[\check{w}_{i2}] = \check{w}_{i1} + g(\check{w}_{i1}) + f(\check{w}_{i1} - \check{w}_{1j})\). The term \(g(\check{w}_{i1})\) captures the effect of the internal equity funds on the firm’s future profitability.

\[
g(\check{w}_{i1}) = \check{w}_{i1} - \frac{1}{2} \alpha \check{w}_{i1}^2,
\]

where \(\alpha\) is such that \(g(\cdot)\) increases in the relevant range of parameters, which implies that \(\alpha < \check{w}_{i1}\) for all cases. Note that the relationship between the future expected value of firm’s \(i\) equity and the level of internal funds is strictly concave. As \(\check{w}_{i1}\) increases from zero, the firm becomes progressively less financially constrained and \(g(\check{w}_{i1})\) increases at a declining rate, until a certain fixed amount that corresponds to the value of an unconstrained firm. The difference between this fixed upper level and the value of \(g(\cdot)\) of the financially constrained firm is convex, increasing as \(\check{w}_{i1}\) declines. This implies a convex cost function for the amount of external finance. Note that the higher the value of the costs from being constrained, \(\alpha\), the lower the firm’s expected value from operating with less equity. When the firm decides to borrow more outside debt to produce, it does so at increasingly higher financing costs. Because of this the firm acts as if it were averse to outside financing, and has an incentive to hedge. \(^3\)

\(^2\)See, for example, Bodnar, Hayt and Marston (1998).

\(^3\)This reason for hedging is the same as in Froot, Scharfstein and Stein (1993).
The last term in the expression of the expected value of firm’s $i$ equity, $f(\hat{w}_{1i} - \hat{w}_{1j})$, takes into account that there are strategic effects that arise when firms with different levels of equity face marginal costs differences. We assume that

$$f(\hat{w}_{1i} - \hat{w}_{1j}) = \max\{\beta^+(\hat{w}_{1i} - \hat{w}_{1j}), \beta^-(\hat{w}_{1i} - \hat{w}_{1j})\}.$$  

with $\beta^+ > \beta^- > 0$. Thus, $f(\cdot)$ is increasing and convex in the relative levels of $\hat{w}_1$, which is a common result in many Cournot type models. The shape of $f(\cdot)$ implies that the relative situation in the firms’ real, as well financial condition matters to the aggregate level of profits in the industry. It means that it is better for one firm to be ahead when the rival is falling behind, than to do just fine when the rival also does okay. The more pronounced this difference is, the larger is the firms’ relative competitiveness, which, in turn, results in higher aggregate industry profits. That is, aggregate profits under a duopoly are lower than aggregate profits under monopoly, with value increasing as the difference between the firms approaches a monopoly. This function requires some further motivation. One possible explanation is that firms financed with debt can fall below a certain level associated with financial fragility. A firm that falls into this region, suffers from some dissipative direct cost which grows with the level of indebtedness, as well as indirect costs resulting from the disruption in the firm’s operations which benefit the rivals more than what the firm loses. These costs could be lost market share with a disproportionate shift in power to the leading firm in the industry and greater occurrence in restrictive practices.

One of the prominent features of the model is that this indirect cost depends on the financial status of the rival firm. If firm $j$ is financially constrained, then firm $i$'s indirect cost from falling into financial difficulties is lower than if firm $j$ is at the same time in financial strong. Another possible story is that sometimes, highly leveraged firms must resort to the sale of core assets in order to restore stability. For example, cash strapped airlines often need to sell assets to raise money needed to implement turnaround plans. Assets sales, at least in the short run, affect the firm’s production capacity and performance. Specifically, suppose that firms simultaneously set prices for a homogeneous product and that the marginal cost is constant up to capacity. In this example, the assumptions equivalent to those made in our model are that capacity constraints are binding and that each firm’s capacity decreases with the amount of leverage. The idea is that some of the assets that the firm must sell in order to service its debt directly impact on its production capacity, and favor rival firms, which pick up market share at higher profits.

Another case is when consumers upon observing high degrees of financial dependence are likely to increase their expectation that the firm may be in trouble in the future. This, in turn, affects the firm’s ability to sell today. Suppose that the firm sells a durable good with indirect network externalities, personal computers, for example. If consumers expect that the firm is financially fragile in the future, they may as well think that it will be more difficult to have their PCs serviced in the future, that less software will be developed and so on. Airlines also fit
this example: consumers are willing to pay less for tickets in a weaker airline because, among other reasons, they are unsure about service, maintenance and frequent-flyer miles. Specifically, assume that each consumer is characterized by some parameter $\vartheta$, uniformly distributed in the interval $[\underline{\vartheta}, \overline{\vartheta} + 1]$, $\underline{\vartheta} > 0$. A consumer of type $\vartheta$ is willing to pay $\vartheta \rho_i$ for the good supplied by firm $i$, where $\rho_i$ is the posterior that the firm will service the customer well in the future. If firm $i$'s operating standards decline because of increasing leverage, then $\rho_i = \underline{\rho}$; otherwise, $\rho_i = \overline{\rho}$. Assume that firms compete by simultaneously setting prices. Without loss of generality, assume $\rho_i > \rho_j$. It can be shown [Shaked and Sutton (1982)] that firm $i$'s profits are given by $(2\overline{\vartheta} - \underline{\vartheta})^2(\rho_i > \rho_j)/9$, whereas firm $j$'s profits are $(\overline{\vartheta} - 2\underline{\vartheta})^2(\rho_i > \rho_j)/9$. This in turn implies that

$$\beta^+(\cdot) - \beta^-(\cdot) = 4(\overline{\vartheta} - \underline{\vartheta})^2 + \overline{\vartheta}^2 + \underline{\vartheta}^2 > 0,$$

as required. A third example is given by the case of financially fragile firms that must reduce their investments in quality. Even if quality is not directly observable, consumers will anticipate that financial constraints might create incentives for the firm to cut corners. Accordingly, their willingness to pay for the firm’s product diminishes, as Titman (1984) and Maksimovic and Titman (1991) have shown. A formal model of this situation would look very similar to the one presented in the previous paragraph, justifying the assumption that $\beta^+(\cdot) - \beta^-(\cdot) > 0$. Also, it should be noted that the assumption regarding the shape of $f(\cdot)$ appears often in the literature of Industrial Organization, where it is commonly referred to as the strategic effect, or the joint profit effect.

We, therefore, proceed by assuming that an increase in competition distributes profits differently among the rival firms and reduces the aggregate level of profits in the industry. Because of this strategic effect, firms have an incentive to get away and ahead of their rivals. As explained later, the best way to attempt that is by means of the hedging policy. However, in trying to distance themselves from their competitors, firms understand the risks that a bad outcome will force them later to borrow at higher costs. The optimal decision confronting the management of each firm combines production, financing, as well as hedging and the interactions each play on each other.

The firms make two choices at the beginning of period 1 with the objective of maximizing the expected value of the equity at the end of period 2. In their first choice (stage 1 in period 1) firms simultaneously decide on the production. Once production is chosen, then firms finance part of it with equity and the rest with debt. In the second choice (stage 2 in period 1) firms simultaneously decide the level of hedging. The proofs of some of the results are relegated to the Appendix.
B. The Firms’ Hedging Decisions

We begin by analyzing the firms’ hedging decisions after the level of production is set. In (1), all terms except the last one are exclusively determined by the firms’ choice of output. For simplicity, the value of these terms are denoted, in the case of firm $i$, by $Z_i$. Firm’s $i$ expected equity value at the end of period 2 can be re-stated as

$$E[\hat{w}_{i2}] = Z_i + Z_i - \frac{1}{2} \alpha [Z_i^2 + h_i^2 d_i \varepsilon^2]$$

$$+ \frac{1}{2} \max \{ \beta^+ (Z_i + h_i d_i \varepsilon - (Z_j + h_j d_j \varepsilon)), \beta^- (Z_i + h_i d_i \varepsilon - (Z_j + h_j d_j \varepsilon)) \}$$

$$+ \frac{1}{2} \max \{ \beta^+ (Z_i - h_i d_i \varepsilon - (Z_j - h_j d_j \varepsilon)), \beta^- (Z_i - h_i d_i \varepsilon - (Z_j - h_j d_j \varepsilon)) \}$$

(2)

where the last two terms are the values of $f(\cdot)$, given that the exchange rate can take two equally probable values $(-\varepsilon, +\varepsilon)$, with $-\varepsilon < \varepsilon < +\varepsilon$.

To understand the interaction between the firm’s product market strategy and its hedging decisions, we first look at hedging when the financial status of a firm has no bearing on the functioning of the product market. This implies that only the costs from being financially constrained represented in the term $g(\cdot)$ matter, and the two last terms in (2) disappear. It is then clear that when $f(\cdot) = 0$ the firm has more to lose from an increase in the value of the liabilities from an appreciating currency that it has to gain from a decrease in debt of equal amount if the currency depreciates. The optimal hedging amount is thus to minimize the variance of the currency debt payments translated into the average currency, and this is achieved by complete hedging, $h_i = h_j = 0$. So, when the firm’s value is independent of the financial status of its rival, a firm hedges completely its exchange rate risk to minimize the expected cost of resorting to costly outside financing in the future. This practice, denoted by practitioners as "matching currency footprints", matches perfectly the currency denomination of the assets with that of the liabilities.

A more interesting situation is when what happens to one competitor also affects the status of the rival firm. We analyze this case by first showing that it is not in at least one firm’s best interest to hedge in the same direction as the competitor.

**Lemma 1**  If $h_j \neq 0$, it is never a best response for firm $i$ to choose $h_i$ with the same sign as $h_j$.

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4In the analysis we focus on pure strategy equilibria.
Since the exchange rate can move by the same amount in either direction with equal probability, when the firm sets a value of \( h \neq 0 \), the sign of \( h \) is not relevant for the future availability of internal equity funds and the firm’s future profitability. On the other hand, choosing to hedge in the opposite direction of the rival achieves the firm maximum differentiability from it, for a given exchange rate exposure. As a result firms prefer to hedge in different directions and choose different currency denominations for their debt. One firm denominates the debt more in one currency, and the other firm denominates more of the debt in the other currency. From this result, in the following we will assume without loss of generality that \( h_i \geq 0 \) and \( h_j \leq 0 \). The question is then, how much will each firm decide to hedge? This is answered in the following proposition:

**Proposition 1** The following pairs \((h_i, h_j)\) are the pure-strategy equilibria of the hedging sub-game:

\[
(0, 0) \quad \text{for} \quad \frac{\beta^+ - \beta^-}{\alpha} < \frac{4}{3}|Z_i - Z_j|
\]

\[
\left(\frac{\beta^+ - \beta^-}{2\alpha d_i \varepsilon}, -\frac{\beta^+ - \beta^-}{2\alpha d_j \varepsilon}\right) \quad \text{for} \quad \frac{\beta^+ - \beta^-}{\alpha} \in \left[\frac{4}{3}|Z_i - Z_j|, 4|Z_i - Z_j|\right]
\]

\[
\left(\frac{\beta^+ - \beta^-}{2\alpha d_i \varepsilon}, -\frac{\beta^+ - \beta^-}{2\alpha d_j \varepsilon}\right) \quad \text{for} \quad \frac{\beta^+ - \beta^-}{\alpha} > 4|Z_i - Z_j|
\]

If the firms do not differ by much in terms of their values, \( Z_i - Z_j \), the best strategy is to hedge only partially. By being less conservative and speculating somewhat using the currency denomination of the liabilities, each firm tries to overtake the competitor. And the best way is, according to lemma 1, to hedge partially and in different directions. However, when the firms differ by much in terms of the value of their equities, it is unlikely that any attempt to gain from an exchange rate movement will succeed in altering significantly the firms’ relative wealths. On the contrary, not hedging completely may prove too costly because it introduces volatility with a negative impact on the costs of accessing the capital markets. And if the much wealthier firm would decide not to hedge, it would simply make itself vulnerable to the possibility that the weaker firm would catch up with it. Depending on the relevant parameters, both firms either completely hedge or partially hedge, but it is never the case that one company chooses a complete hedge and the other a partial hedge. In view of these results one might question whether a hedging strategy designed to increase profits is necessarily bad. Bodnar, Hayt and Marston (1998) seem to appear troubled that when asked which best describes the motivation behind their risk management activities, 40 % of the firms in their survey responded they chose increased profit relative to a benchmark rather than reduced volatility. Perhaps, our findings will help to understand why some companies in industries where the degree of rivalry is more intense act in this way and why that seems to be consistent with value maximization.
Figure 1: Best responses by the two firms. Two equilibria exist, one with complete hedging and the other with partial hedging. Parameters: $Z_i = 2, Z_j = 2.7, d_i = 2, d_j = 2, \varepsilon = 1, \alpha = 3, \beta^+ = 3, \beta^- = 1$.

Figure 2: Firm $i$’s profit in the complete hedging equilibrium in the region in which two equilibria exist. Parameters: $Z_i = 2, Z_j = 2.7, d_i = 2, d_j = 2, \varepsilon = 1, \alpha = 3, \beta^+ = 3, \beta^- = 1$. 
A closer look at the strategic effects on hedging policy reveals that hedging policies are either strategically neutral or strategic complements with respect to the level of hedging. At the same time, hedging policies are either strategically neutral or strategic substitutes with respect to the direction of the hedge.

For each firm the higher the currency exposure of its competitor, the more likely is that the firm either overtakes the competitor if the firm has started financially weaker, or increases its advantage if the firm has started financially stronger, in one exchange rate occurrence. Then, the firm has a greater incentive to choose partial hedging over complete hedging, in which case no advantage can be attained. This is most obvious when both complete and partial hedging are possible equilibrium strategies. In this case, partial hedging is a best response when the competitor chooses not to hedge completely. And the higher (smaller) the risks the competitor is willing to take, the more (less) aggressive is the firm’s hedging response.

The reason for the apparent confusion between strategic complementarity and strategic substitutability of hedging results from the fact that the value of $h_i$ embodies two decisions: one is the degree of hedging, measured by the absolute value of $h_i$, and the other is the direction of hedging, indicated by the sign of $h_i$. In referring to the degree of hedging, the firms’ decisions are strategic complements. The higher the absolute level of $h_j, |h_j|$, the higher the absolute level of $h_i, |h_i|$. However, in terms of the direction of hedging, the firms’ decisions are strategic substitutes, since a positive $h_j$ implies a negative $h_i$. That is, the higher the value of $h$ one firm chooses, the lower the value of $h$ that the other firm wants to choose.

The firm’s hedging decision is influenced by the degree of the firm’s indebtedness, the level of exchange rate uncertainty, the magnitude of the strategic effect and the level of penalty that results from borrowing in the capital markets:

**Corollary 1** If in equilibrium partial hedging is chosen, the effect of a change in the exchange rate on each firm’s equity capital is a gain or a loss of $(\beta^+ - \beta^-)$. Hedging increases with exchange rate volatility, $\hat{\varepsilon}$, as well as with the amount of debt, $d$. Hedging decreases with the benefit of an increase in relative equity, $\beta^+ - \beta^-$, and increases with $\alpha$.

As expected, firms’ respond with more conservative hedging strategies to greater exchange rate volatility. The incentives to take advantage of exchange rate speculation decline with more volatile exchange rates, because the per unit deviation from completely hedging accomplishes more in terms of getting ahead of the competitor when the exchange rate is more volatile than when it is stable. Hence the firm does not have to deviate as much to gain distance from its rival as it does during periods of low exchange rate uncertainty. Firms can easily adjust their
hedging to incorporate changes in the perceived volatility of the exchange rates by, for example, altering the currency composition of their debt, or by entering into currency swaps contracts.

The result relating hedging to the relative amount of leverage is also not surprising. The firm with less debt pursues a more aggressive hedging strategy and the firm with more debt hedges more. Given its lower starting position, the more indebted firm has more difficulty in getting ahead by taking a more aggressive hedging policy. The higher leverage puts the firm in a position that if it is combined with a more aggressive choice of hedging can mostly benefit the stronger competitor. This firm, on the other hand, can afford to take greater risks and therefore it hedges less with the intent of further distancing itself. Although the reason differs from that in the model of Bolton and Scharfstein (1990), the result herein in terms of the rivals’ behavior is similar to theirs.

Finally, hedging decreases the larger the benefit from being ahead when the rival falls behind, and hedging increases the higher is the penalty from operating with the same level of external funds.

C. The Firms’ Product Market Decisions

The hedging decision of each firm depends on the production decisions of both the firm and the rival, but production decisions must also be taken in view of what the firms decide for their hedging strategies. Before we concluded that there are two possible hedging strategies depending on the regimes we identified, complete hedging and partial hedging. For the moment, we abstract from the fact that these regimes are endogenously determined by production and assume that the regimes are given.

C.1 Production Decision When Both Firms Hedge Completely

When the difference in equity values between the firms is significant, both firms decide to hedge their exchange rate exposures completely. To determine the firms’ equilibrium behavior in the product market we derive the necessary conditions for a profit maximization. Under the assumptions made these turn out to be sufficient conditions, as well. The necessary condition of the financially weaker firm for a profit maximizing choice of \( x_i \) is given by

\[
\frac{\partial E[w_{i2}]}{\partial x_i} = (1 + 1 + \beta^{-} - \alpha(w_{i0} + (\theta - x_i - x_j)x_i - cx_i))(\theta - 2x_i - x_j - c)
+ \beta^{-}x_j = 0 .
\] (3)

The first term represents the marginal gain in wealth from raising capacity over the two periods, net of the marginal cost from funding production with outside debt. The last term is the marginal benefit the firm has when it raises capacity and lowers the profits of the competitor. From the
expression, $x_i$ is chosen such that $\theta - 2x_i - x_j - c$ is negative, and, from collecting the terms that are multiplied by the coefficient $\beta^+$, also that $\theta - 2x_i - c$ is positive for any level of $x_j > 0$.

The first order condition above differs from the usual Cournot profit maximization condition, $\theta - 2x_i - x_j - c = 0$, because a firm also benefits from the lower profits of its competitor. Thus, firms behave more aggressively in the product market in our setting than in the usual static game.

The financially stronger firm’s necessary and sufficient condition for a profit maximizing choice of $x_i$ is given by

$$\frac{\partial E[w_i]}{\partial x_i} = (1 + 1 + \beta^+ - \alpha(w_i0 + (\theta - x_i - x_j)x_i - cx_i))(\theta - 2x_i - x_j - c) + \beta^+ x_j = 0. \quad (4)$$

This implies that at the optimum output level, $\theta - 2x_i - x_j - c$ is negative and $\theta - 2x_i - c$ is positive. It is clear that the firms’ production choices depend on the financial situations of the two firms, with the financially stronger firm producing more than the financially weaker firm. The higher capacity choice of the financially stronger firm arises for two reasons. First, the stronger firm has a lower marginal cost of production, since for this firm the term $\alpha(w_i0 + (\theta - x_i - x_j)x_i - cx_i$ is smaller. Second, the stronger firm also benefits more from a reduction in the competitor’s profits than the financially weaker firm. This benefit is represented by the last term, $\beta^+ x_j$, which is greater than what the weaker firm benefits if it raises capacity and hurts the rival’s profit, $\beta^- x_j$.

This final term creates an incentive for an even more aggressive behavior on the part of the stronger firm. Knowing that it can negatively affect the wealth of the weaker firm and make it more difficult for this to raise funds in the capital market, the wealthier firm increases its output beyond the capacity at which it would choose to produce in the absence of the strategic effect.

From the cross derivative

$$\frac{\partial^2 E[w_i]}{\partial x_i \partial x_j} = -\left(1 + 1 - \alpha(w_i0 + (\theta - x_i - x_j)x_i - cx_i))x_i(\theta - 2x_i - x_j - c)\right. + x_i(\theta - 2x_i - x_j - c). \quad (5)$$

one can see that, in contrast to the standard Cournot model, the quantities produced by the two firms, $x_i$ and $x_j$, need not be strategic substitutes over the whole range of parameter values. They are, however, strategic substitutes for all non-positive and sufficiently small positive values of $(\theta - 2x_i - x_j - c)$. Thus, production quantities are strategic substitutes for the equilibrium set containing $(x_i, x_j)$.

It is important to note that when firms have the choice between using hedging or production to get ahead of their rivals, they will try to gain distance by being more aggressive in their hedging and not by pursuing more aggressive production strategies. If a firm increases its production at
the optimum by an amount $\Delta x_i$, its first period wealth will go down by $(\theta - 2x_i - x_j - c - \Delta x_i)\Delta x_i$, whilst the wealth of the rival will go down by a lower amount, $x_j \Delta x_i$. The decline in the firm’s wealth comes from selling the original output quantity $x_i$ at a new, lower price, $(\theta - x_i - x_j - \Delta x_i)$, in addition to selling at this reduced price the new added quantity; revenues will decline and at the same time total costs increase by $c \Delta x_i$. This is worse than what the rival suffers from selling the quantity $x_j$ at the price reduced by $\Delta x_i$. Hedging can create difference relative to the rival in a much less expensive way than attempting to do so with production decisions.

### C.2 Production Decision When Both Firms Partially Hedge in Opposite Directions

We have seen that when the firms are not distant in terms of their available equity capital, they both hedge partially. Then, a firm’s necessary and sufficient condition for maximizing wealth is given by

$$\frac{\partial E[w_i]}{\partial x_i} = (1 + 1 + \frac{1}{2}(\beta^+ + \beta^-) - \alpha(w_{i0} + (\theta - x_i - x_j)x_i - cx_i)(\theta - 2x_i - x_j - c) \quad (6)$$

The quantity produced by the financially stronger firm is again larger than that of the financially weaker firm. The reason for this is the lower marginal cost of production of the stronger firm, since with partial hedging both firms have approximately the same interest in reducing the competitor’s profits. This can be seen from the term $\frac{1}{2}(\beta^+ + \beta^-)x$, which is approximately the same for the financially weaker and stronger firms. This similar interest to affect the rival means that for each firm $\theta - 2x_i - x_j - c < 0$. Being negative this term suggest that, leaving other things equal, each firm is more aggressive in setting its output level when it is optimal to partially hedge in equilibrium than when each firm is the financially weaker of the firms, and because of that it is optimally to hedge completely. Similarly, the stronger firm is less aggressive in setting its output when it partially hedges than when it hedges completely.

For each contender, the cross derivative of the objective function is identical to (5). Production quantities are again strategic substitutes. Strategic substitutability implies that, for a set of parameter values for which both partial and complete hedging is possible, the amounts produced can be compared and ranked. The wealthier firm produces more then the financially weaker, regardless of the hedging amount. Partial hedging is associated with less production than complete hedging for the wealthy firm and conversely, is associated with more production in the case of the financially weaker firm. More concretely, the amount produced by the wealthier firm when it hedges completely is greater than the amount produced by this firm when it partially hedges. In turn, this amount is more than the amount produced by the weaker firm when this firm partially hedges, and this is more than the amount produced by the weaker firm under complete hedging.
Production and hedging decisions interact in an interesting way. Production affects the level of indebtedness, which in turn affects the firms’ relative financial ranking. The firms’ financial ranking affects the choice of hedging, and hedging affects production decisions. Since hedging has an impact on the degree of rivalry in the product market, it must therefore be an integral part of a firm’s business strategy. Such conclusions do not appear to be rejected by recent empirical research. He and Ng (1998) find that, in a sample of Japanese multinationals, firms with low short term liquidity and with high financial leverage are less exposed to fluctuations in exchange rates. The authors find that these firms tend to hedge more their currency fluctuations just as the model predicts that financially weaker firms would have an incentive to hedge more, although their finding does not include any condition on the structure of the industries analyzed, and might as well be applied to the case of perfect competition. He and Ng also find that foreign exchange rate exposure increases with firm size. According to the results above, in an industry with a few large firms competing actively, one would expect to see less than complete hedging than in a more dispersed industry both by number and by the relative sizes of the firms.

II The Role of Hedging in the Intensity of Industry Rivalry

Choosing the currency denomination of the debt allows the firms to attain two purposes. First, it protects the firms against exchange rate exposure. Second, it is used by firms in their attempt to get ahead of the rival, and in this sense it allows the firms to create rivalry in financial terms, in addition to the more common form of rivalry in real (production) terms. To see the effects of hedging in creating industry rivalry, we can contrast what is the level of aggregate production when both firms hedge completely versus when both firms remain totally unhedged.

Consider that both firms fully hedge in equilibrium and that firm \( i \) is the financially weaker firm. The solution to expressions (3) is the solution to a cubic function in \( x_i \), the optimal output capacity, given that the rival is at its optimal level. The second derivative of the expected equity value, \( E[\tilde{w}_{i2}] \), with respect to \( x_i \) is \(-\left(2x_i - x_j - c\right)^2 - 2\left(1 + 1 + \beta - \alpha(w_{i0} + (\theta - x_i - x_j)x_i - cx_i)\right)\). Given that \( x_i \) is such that \( (\theta - 2x_i - x_j - c) < 0 \), and that the value of \((1 + 1 + \beta - \alpha(w_{i0} + (\theta - x - y)x - cx)) > 0 \) the second derivative is negative, which implies that there is a unique real solution to the cubic function. The solution is

\[
x_i = \sqrt[3]{\sqrt{\frac{1}{27}m^3 + \frac{1}{4}n^2} - \frac{1}{2}n - \frac{1}{3}m} \cdot \frac{m}{\sqrt[3]{\frac{1}{27}m^3 + \frac{1}{4}n^2} - \frac{1}{2}n}
\]

where \( m = (1 + \alpha w_{i0}) + \beta^+ + \frac{11}{4}(\theta - x_j - c)^2 \) and \( n = -\frac{\beta}{2}(\theta - c + x_j) \).
Suppose that firm $i$ is again the weaker and that the firms, either because there is no hedging instrument or because its management is not allowed or familiar with hedging, do not hedge. Then $h_i = 1$ and $h_j = -1$. If by not hedging firm $i$ could become wealthier in at least one scenario, complete hedging would not be an equilibrium, and the comparison would not be done with complete hedging then. So the possibility of not hedging cannot allow firm $i$ (the weaker firm) to become wealthier than firm $j$. In this case, the expected value of the firm’s $i$ equity is $E[\tilde{w}_{i2}] = Z_i + Z_i - \frac{1}{2} \alpha (Z_i^2 + d_i^2 \varepsilon^2) + \beta^-(Z_i - Z_j)$. The necessary and sufficient condition for a maximum is given by $\frac{dw}{dx} = (1+1+\beta^- - \alpha(w_{i0} + (\theta - x_i - x_j)x_i - cx_i))(\theta - 2x_i - x_j - c) - d_i \varepsilon^2 + \beta^- x_j = 0$. The expression differs from equation 3 in C.1 by including an additional term $d_i \varepsilon^2$, which because of the negative sign, implies that the optimal amount produced, $x_i$, when the firms do not hedge is always less than when both firms hedge. Thus, hedging has important effects that lead to increase in the amount of aggregate production, and higher welfare by lowering prices of the good produced. Firms that do not hedge at all at time $t = 0$ are more exposed, in that their net profits at $t = 1$ are more volatile due to movements in the exchange rate. This can be very costly to the firm’s ability to raise external funds. Volatility would be good if the firm could get ahead, but the rival firms are far apart enough for that to have any impact in their relative positions. Consequently, non-hedging firms need to be more parsimonious in their production to conserve on leverage, since not hedging makes them more exposed. This argument does not apply only to the financially weaker firm, and is also true in the case of the financially stronger firm. Although the stronger firm, knowing that the weaker firm would be unhedged, could possibly be more aggressive and increase its production to damage the already weaker firm, if it chooses to do so it needs to borrow more, which increases its exposure and the risk of falling behind as a result of an adverse shock in the exchange rate.

### III Hedging and Production when Firms Produce in Segmented Local Markets

The idea that firms located in different countries compete vigorously in the global economy is a very common one. Intense rivalry is often associated with drastic actions by firms as the result of deviations from purchasing power parity, namely differentiated pricing policies (pricing to market) and higher prices passed on to consumers of countries with depreciating currencies (pass-throughs).

In this section we ask what is the optimal hedging strategy and how much is production affected by exchange rate uncertainty when firms have costs in different currencies, but sell in the global market? Do producers that differ by their relative wealth, as well as the location of their costs tend to hedge more or less relative to the case of the truly global firm?

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Later, we will ask to what extent firms with international sales adjust production when a change in the exchange rates reduces their profit margins and alters their market share. How is the extent of pass-throughs affected by exchange rate hedging?

A. Firms With Local Productions That Sell Globally.

When firms produce locally, their costs are denominated in the currency of the country and fluctuate with the exchange rate. If the law of one price held for the inputs, the costs in different currencies would instantaneously adjust to reflect the exchange rate change, and there would be no difference between sourcing in one currency or the other. Consistent with most empirical evidence, we assume that the law of one price does not hold, and that costs measured in each currency for inputs are unaffected by changes in exchange rates. Then, the expected equity at \( t = 1 \), measured in the average of the individual currencies, is:

\[
\hat{w}_{11} = \hat{w}_{10} + (\theta - x_i - x_j)x_i - c\xi x_i + h_i d_i \xi = U_i + (h_i d_i - cx_i)\xi. \tag{7}
\]

The expected value of the equity at time \( t = 2 \) is:

\[
E[w_{i2}] = U_i + U_i - \frac{1}{2} \alpha[U_i^2 + (h_i d_i - cx_i)^2 \xi] \\
+ \frac{1}{2} \max \{ \beta^+(U_i + (h_i d_i - cx_i)\xi - U_j + (h_j d_j - cx_j)\xi), \tag{8} \beta^-(U_i + (h_i d_i - cx_i)\xi - U_j + (h_j d_j - cx_j)\xi) \} \\
+ \frac{1}{2} \max \{ \beta^+(U_i - (h_i d_i - cx_i)\xi - U_j - (h_j d_j - cx_j)\xi), \tag{9} \beta^-(U_i - (h_i d_i - cx_i)\xi - U_j - (h_j d_j - cx_j)\xi) \}. \tag{10}
\]

When the same firm may have either less equity or more equity than its rival regardless of the realized value of the exchange rate, the interaction term \( f(\cdot) \) is, as before, either \( \beta^- (U_i - U_j) \) or \( \beta^+ (U_i - U_j) \). When one of the firms is financially wealthier if the exchange rate moves in one direction and financially weaker if the exchange rate moves in the opposite direction, the interaction term for firms hedging in the same direction is in one case:

\[
f = \frac{1}{2} (\beta^+ + \beta^-) (U_i - U_j) + \frac{1}{2} (\beta^+ - \beta^-) [(h_i d_i - cx_i)\xi - (h_j d_j + cx_j)\xi] \tag{11}
\]

and in the other case:

\[
f = \frac{1}{2} (\beta^+ + \beta^-) (U_i - U_j) - \frac{1}{2} (\beta^+ - \beta^-) [(h_i d_i - cx_i)\xi - (h_j d_j + cx_j)\xi]. \tag{12}
\]

It is clear that if it was not optimal for two global firms to hedge in the same direction, it is even less appropriate for local producers to hedge in the same direction. By hedging in opposite directions, firm \( i \) can improve its interaction term, which then becomes:

\[
f = \frac{1}{2} (\beta^+ + \beta^-) (U_i - U_j) + \frac{1}{2} (\beta^+ - \beta^-) [(h_i d_i - cx_i)\xi + (h_j d_j + cx_j)\xi]]. \tag{13}
\]

The result about the direction of the hedges is not surprising. More interesting is, for future reference, the amount of hedging chosen by the firms. Following the argument presented in Proposition 1, one can see that when one firm is at least as wealthy as the rival firm in both exchange rate states (regime 1), the amount of hedging that maximizes the future expected value of the equity is still:

\[
h_i = \frac{\alpha}{\delta_i}, h_j = -\frac{\alpha}{\delta_j}. \tag{14}
\]

When firm \( i \) is wealthier if the exchange rate moves in one direction, but financially weaker if the exchange rate moves in the opposite direction, the hedge amount that maximizes \( E[w_{i2}] = \)
Local producers, on the other hand, must hedge taking into account that their share of the market will shrink. Global firms thus have higher levels of production than local producers selling in the same currency. Indeed, local firms must use their currency debt to counter adverse changes in the exchange rate that make their costs go up when these are translated into the average currency. If firm’s $i$ costs measured in the average currency go up when $\varepsilon$ takes the value of $+\varepsilon$, the value of the foreign currency liabilities must go down by an amount that in addition to giving a boost to the company finances and provide a positive distance in relation to the rival, $\frac{\beta^+-\beta^-}{2\alpha_d}\varepsilon$, also compensate for the higher production costs, $\frac{cr_i}{d_i}$. This cost compensating component of the hedge is the ratio of the costs in one currency to the debt in the other currency. The ratio reflects the help that hedging gives in minimizing the costs of financing production with externally raised funds.

Note that regime 1 occurs as long as $|U_i - U_j| > (h_i d_i - h_j d_j)\varepsilon - c(x_i - x_j)\varepsilon$, otherwise regime 2 holds. The last term inside the parenthesis on the right hand side is positive, since $x_i > x_j$. This implies that the set of parameter values for which regime 1 occurs is larger than in the case analyzed in Section I B, when both rivals firms were global producers. Note that complete hedging for local producers is no longer $h = 0$, but $h = \pm \frac{c}{d}$.

Next, we want to investigate whether firms with production located in different countries produce more to the global market than when these same firms have a choice of sourcing globally. In simpler words, what is the effect of cost location on the degree of industry rivalry when firms optimally hedge? Since the results do not change qualitatively, we perform the analysis for the case of complete hedging, $h_i = \frac{cr_i}{d_i}$, $h_j = -\frac{cr_j}{d_j}$, which is what the firms hedge in regime 1. Suppose that firm $i$ is the financially weaker firm regardless of the exchange rate change. Firm’s $i$ expected equity value is $E[w_{i2}] = U_i + U_j - \frac{1}{2}\alpha[U_i^2 + (h_i d_i - c x_i)^2 \varepsilon^2] + \frac{1}{2}(\beta^+ + \beta^-)(U_i - U_j) + \frac{1}{2}(\beta^+ - \beta^-)((h_i d_i - c x_i)\varepsilon - (h_j d_j + c x_j)\varepsilon)$.

Taking the derivative with respect to $x_i$, after replacing $h_i$ and $h_j$ for their optimal amounts, and equating to zero, gives $(\theta - 2x_i - x_j)(1+\beta^-\alpha(w_{i0}+(\theta-x_i-x_j)x_i)) + \beta^-x_j = 0$. This expression differs from (3) because it leaves out the $-c$ in the term $(\theta - 2x_i - x_j)$ that multiplies the square bracket, as well as in the term $\theta - x_i - x_j$, inside that same bracket. This implies a lower $x_i$ in the case of the local producing firm, compared to the global producer. Thus, the output quantity that maximizes the value of the hedged firm with local production is lower than the optimal output of the global firm. The local producer needs to do a greater adjustment of both prices and quantities to reflect the competitive cost differentials caused by exchange rate shifts. Facing competition, the local firm that is weaker chooses to reduce the quantity it sells, and thus both the total market and the firm’s share of that smaller market will shrink. Global firms thus have higher levels of production than local producers selling in the global market. Local producers, on the other hand, must hedge taking into account that
if the exchange rate moves in one direction they will be less competitive than their rivals, and therefore deviate from the full hedge of the global producing firm.

B. Pass-throughs and Hedging

Many local firms with international sales consider adjusting their production and prices in foreign markets when a change in the exchange rates reduces their local currency profit margins and alters market shares. The extent of pass through the exchange rates changes into the prices of goods denominated in depreciating currencies when costs cannot be easily diversified has been the subject of extensive research. Feenstra (1989), and later Feenstra, Gagnon and Knetter (1996) find that in many industries the pass-through is significant but incomplete (in the order of 30%), meaning that firms adjust markups to offset part of the exchange rate changes. A recent article by Bodnar, Dumas and Marston (2001) explicitly relates the degree of firm’s exposure to the size of pass-throughs when exporting firms with costs based in the local currency compete with foreign firms that produce and sell in foreign markets. These authors point out that exchange rate exposure and pass-throughs need to be jointly estimated to be able to identify relative market shares and the degree of product substitutability. But as intuition would suggest that pricing which affects firms’ profits cannot be separated from exposure, there should be also a relation between hedging and pass-throughs, since hedging must be decided in light of the firm’s exposure and thus the degree of pass through. Clearly, all these should depend on the firm’s and the industry’s characteristics. In this article we focus on the form of competition between firms, assumed to be quantity based. Other factors such as the substitutability between products, differences in the marginal costs of production are ignored for the moment. Including imperfectly substitute products would produce quantitatively different results, but not qualitatively, as Bodnar, Dumas and Marston seem to conclude from the estimation performed for several Japanese exporting industries. It is also easy to incorporate differences in marginal costs of production in our model. Later, a comparison between pass-throughs of purely local cost firms and totally global firms will shed some light on the dependence of pass-throughs on the firm’s location.

Our analysis of pass-throughs begins with one firm being local and selling in the global market, where the multinational competitor also produces and sells. To analyze the impact on the local firm’s future wealth from an adverse change in the exchange rate, we consider that when the exchange rate takes the value of $+\varepsilon$, firm’s $i$ marginal costs go up relative to the global competitor $j$. This is the case because firm’s $i$ costs go up when measured in the average currency, which is the currency of the costs of firm $j$. Consider also that firm $i$ is financially weaker in this exchange rate scenario, but stronger otherwise. This corresponds to the case when the two competitors before the exchange rate moves are close to each other in terms of their relative financial wealth, but the distance changes to favor one firm or the other depending on
the direction of the exchange rate move. Since firms have approximate financial wealth before the exchange rate moves, they optimally hedge partially at $t = 0$, $h_i = \frac{\beta^+ - \beta^-}{2\alpha d_i}$ and $h_j = -\frac{(\beta^+ - \beta^-)}{2\alpha d_j}$, respectively. After the exchange rate has changed, firm’s $i$ equity value is

$$w_{i2\epsilon \epsilon} = U_i + \frac{(\beta^+ - \beta^-)}{2\alpha} + \left[U_i + \frac{(\beta^+ - \beta^-)}{2\alpha}\right] - \frac{1}{2}\alpha[U_i^2 + \frac{(\beta^+ - \beta^-)^2}{4\alpha^2}]$$

$$+ \frac{1}{2}(\beta^+ + \beta^-)(U_i - (U_j - cx_j)) + \frac{(\beta^+ - \beta^-)^2}{2\alpha}$$

Note that while firm $i$ makes money on the hedge, firm $j$ loses money on the hedge. The necessary and sufficient condition for profit maximization is

$$\frac{d w_{i2\epsilon \epsilon}}{dx_i} = [1 + \frac{1}{\alpha}(w_{i0} + (\theta - x_i - x_j)x_i)](\theta - 2x_i - x_j) + \frac{1}{2}(\beta^+ + \beta^-)(\theta - 2x_i) = 0$$

which is the expression that would result for $\frac{dE(w_{i2})}{dx_i}$ in the case of a local producer. That is, if the firm is optimally hedged and takes into account when hedging the local content of its costs, then it should not reduce its quantity produced after hit by a bad exchange rate move that affects its costs. However, since the firm is not fully protected, its production will go down relative to the case where the firm fully hedges. Consequently, it should pass through only the exposure that it takes from trying to gain a strategic advantage.

To see whether this result depends or not on the relative financial strength of the firms, consider that both firms decide to hedge completely because they are financially far apart. Firm $i$ is local and has wealth at time $t = 1$ of $\hat{w}_i = w_{i0} + (\theta - x_i - x_j)x_i - c\varepsilon x_i + h_i d_i \varepsilon = U_i + (h_i d_i - cx_i)\varepsilon$; firm $j$ is global and has wealth of $\hat{w}_j = w_{j0} + (\theta - x_j - x_i)x_j - cx_j + h_j d_j \varepsilon = U_j - cx_j + h_j d_j \varepsilon$. The optimal hedging is $h_i = \frac{\varepsilon}{d_i}$ and $h_j = 0$, respectively. When both firms hedge as much as possible and firm $i$ is hit by a bad currency shock when $+\varepsilon$, the equity value at $t = 2$ is

$$w_{i2\epsilon \epsilon} = U_i + U_i - \frac{1}{2}\alpha U_i^2 + \beta^-(U_i - U_j + cx_j)$$. The condition for a maximum is $[1 + \frac{1}{\alpha}(w_{i0} + (\theta - x_i - x_j)x_i)](\theta - 2x_i - x_j) + \beta^-(\theta - 2x_i) = 0$, which is the result of $\frac{dE(w_{i2})}{dx_i}$ when it is optimal to completely hedge. So, local firms when optimally hedge fully do not reduce, relative to their plans before the exchange rate moves, their production capacity and increase prices after being hit by a bad realization of the exchange rate that raises currency translated costs. At first, it might be unclear as to why firms that are partially hedged do not pass through when they are hit by a change in the value of the exchange rate that raises their costs. The reason is that these firms are fully hedged against their production risks. Partial hedging attains distance from rivals and gaining distance through production, that is, by deliberately trying to take risks in production is expensive. Hedging is therefore critical in that without it firms will try to cut capacity and pass through the unprotected change in exchange rates into the prices they charge in international markets.
In measuring the output capacity cuts that result from exchange rate fluctuations, it is worth noting a purely translation effect. When profits and values are measured in the average currency, the local firm cuts in capacity are mainly driven by higher marginal costs. When profits and values are instead measured in the local currency, the local firm selling in the global markets against a global competitor at prices denominated in the average currency, will have lower revenues from the fall in price and will lose competitiveness, reacting by cutting down its output by more than in the previous case. The appreciation of the local currency makes the local firm lose profits when measured in the average currency relative to an unchanged currency, and this happens precisely when the average currency is worth less, so those losses are even more costly.

Also, the bigger the parameter $\theta$, the lower the elasticity of the price to demand and the greater the market power of the firm (note that as $\theta$ goes up, the optimal quantity produced, $x_i$, drops). Therefore, other things equal, the unhedged firms’ capacity is cut by more as a result of an adverse shock in the exchange rate, the higher is $\theta$. The greater the industry’s competition, the less able is the firm to cut capacity and pass-through to prices the bad shocks in the exchange rate. Hedging also reduces the level of pass-through, but for a different reason, and that is that the firm has less incentive to alter its production given that its hedged profits change little. Many authors researching pass-throughs by local producers selling to foreign markets concur that pass-throughs are lower in the US market. The traditional explanation is that the US market is more important to every firm and therefore more competitive than other markets, resulting in more incomplete pass-throughs. A larger, more important market also induces firms to hedge more the value of the profits to be made in that market. The analysis of pass-throughs need to be done along with the exposure of a firm’s profits, and these depend as much on the firm and industry characteristics, as they do on the hedging strategy of the firms.

In the case of global firms it is not possible to talk about a firm being hit by an adverse move in the exchange rate. However, it is possible to contrast production of a global firm with that of a local firm when both are subject to the same exchange rate shock. It can be shown that, if regime 1 applies and both firms fully hedge because there is no incentive to financial speculate given the differences in the wealth of the rivals, the necessary and sufficient condition for a maximum is exactly expression (6). This solution gives a higher output than in the case of a local firm that is hit by the same -in this latter case ”bad”- exchange rate change. Hence, the model seems to generate the following results: 1) the pass through for a fully hedged local firm or a fully hedged global firm is none; 2) there is a change of output level and corresponding pass through for a partially hedged local firm; 3) the change in output level and pass through for an unhedged global firm is lower than the pass through for a local producer selling in global markets against global competitors. Results 1) and 2) imply that for hedged firms, changes in production resulting from adverse changes in exchange rates depend not on location but on
the relative position of the firms in the industry. Interestingly, a much stronger firm cuts its production much less than if that firm is closer to its direct competitors. Hence, dominant firms in the industry, closer to being monopolists, choose to pass through much less as a result of being local than local firms which compete neck to neck with their rivals. With respect to result 3), it appears that the conjecture made by Knetter and Goldberg (1997) that increased foreign outsourcing means a decline in the share of costs incurred in the local currency, which further reduces the degree of pass through is correct, but only insofar as the firms do not hedge, or cannot hedge completely.

Our model also may help in explaining Griffin and Stulz (2001) findings that for a good deal many industries the competitive effects of exchange rate shocks are economically negligible. As the authors point out "The effect of exchange rate shocks on firm value is made even more complex because firms often hedge their foreign exchange exposures. As a result, a firm could increase its operating income following a devaluation of its currency, but this increase could be offset by losses on hedges and that firm value would be unaffected" (pp.218). The authors also conclude that industry shocks have common effects across countries rather than competitive effects. This is in line with our conclusion that hedging alters the pass-throughs which become independent of location and instead depend on the relative ranking of the firms in the industry.

An important implication of this model is that tests of equity price sensitivity to exchange rates need to be done at the industry level and take into account the firms’ degree of rivalry.

Also, there are many motives why firms could hedge differently from what we prescribe in this article and yet that would still be optimal. It may be that the distribution of exchange rates is not known and constant, but instead varies over time. It is, however, not sufficient to say that the expected change in the exchange rate changes or that its variance also changes, or that the probabilities of an upward change differs from the probability of a downward change, since all these could be easily accommodated in the model without changing qualitatively the results. It must be that changes in the distribution are random, for pass-throughs to occur in a correctly hedged industry. Second, firms may have to create "real" responses to exchange rate exposures when financial hedges cannot do the job because liquid markets for exchange rate hedges and derivative securities do not go beyond a relatively short horizon and only exist for a few exchange rates. It is clear from what we saw before that given the limitations of financial hedges, firms have to make stark adjustments to capacity when responding to exchange rate shocks. Finally, a word of caution because pass-throughs depend on how the exchange rate affects both mark-ups and marginal cost. Markups are affected by the curvature (elasticity) of demand in import markets. In our case all destination markets are characterized by a constant elasticity of demand, so the output should correspond to a price equivalent to a fixed markup over marginal cost.
IV Extensions

Several interesting questions remain to be considered. In this section we briefly analyze some additional extensions of the basic model.

A. Hedging and Production with Demand and Exchange Rate Uncertainty

Since the model presented above only has one source of uncertainty, it does not capture the possibility that production can be also subject to shocks that affect the magnitude of both the costs and revenues. It is natural then to ask what are the effects of introducing uncertainty in the product markets. Randomness in costs will not change the hedging strategy of the firm at all unless we change the assumed sequence of actions. In our setting, when the firm produces it must observe the costs, which determine the amount it needs to borrow to cover the cash shortfall, \( w_{i0} - cx_i \), and also affect the hedging to follow. Whatever is the level of the marginal costs, the firm must know it when it hedges. Unless hedging takes place before the firm decides on production, uncertainty about costs will not affect the firm’s hedging and the effects of hedging on production itself. A different and plausible case is when, after production and hedging have taken place, the firm verifies that its revenues have varied. In this case, it is also possible that shocks to the revenues be independent across rival firms or correlated, as well as that the realized revenues for each firm are related to the level of the exchange rate.

To see how demand uncertainty influences hedging and production decisions, imagine that each global firm -that produces and sells in both currencies- after producing \( x \), sells either the total production \( x \), or a lower amount, \( x - \nu \), with equal probability. \( \nu \) represents, for example, the units that are either defective or not sold and perishable, such as the number of revenue miles lost from unsold tickets in an airline. When the shocks to demand are independent across firms, matters complicate as there are eight possible states, four for each realization of the exchange rate when firm \( i \) and firm \( j \) both receive or not a shock, and when one firm receives a shock but not the other. The expected level of wealth of firm \( i \) at \( t = 1 \) is

\[
E(w_{i1}) = w_{i0} + (\theta - x_i - (x_j - \frac{\nu}{2}))x_i - \frac{1}{2} \nu(\theta - 2(x_i - \frac{\nu}{2}) - (x_j - \frac{\nu}{2})) - cx_i
\]

where the second term is the expected revenue when firm \( i \) is not affected by a shock, but firm \( j \) is either affected or not, and the third term is the expected loss to firm \( i \) when the firm is hit by a shock of \(-\nu\), when firm \( j \) can be either hit by a shock or not. Note that the expected wealth does not contain the debt, for the same reason why in the simplest model also did not, and that is that the currency denominated debt may increase or decrease by an equal amount with how the exchange rate moves in one direction or its opposite. The expected wealth at time \( t = 2 \) depends on the above expression and shows the importance of shocks to own demand and to the rival’s demand. The optimal hedging policy still continues to be the same, that is \( h_i = -h_j \)
if firms partially hedge, and \( h_i = h_j = 0 \) when the difference in wealth between the two firms, after accounting for the expected losses in demand, is large. When the differences in wealth between rival firms is small, firms still pursue partial hedging policies to create financial rivalry and attempt to get ahead of its rivals. But the level of hedging depends on the relative ranking of the firms’ wealth that result from the shocks to demand. If one firm is always stronger if the exchange rate moves in one direction and always the weaker if the exchange rate moves in the opposite direction, then the exchange rate shock dominates the demand shock in the relative performance of the firms and the results of the basic model with only exchange rate uncertainty hold. If firms partially hedge, firm \( i \) will hedge \( h_i = \frac{\beta^+ - \beta^-}{2a_d\epsilon} \). There is also the possibility that one firm is stronger if the exchange rate moves in one direction, except when that firm receives a negative shock to demand and not the other firm, in which case it becomes the weaker even for an exchange rate that in principle does give it a cost advantage. This corresponds to the case when firm \( i \) is ahead (behind) of firm \( j \) if the exchange rate is \( +\epsilon \) \((-\epsilon)\), unless firm \( i \)' sales are \( x_i - \nu \left(x_i\right) \) and firm \( j \)' sales are \( x_j \left(x_j-\nu\right) \). Then, the optimal hedging is \( h_i = \frac{\beta^+ - \beta^-}{4a_d\epsilon} = -h_j \). Since this is also the optimal hedging when the firm is either always financially weaker (or always financially stronger) except when it receives no shock to its demand and the opponent receives a negative shock to its demand (or when the opposite occurs, and the rival gets no shock to demand but the firm itself does), then it is true that demand shocks affect the level of hedging.

The possibility that shocks to demand may alter the relative ranking under a particular value for the exchange rate, makes the firms behave more conservatively and cut their deviation from complete hedging by a significant amount (in this case of symmetric probabilities by one-half).

Could the conclusions above be influenced by the assumption that the shocks to the firms’ demands are independent? To see whether this is the case we next consider when shocks to the firms’ revenues are perfectly correlated. In this case there are four possible states, two for each realization of the exchange rate when firm \( i \) and firm \( j \) receive or not both a shock. The expected level of wealth of firm \( i \) at \( t = 1 \) is

\[
E(w_{i1}) = w_{i0} + (\theta - x_i - x_j)x_i - \frac{1}{2}\nu(\theta - x_i - x_j - 2(x_i - \nu)) - cx_i
\]

where the second term is the expected revenue when both firms are not affected by a shock, and the third term is the expected loss to firm \( i \) when both firms are affected by a shock. From \( E(w_{i1}) \) it is simple to derive \( E(w_{i1}) \) and see that the hedging strategies of the firms remain as before. When the firms are far apart in terms of wealth, the optimal strategy is again \( h_i = h_j = 0 \), and when the firms are relatively close in financial strength the optimal hedge is \( h_i = -h_j = \frac{\beta^+ - \beta^-}{2a_d\epsilon} \).

Consequently, the probabilistic nature of the shocks affecting the firms do not seem to matter as to the conclusion when firms hedge partially or completely, although the mere possibility of independent demand shocks may have an impact on the amount of hedging. In any case, however, it is true that demand uncertainty in addition to exchange rate uncertainty leads to
more conservative behavior, in that the parameter values leading to complete hedging by both firms tends to increase for both firms.

The case of demand correlated with the exchange rate is an interesting one that remains to be analyzed. Suppose a German producer competing with an US producer, both selling in the global market. When the Euro appreciates relative to the US dollar, the costs of the German producer go up relative to the costs of the US rival. Consider that the firm producing in the strong currency is more vulnerable to demand shocks than the firm producing in the weak currency. That is, the German firm could potentially see its sales go down at the same time that the Euro is appreciating. Low sales and a bad exchange rate outcome that raise its costs lead the firm to increase its future indebtedness, which affects both its future financial condition, as well as its relative position in the industry. The expected wealth at $t = 1$ is $E(w_{i1}) = w_{i0} + (\theta - x_i - x_j)x_i - \frac{1}{4}\nu(\theta - 3x_i - x_j - \nu) - cx_i$, where the third term represents the expected loss when the firm receives a negative shock to its demand, which happens with probability one-fourth, and the other three-fourths the firm sells the $x_i$ that it produces. If the firm despite the negative shock is always the financially stronger firm, there is no reason to change its hedging policy and will just compensate for the possible exchange rate impact on its total costs, $h_i = \frac{\partial h}{\partial t}$; similarly $j$ will prefer to hedge $h_j = -\frac{\partial h}{\partial t}$. If firm $i$ is always the stronger in one exchange rate scenario and always the weaker when the exchange rate moves in the opposite direction, the two firms hedge partially an amount $h_i = -h_j = \frac{\beta^+ - \beta^-}{4\alpha d_i \tilde{\varepsilon}} + \frac{c_i}{d_t}$. And if firm $i$ is the financially stronger despite an appreciating currency that raises its costs measured in the average currency, except when the demand for its product declines, and the opposite happens for firm $j$, then both firms will again hedge partially, and in opposite directions an amount $h_i = -h_j = \frac{\beta^+ - \beta^-}{4\alpha d_i \tilde{\varepsilon}} + \frac{c_i}{d_t}$. The intuition for a more conservative hedge is the same as above: the possibility of falling behind because of simultaneous adverse shocks to the exchange rate and to the demand that makes the firm weaker when otherwise it would be the stronger firm, reduces the incentives to hedge only partially.

Exchange rate pass-throughs when firms confront both demand and exchange rate risks can be also analyzed. Imagine that firm $i$ has its costs up by a bad exchange rate outcome, and its sales down by a bad market for its product. Firm $j$, on the other hand, sees its relative costs decline since it produces in the weak currency and also does not suffer a shock to its sales. The two adverse shocks make firm $i$ weaker than its rival. Consider that this extreme case is the only one where firm $i$ becomes the weaker firm when the exchange rate takes that value. Solving for firm $i$’ optimal level of production after the realization of two bad shocks (exchange rate and demand) and using the optimal hedge ratios $h_i = -h_j = \frac{\beta^+ - \beta^-}{4\alpha d_i \tilde{\varepsilon}} + \frac{c_i}{d_t}$ gives a necessary and sufficient condition for the optimal production $\frac{dw_{i2,\tilde{\varepsilon}} - \alpha}{dx_i} = [1 + 1 - \alpha(w_{i0} + (\theta - (x_i - \nu) - x_j)(x_i - \nu))(\theta - 2(x_i - \nu) - x_j) + \frac{1}{2}(\beta^+ + \beta^-)(\theta - 2x_i)] = 0$. The solution to this expression is different.
from the optimal level of production that firm \( i \) chooses ex-ante due to the term \( \nu \), when it plans production on the basis of expected exchange rate values and expected levels of demand. So, in this case an optimally hedged firm alters its level of production in response to adverse changes in exchange rates and shocks to demand, and the level of pass-through is positive after encountering a low sales scenario, in addition to an adverse exchange rate. Using the same logic as before in Section II.B it can be shown that a much stronger firm than its rivals would cut production by less than if the firm were closer to its rival.

### B. Hedging With Options

So far we have considered only hedging strategies with linear payoffs, such as straight currency denomination of the firm’s debt, foreign exchange forward contracts and currency swaps. Most surveys on risk management document that these are the most commonly used contracts. However, options can achieve state contingent payoffs that linear contracts cannot that sometimes suit better the hedging needs of corporations. In this section we analyze hedging strategies with options. In doing so we answer two questions. First, whether hedging with different contracts influence the firms’ strategies in the product market. Second, when product market rivalry interacts with hedging, what type of hedging contracts do firms prefer to use, and for what reason?

We can look at contingent hedging strategies using the same set up as in Section II. Consider the case of a call option at the money that pays \( \max\{0, \hat{\varepsilon} - \varepsilon\} \) if \( \hat{\varepsilon} = +\varepsilon \), and \( \max\{0, |\hat{\varepsilon} - \varepsilon|\} \) if \( \hat{\varepsilon} = -\varepsilon \). The fair price of the first option is \( \zeta(\varepsilon) = \sum_{\hat{\varepsilon}} p(\hat{\varepsilon}) \max\{0, \hat{\varepsilon} - \varepsilon\} \), where \( p(\hat{\varepsilon}) \) is the probability that the exchange rate takes the value \( \hat{\varepsilon} \). A firm that uses \( \alpha \) number of options to change the currency risk profile of its future wealth, has wealth at period \( t = 1 \) of \( \hat{w}_{i1} = w_{i0} + (\theta - x_i - x_j)x_i - cx_i + d_i\hat{\varepsilon} + \alpha_i \max\{0, \hat{\varepsilon} - \varepsilon\} - \alpha_i\zeta(\varepsilon) \). Note that the debt remains unhedged and therefore is one-hundred per cent denominated in a single currency. The option premium, \( \zeta(\varepsilon) \), is expressed in the average currency. Using the same logic as in Section II it can be shown that if the firms buy any options at all, then it is optimal that they buy options that pay when the exchange rate moves in the opposite direction of the options the rival firm has purchased. Consider the case when firm \( i \) is always financially stronger, no matter what value the exchange rate takes. The expected value of the wealth at time \( t = 2 \) when firm \( i \) has options that pay if the exchange rate moves to \(+\varepsilon\) is:

\[
E[\hat{w}_{i2}] = 2Z_i + \alpha_i \Delta(\varepsilon) - 2\alpha_i\zeta(\varepsilon) - \frac{1}{2} \alpha_i [(Z_i + d_i\varepsilon)^2 + \frac{1}{4} \alpha_i^2 \Delta(\varepsilon)^2 - \alpha_i^2 \zeta^2(\varepsilon)]
\]

\[
+ \frac{1}{2} \{ \beta^+(Z_i + d_i\varepsilon + \alpha_i \Delta(\varepsilon) - \alpha_i\zeta(\varepsilon) - (Z_i + d_i\varepsilon - \alpha_i\zeta(\varepsilon)) \}
\]

\[
+ \frac{1}{2} \{ \beta^-(Z_i - d_i\varepsilon - \alpha_i\zeta(\varepsilon)) - (Z_j - d_j\varepsilon + \alpha_j \Delta(\varepsilon) - \alpha_j\zeta(\varepsilon)) \} \]

(13)
where $\Delta(\varepsilon) = |\tilde{\varepsilon} - \varepsilon|$. The value of $g(\cdot)$ strictly decreases with $o_i$ for values such that $\frac{1}{2}\Delta(\varepsilon)^2 > \varsigma^2(\varepsilon)$, and otherwise increasing. For a fairly priced option the equality holds, since for such option $\varsigma(\varepsilon) = \frac{1}{2}\Delta(\varepsilon)$. This implies that, in equilibrium, purchasing fairly priced options does not affect $g(\cdot)$. On the other hand, for firm $i$, $f(\cdot) = \frac{1}{2}(\beta^+ + \beta^-)(Z_i - o_i\varsigma(\varepsilon) - Z_j + o_j\varsigma(\varepsilon)) + \frac{1}{2}(\beta^+ - \beta^-)(d_i\varepsilon + d_j\varepsilon) + \frac{1}{2}\beta^+o_i\Delta(\varepsilon) + \frac{1}{2}\beta^-o_j\Delta(\varepsilon)$, if the firm is wealthier when the exchange rate moves from $\varepsilon$ to $+\varepsilon$ and the firm cashes in on the options contracts, and financially weaker than its rival when the exchange rate moves to $-\varepsilon$ and the options expire worthless. Note that in this case, the condition for optimal hedging with options implies that

$$\beta^+\Delta(\varepsilon) = (\beta^+ + \beta^-)\varsigma(\varepsilon)$$

At the margin, the strategic gain from getting ahead of the rival with the use of options equals the financial effect imposed by the purchase of the options, a cost that is borne no matter how the exchange rate evolves.

When the firm is always the financially stronger or the financially weaker firm, the condition for optimal hedging with options is instead $\beta^+[\frac{1}{2}\Delta(\varepsilon) - o_i\varsigma(\varepsilon)] = 0$, and since the expression inside the parenthesis equals zero for a fairly priced contract, the firm is indifferent between remaining unhedged and trading options.

Options are expensive in that they require an up-front disbursement that affects the indebtedness of the firm, which is financed with costly external funds. A simple way of showing the effect of using options on the financial situation of the firm is by analyzing whether a firm is better or worse off if it optimally hedges with currency debt instead of trading currency options. With currency debt, the firm’s wealth at time $t = 1$ is $\tilde{w}_{i1} = w_{i0} + (\theta - x_i - x_j)x_i - cx_i + h_id_i\hat{\varepsilon}$. Recall that when it is optimal for the firm to partially hedge because the financial situation of the rival firm is not very different, $h_i = \frac{\beta^+ - \beta^-}{2\alpha\tilde{\varepsilon}}$. Using this in the expected value of $\tilde{w}_{i1}$, gives $w_{i0} + (\theta - x_i - x_j)x_i - cx_i + \frac{\beta^+ - \beta^-}{2\alpha}$. If instead the firm trades currency options and denominates all its debt in a particular currency, the wealth at $t = 1$ is $\tilde{w}_{i1} = w_{i0} + (\theta - x_i - x_j)x_i - cx_i + d_i\hat{\varepsilon} + \frac{1}{2}o_i\Delta(\varepsilon) - o_i\varsigma(\varepsilon)$. Taking expectations, knowing that with partial hedging with currency options $\Delta(\varepsilon) = \frac{[\beta^+ + \beta^-]}{\beta^+}\varsigma(\varepsilon)$, and comparing with the expected wealth with currency debt, implies $\frac{\beta^+ - \beta^-}{2\alpha} \leq o_i[\frac{1}{2}(\beta^+ + \beta^-) - 1]\varsigma(\varepsilon)$. The expression inside the parenthesis is always negative, since $\frac{1}{2}(\beta^+ + \beta^-) < 1$, while the left hand side is always positive. Firms find that using options is an expensive way of speculating to get ahead of its rivals. For a fairly priced option contract, firms will never do it. To gain the desired financial advantage relative to their rival, the firm must make an immediate investment in options and this increases the firm’s indebtedness, which is equivalent to starting from a relatively (to the rival) lower financial standpoint. That requires buying an even greater number of options to try to get ahead, which in turn imposes a larger up-front investment financed with debt, and so on.
V Empirical Implications

Hedging depends on own and the rival’s financial situation. Differences in size, or performance and wealth should affect hedging. Hedging depends not just on own measures, but also on relative measures. Hedging depends on the intensity of product market competition. In markets in which positions are clearly defined and stable, firms minimize financial risk. This is not the case if product market competition is intense.

*Firms hedge less and they hedge different risks when they are in intense competition*

If firms are close in financial and market position, firms are predicted to hedge less than when a clear leader has established itself in the market. It is actually possible that firms encountering intense competition do not hedge at all but rather speculate. Our approach also predicts that firms in intense product market competition hedge different risks. Copying each other without hedging completely is never an equilibrium outcome. Different than in tournaments, it is not only the rank that counts but also the difference in financial means between the market leader and the remaining competitors. This implies, for example, that in young and evolving industries, in which market positions are changing frequently, firms should hedge less than in mature and stable industries.

*Firm’s pass-through more of an adverse exchange rate development when their competitors are on equal financial footing*

Firms optimize their exposure. The optimal level of exposure is determined entirely by the relative financial strength of the players in an industry and is independent of whether a firm is producing locally or globally. Thus, the reduction of production in case of an adverse exchange rate development does not depend on where the firm is producing. Pass-throughs by both locally and globally producing firms are relatively large when competitors are close, because equilibrium exposure is large as well.

VI Conclusions and Final Remarks

Hedging allows firms to stabilize their internally generated funds and undertake necessary production decisions, which might have otherwise to be bypassed in the face of costly external financing. The costs of external financing have an impact on the firms’ competitiveness. But
hedging is also a way of achieving financial rivalry and getting ahead of competitor firms. The value of trying to distance from competitors largely lies on the strategic interactions between firms in the industry. The strategic component is analyzed here in a simple duopoly model that takes into account the role of expected profits on own future financial constraints as well as on those of the rivals, both affecting the value of the equity. It is shown that firms have a strong incentive to increase the odds of becoming ahead of their rivals, given that their rivals will likely fall behind. This implies that, in equilibrium, (a) firms choose to hedge in different currencies, and (b) firms hedge less the greater is the product-market effect relative to the costs of being financially constrained; (c) an important part of the motivation for firms’ hedging decisions is to increase profit relative to their competitors (benchmark) rather than to reduce volatility. Other less-surprising implications of our model are that: (d) the equilibrium degree of hedging is increasing in the level of debt, in the degree of exchange-rate volatility, and that (e) when firms are sufficiently distant in terms of relative financial wealth, they choose the maximum hedge ratio. Not surprisingly, this is also what firms do when there are no interactions in the product-market. Of course, some of the results obtained depend on the degree of industry rivalry. In particular, the strategic effects influencing the optimal hedge should diminish as the number of firms in the market grows. In general, the model justifies that in hedging each firm takes into account what risks to hedge in relation to its more direct rivals. As a concept, exposure is not meaningful if it abstracts from the particular market structure and the degree of rivalry in the industry where a firm competes.

We consider the case of global firms, as well as firms with operations based in different countries. This allows us to evaluate the importance of location in both hedging and product market decisions. We also measure the impact of hedging on pass-throughs, when the firm is hit by a bad exchange rate outcome. We conclude that when hedging is properly done, by that we mean that hedging takes into account the particular exchange rate exposure arising from location, pass-throughs should be immaterial if the firm fully hedges, but not when the firm is partially hedged. Discounting the fact that a different competition model could have a slightly different outcome, the conclusion seems to conform with the evidence that exposures are very small to significantly impact share prices, but the evidence that pass-throughs are in the order of 30% can only be reconciled with the results of the model in the case of sectors where the firms compete neck to neck with each other. Correlation between shocks to the exchange rate and to the firm’s demand aggravate the exchange rate adjustment after the bad shock. Alternatively, such level of pass-throughs could be explained if firms would find it difficult to hedge value, difficult to

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6 See Griffin and Stulz (2001)

7 see Knetter (1993)
hedge beyond shorter maturity horizons, as well as by other factors that affect foreign exchange hedging not included in the model.

There are many extensions that can be readily incorporated in the model. We discuss several of them at length. The reader may notice that we have not modelled the choice of the debt level. Instead, we have implicitly assumed that the firm optimally chooses a positive level of debt. However, one might ask why the firm chooses to be partly financed with outside debt in the first place when the model prescribes costs from being financially constrained and, albeit outside the model, debt imposes other costs, such as financial distress costs that reduce the firm’s value. It can be shown that the inclusion of financial distress costs produces the same sort of results herein. The intuition is that financial distress leads to the downfall of one rival to the great benefit of the remaining rival, which is similar to the outcome in this model. Second, external financing imposing deadweight costs have been justified when it is costly to outside investors, but not insiders to verify the firms’ performances, as in the models of Townsend (1979) and Gale and Hellwig (1985), as well as in a more recent application to hedging by Froot, Scharfstein and Stein (1993). It is also easy to incorporate the trade-off between debt tax shields and the deadweight costs associated with financial constraints. Clearly, with taxes and financial constraints, the optimal debt ratio must be decided simultaneously with the level of hedging. However, preliminary results show that nothing of substantive would change in the results if taxes were explicitly considered. For example, with a constant marginal corporate tax rate, \( \tau \), it is possible to show that the firm hedges less (a higher value \( |h_i| \)) when the optimal level of debt \( d_i \) is lower. Also, if the corporate tax rate increases, so does the debt tax shields and, as a result, the optimal degree of firm leverage increases for given levels of hedging.

**Appendix**

Proof of Lemma 1

Suppose that \( h_j = -h^\circ_j < 0 \) and \( h_i = -h^\circ_i < 0 \). We show that \( h_i = 0 \) or \( h_i = h^\circ_i \) yield a strictly higher benefit for firm \( i \). The expected value of the equity of a firm at time 2 depends on the expected values of \( g(\cdot) \) and \( f(\cdot) \). The term \( g(\cdot) \) strictly decreases with the absolute value of \( h \). The function \( f(\hat{w}_{i1} - \hat{w}_{j1}) \) can take four different forms, depending on the relative values of the equity of the firms: (1) firm \( i \) may have less equity (more debt) at the end of period 1 than firm \( j \) in both exchange rate scenarios; (2) firm \( i \) may have more equity (less debt) than firm \( j \) in both scenarios; (3) firm \( i \) may be less indebted than firm \( j \) only in the case of an \( \epsilon = +\epsilon \), and may be more in debt than firm \( j \) for \( \epsilon = -\epsilon \) or (4) firm \( i \) may be less indebted than firm \( j \) only in the case of an \( \epsilon = -\epsilon \), and may be more in debt than firm \( j \) for \( \epsilon = +\epsilon \). The value of \( f(\cdot) \) in the four cases is given by \( \beta^- (Z_i - Z_j) \), \( \beta^+ (Z_i - Z_j) \), \( \frac{1}{2} (\beta^+ + \beta^-) (Z_i - Z_j) + \frac{1}{2} (\beta^+ - \beta^-) (-h^\circ_i d_i \epsilon + h^\circ_j d_j \epsilon) \),
and \( \frac{1}{2} (\beta^+ + \beta^-) (Z_i - Z_j) + \frac{1}{2} (\beta^+ - \beta^-) (h_i^2 d_i \varepsilon - h_j^2 d_j \varepsilon) \), respectively. In the first two cases the value of \( f(\cdot) \) does not depend on \( h_i \). Choosing \( h_i = 0 \) then increases firm \( i \)'s expected equity value, because \( g(\cdot) \) is concave. In the third case, firm \( i \) can achieve a value of \( f(\cdot) \) of at least \( \frac{1}{2} (\beta^+ + \beta^-) (Z_i - Z_j) + \frac{1}{2} (\beta^+ - \beta^-) (h_i^2 d_i \varepsilon + h_j^2 d_j \varepsilon) \) if it switches from \( -h_i^2 \) to \( h_i^2 \) This provides a strict improvement of \( f(\cdot) \)'s expected value. \( g(\cdot) \) is unchanged by the switch, and therefore the switch increases the expected equity value. In the fourth case, by switching from \( -h_i^2 \) to \( h_i^2 \) firm \( i \) will be better off in \( +\varepsilon \) and worse off in \( -\varepsilon \). Then, firm \( i \) is able to achieve the same value of \( f(\cdot) \) as in scenario (3). Therefore, this is also a strict increase in \( f(\cdot) \)'s expected value. Since \( g(\cdot) \) remains unchanged, switching increases the expected equity value.

Proof of Proposition

We first prove a weaker result.

**Lemma 2** If the firm is at least as wealthy (measured by the value of the equity) as the other one in both states, the best response of a firm is to hedge completely, \( h = 0 \). If one firm is wealthier in one exchange rate scenario, and the other firm wealthier in the other exchange rate scenario, the best responses are \( h_i = \frac{\beta^+ - \beta^-}{2ad_i \varepsilon} \) and \( h_j = -\frac{\beta^+ - \beta^-}{2ad_j \varepsilon} \).

**Proof.** Call (regime 1) the case of the same firm being wealthier regardless of the exchange rate realization, and (regime 2) the case when one firm is wealthier if one value of the exchange rate occurs, and the rival firm being wealthier if the other value of the exchange rate occurs. In regime 1 the expected value of \( f(\cdot) \) is independent of the level of hedging. When all terms that are not affected by \( h \) are denoted by the constant \( 1K_i \), \( E[\tilde{w}_{i;j}] = 1 K_i - h_i^2 d_i \varepsilon^2 \). This term is maximized when firm \( i \) chooses \( h_i = 0 \). Analogously, \( h_j = 0 \).

In regime 2, \( f(\cdot) \) changes with \( h \). Denoting the independent terms by \( 2K_i \), \( E[w_{i;j}] = 2 K_i - h_i^2 d_i \varepsilon^2 + \frac{1}{2}(\beta^+ - \beta^-)[Z_i - Z_j + h_i d_i \varepsilon - h_j d_j \varepsilon] \). The necessary and sufficient condition for a maximum is \( h_i = \frac{\beta^+ - \beta^-}{2ad_i \varepsilon} \). Analogously, the optimal choice for firm \( j \) is \( h_j = \frac{\beta^+ - \beta^-}{2ad_j \varepsilon} \). ■

Note that the equity value is continuous in the level of hedging even when a change in regime occurs. Note also that a higher level of hedging increases the set of parameters in which regime 1 prevails. Thus, firm \( i \)'s best response correspondence contains only the elements \( 0 \) and/or \( \frac{\beta^+ - \beta^-}{2ad_i \varepsilon} \) and is never empty. As a consequence, \( (0,0) \) and \( \left( \frac{\beta^+ - \beta^-}{2ad_i \varepsilon}, -\frac{\beta^+ - \beta^-}{2ad_j \varepsilon} \right) \) are the only pure-strategy candidates for the equilibrium of this subgame.

Taking into account that regime 1 occurs for \( h_i d_i \varepsilon - h_j d_j \varepsilon \leq |Z_i - Z_j| \) and regime 2 otherwise, it is straightforward to check that the strategy pairs given in the proposition indeed constitute the pure-strategy equilibria of the subgame.

Proof Corollary 1
The gain or loss in the expected value of equity from a change in the exchange rate is simply

\[ \Delta E[w_{i2}] = -\frac{1}{2} \frac{\partial h_i}{\partial \varepsilon} d_i^2 \varepsilon^2 + \frac{1}{2} (\beta^+ - \beta^-) \frac{\partial h_i}{\partial \varepsilon} d_i \varepsilon, \]

which after substituting for \( \frac{\partial h_i}{\partial \varepsilon} \) gives

\[ \Delta E[w_{i2}] = \left( \beta^+ - \beta^- \right) \frac{\varepsilon}{d_i} \left( 1 - 2 \right). \]

Using the result of \( \frac{\partial h_i}{\partial \varepsilon} = -\frac{\beta^+ - \beta^-}{2d_i \varepsilon^2} \) which is always negative, and so is \( \frac{\partial h_i}{\partial d_i} = -\frac{\beta^+ - \beta^-}{2d_i \varepsilon} \)

The solution to the cubic function in expression (7)

Define \( u = \theta - x_j - c \). Then (3) can be rewritten as:

\[ k(1 + \alpha - w_{i0}) + \beta(\theta - c) - ux_i(u - x_i) - 2\beta^- x_i + 2x_i^2(u - x_i) - 2x_i(1 + \alpha - w_{i0}) = 0. \]

Collecting terms gives

\[ -2x_i^3 + 3ux_i^2 - x_i[2(1 + \alpha - w_{i0}) + 2\beta^- + u^2] + u(1 + \alpha - w_{i0}) + \beta^- (\theta - c) = 0. \]

Define \( a = -\frac{3}{2} u, b = (1 + \alpha - w_{i0}) + \beta^- + \frac{u^2}{2} \), and \( d = -\frac{3}{2} (1 + \alpha - w_{i0}) - \beta(\theta - c) \). Then, \( x_i \) is the single real root of the cubic function is \( x^3 + ax^2 + bx + d = 0 \), with \( a < 0, b > 0 \) and \( d < 0 \). To solve the function \( x^3 + ax^2 + bx + d = 0 \) we operate the change in variables first done by Cardano, \( x_i^3 + (b + a^2)x_i + (d - \frac{1}{3}ab + \frac{2}{27}a^3) = 0 \) to eliminate the coefficient in the square term. We then solve \( x^3 + mx + n = 0 \), where \( (b + a^2) = m \) and \( (d - \frac{1}{3}ab + \frac{2}{27}a^3) = n \) to get expression (7).

References


Povel, P., and M. Raith, (2001): Liquidity constraints, production costs and output decisions, mimeo


