Strategic hedging

Udo Broll *
Department of Economics, Saarland University
D-66041 Saarbrücken

Peter Welzel
Department of Economics, University of Jena
D-07740 Jena

Kit Pong Wong
School of Economics and Finance, University of Hong Kong
Pokfulam Road, Hong Kong

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For a Cournot duopoly with a foreign firm exporting to the home firm's market hedging against unfavorable shifts in the stochastic spot exchange rate is analyzed. In a two-stage setting with product market and hedging decisions we show that hedging can be used as a strategic device. Under constant and decreasing absolute risk aversion an increase in hedging volume by the foreign firm promotes its exports and lowers the equilibrium output of the home firm. In contrast to the well-known full-hedging result in a perfectly competitive environment, we find that the foreign firm will over-hedge for strategic reasons. Furthermore, the separation result from the literature on hedging under perfect competition no longer holds in the duopoly framework, i.e., equilibrium output levels depend on the preference of the foreign firm and the probability distribution of the spot exchange rate.

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*Corresponding author. Department of Economics, Saarland University, D-66041 Saarbrücken, Germany. Fax: +49-681-302-4353, E-mail: broll@iwb.uni-sb.de

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1. Introduction

In recent years, international firms have become increasingly aware of how their operations can be affected by currency risks beyond their control. In some cases, the volatility of exchange rates had destabilizing impacts on the firms' strategies and economic performance. In principle, international firms could have insulated themselves from exchange rate uncertainty by using derivatives markets. As the literature reports, much of the growth in the derivatives markets came from corporations.

Most of the literature on risk aversion and exchange rate uncertainty dealing with allocation and hedging decisions in an international environment has incorporated the assumption that the firm is concerned with expected utility of profits in a perfectly competitive market. However, in many circumstances profits depend on market structure. Therefore the analysis should be imbedded in a framework of imperfect competition.

Our objective in the present paper is to bring together oligopoly theory and the literature on decision making under uncertainty to work out strategic effects of hedging on the equilibrium of an international Cournot duopoly. We consider an exporting foreign firm competing with a home firm in its home market. The exporter faces an uncertain spot exchange rate for its revenue at the time of the output decision. It can use a currency futures market to hedge against this risk. If hedging volume is decided before output quantity, hedging can be shown to have a strategic effect under plausible assumptions on the preferences of the decision maker.

This is clearly not the first paper to address the issue of oligopoly and exchange rates. The strong appreciation of the US dollar against other major currencies in the early 1980s stimulated a literature on so-called exchange rate pass-through or pricing to market. This work has focused on the extent to which a currency's appreciation leads to lower prices of imported goods. Dornbusch (1987a, 1987b) was among the first to work out the importance of market structure for this question. Since then pass-through phenomena have been analyzed in numerous settings (for recent work see e.g. Kirman and Phlips, 1996; Hens, 1997). Notice, however, that this strand of the literature analyzes changes in the level of a deterministic exchange rate, whereas our paper is concerned with a stochastic exchange rate, its consequences on market conduct and performance, and its relationship to hedging decisions in particular. Suprisingly enough, oligopoly theory has examined the cases of demand and cost uncertainty quite extensively, but still lacks an analysis of exchange rate uncertainty. To our knowledge the discussion paper by Welzel (1997) in which some of the ideas developed here were explored tentatively in a much less general framework was the first attempt in this direction.

The plan of the paper is as follows: In section 2 we outline our model of an international Cournot duopoly with both firms competing in the home market. Since the foreign firm does not know ex ante the ex post realization of the uncertain exchange rate, it faces exposure to exchange rate risk. To examine the role of financial instruments to hedge against such risk in the duopoly framework a two–stage game is considered: The exporting firm which has access to a currency futures market chooses a hedging volume in stage 1, and both firms simultaneously choose output levels in stage 2 before the uncertainty of the exchange rate is resolved. exchange rate risk. After determining the equilibrium of the two–stage game in section 3, we consider economic implications of the model in section 4. It turns out that hedging can be used not only as a risk reducing instrument but also as a strategic device, if the exporting firm has constant or decreasing absolute risk aversion. It changes the home firm's expectation of what the exporting foreign firm will do in the output game and therefore can be considered a strategic move in the sense of Schelling (1960). Concluding remarks can be found in section 5.

2. The model

Consider two countries, labeled home (H) and foreign (F), each of which has one firm producing a single homogeneous good. The home firm produces output Q_H according to a cost function, $C_H(Q_H)$, denominated in the home currency. Likewise, the foreign firm produces output Q_F according to a cost function, $C_F(Q_F)$, denominated in the foreign currency. The two cost functions are assumed to be strictly increasing and convex.

The home and foreign firms compete as Cournot quantity-setters in the home market. The inverse industry demand of the homogeneous good is specified by a downward-sloping function, $P(Q_H + Q_F)$, which gives the per-unit selling price denominated in the home currency. We assume that the output of the home firm and the export of the foreign firm are strategic substitutes, as defined by Bulow et al. (1985), so that $P'(Q_H+Q_F)+P''(Q_H+Q_F)Q_H < 0$ and $P'(Q_H+Q_F)+P''(Q_H+Q_F)Q_F < 0$. In the absence of uncertainty, the reaction functions of the home and foreign firms would be downward sloping given the assumption of strategic substitutes.

The foreign firm possesses a von Neumann-Morgenstern utility function, $U(\Pi_F)$, defined over its profit denominated in the foreign currency, Π_F. We assume this firm to be risk averse so that U is a strictly increasing and concave function. Let $\tilde{S}$ denote the spot exchange rate at date T, i.e., the amount of foreign currency that can be exchanged per unit of home currency at that time. Since the selling price of the homogeneous good is denominated in the home currency and the spot exchange rate $\tilde{S}$ cannot be perfectly predicted, the foreign firm inevitably faces an exchange rate risk exposure, PQ_F, which implies a stochastic profit $\tilde{\Pi}_F$.[1] The foreign firm, however, has access to a currency futures market which trades infinitely divisible futures contracts for the currency. In the absence of commission fees, margin requirements, and capital outlays, transactions in the currency futures market are costless. The home firm cares about its profit denominated in the home currency, Π_H, which is deterministic. As such, the home firm simply maximizes its profit, and its attitude toward risk plays no role in its decision making.

The set-up is a two-stage game under exchange rate uncertainty. In the first stage of the game (the hedging stage), the foreign firm sells (purchases if negative) Z units of the home currency in a currency futures market at a pre-specified exchange rate of the foreign currency against the home currency, F. The currency futures market is assumed to be unbiased so that $F = \mathrm{E}(\tilde{S})$. In the second stage of the game (the production stage), the home and foreign firms, with the futures position of the foreign firm in the currency futures market being common knowledge, engage in Cournot competition in the home market prior to the resolution of the exchange rate uncertainty.

The equilibrium concept employed is Selten's (1975) subgame-perfect Nash equilibrium (SPNE). A SPNE strategy choice is a triple, $[Z^*,\ Q_H(Z),\ Q_F(Z)]$, such that (1) the home and foreign firms cannot make better off by unilaterally deviating,

[1]Throughout the paper, a tilde (~) always signifies a random variable.

and (2) $[Q_H(Z),\ Q_F(Z)]$ constitutes a pair of Cournot-Nash equilibrium output of the home firm and export of the foreign firm, respectively, for all possible futures positions of the foreign firm in the currency futures market, Z.

3. The equilibrium

The characterization of the SPNE proceeds in two steps. The first step is to derive the Cournot-Nash equilibrium in the production stage under each subgame defined by every possible futures position of the foreign firm in the currency futures market, Z. Once this is done, we go back to the hedging stage to solve for the optimal futures position of the foreign firm in the currency futures market.

3.1 The production stage

Consider the production stage under a subgame defined by Z. Before the exchange rate uncertainty is resolved, the foreign firm, taking the home firm's output, Q_H, as given, chooses an output level, Q_F, so as to maximize the expected utility of its profit denominated in the foreign currency:

$$\max_{Q_F}\ \mathrm{E}\{U[\tilde{S}P(Q_H+Q_F)Q_F - C_F(Q_F) + (F-\tilde{S})Z]\}, \tag{1}$$

where E is the expectation operator. The first-order condition for an optimum of program (1) is given by

$$\mathrm{E}\{U'(\tilde{\Pi}_F)[\tilde{S}(P+P'Q_F) - C_F']\} = 0, \tag{2}$$

where we have omitted the arguments inside the functions for simplicity. Inspection of equation (2) reveals that it is necessary that $P + P'Q_F > 0$ for the first-order condition to hold. The second-order condition for a maximum of program (1) is given by

$$A = \mathrm{E}\{U'(\tilde{\Pi}_F)[\tilde{S}(2P' + P''Q_F) - C''_F] + U''(\tilde{\Pi}_F)[\tilde{S}(P + P'Q_F) - C'_F]^2\} < 0, \quad (3)$$

which is satisfied given the assumed properties of U, C_F, and P and the usual requirement that demand is not too convex.

The home firm, taking the foreign firm's export, Q_F, as given, chooses an output level, Q_H, so as to maximize its profit denominated in the home currency:

$$\max_{Q_H} \; P(Q_H + Q_F)Q_H - C_H(Q_H). \quad (4)$$

The first-order condition for an optimum of program (4) is given by

$$P + P'Q_H - C'_H = 0. \quad (5)$$

A necessary condition for equation (5) to hold is that $P + P'Q_H > 0$. The second-order condition for a maximum of program (4) is given by

$$B = 2P' + P''Q_H - C''_H < 0, \quad (6)$$

which is again satisfied given the assumed properties of C_H and P.

A Cournot-Nash equilibrium in the production stage under this subgame is a pair, $[Q_H(Z),\ Q_F(Z)]$, which solves the system of equations (2) and (5) simultaneously. To ensure the existence and uniqueness of the Cournot-Nash equilibrium, we need to impose the Hahn (1962) stability condition, $AB - CD > 0$, where A and B are defined in equations (3) and (6), respectively, and C and D are given by[2]

$$C = \mathrm{E}[U'(\tilde{\Pi}_F)\tilde{S}(P' + P''Q_F)] + \mathrm{E}\{U''(\tilde{\Pi}_F)[\tilde{S}(P + P'Q_F) - C'_F]\tilde{S}P'Q_F\}, \quad (7)$$

[2]See Collie (1992) for a detailed discussion of the existence and uniqueness of Cournot equilibrium in models of international trade under oligopoly.

$$D = P' + P''Q_H < 0. \tag{8}$$

3.2 The hedging stage

In the hedging stage, the foreign firm, anticipating the Cournot-Nash equilibrium outcome in the production stage, $[Q_H(Z),\ Q_F(Z)]$, chooses a futures position in the currency futures market, Z, so as to maximize the expected utility of its profit denominated in the foreign currency:

$$\max_{Z} \ \mathrm{E}\Big\{U\{\tilde{S}P[Q_H(Z) + Q_F(Z)]Q_F(Z) - C_F[Q_F(Z)] + (F - \tilde{S})Z\}\Big\}. \tag{9}$$

The first-order condition for an optimum of program (9), applying equation (2), is given by

$$\mathrm{E}[U'(\tilde{\Pi}_F^*)(\tilde{S} - F)] = \mathrm{E}[U'(\tilde{\Pi}_F^*)\tilde{S}]P'[Q_H(Z^*) + Q_F(Z^*)]Q_F(Z^*)Q_H'(Z^*), \tag{10}$$

where an asterisk (*) indicates an optimum level.

To summarize, we have the following proposition.

Proposition 1. *The unique SPNE of the two-stage game under exchange rate uncertainty is that (i) the futures position of the foreign firm in the currency futures market, Z^*, is defined in equation (10), and (ii) given Z^*, the export of the foreign firm, $Q_F(Z^*)$, and the output of the home firm, $Q_H(Z^*)$, are defined in equations (2) and (5) simultaneously.*

4. Economic implications

In this section, we will make use of the unique SPNE characterized in Proposition 1 to derive a few interesting economic implications.

4.1 Strategic role of hedging

First, we want to show that the futures position of the foreign firm in the currency futures market can play a strategic role in the product market. That is, it has both a direct and an indirect effect. It affects the export of the foreign firm and the output of the home firm in a way benefiting the foreign firm at the expense of the home firm. To this end, we state and prove the following comparative static results.

Proposition 2. *If the preference of the foreign firm exhibits either constant or decreasing absolute risk aversion, then an increase in the futures position of the foreign firm in the currency futures market promotes the export of the foreign firm and concomitantly deters the output of the home firm.*

Proof. Totally differentiating equations (2) and (5) with respect to Z and using Cramer's rule yields

$$Q_F'(Z) = -\frac{BE}{AB - CD}, \quad Q_H'(Z) = \frac{DE}{AB - CD}, \tag{11}$$

where A, B, C, and D are defined in equations (3), (6), (7), and (8), respectively, and E is given by

$$E = \mathrm{E}\{U''(\tilde{\Pi}_F)[\tilde{S}(P + P'Q_F) - C_F'](F - \tilde{S})\}. \tag{12}$$

The Hahn (1962) stability condition ensures that $AB - CD > 0$. Since both B and

D are negative, it follows from equation (11) that for $Q'_F(Z) > 0$ and $Q'_H(Z) < 0$ we need $E > 0$.

To prove that $E > 0$ when U exhibits either constant or decreasing absolute risk aversion, we first write equation (12) as

$$\begin{aligned} E &= -\Big(\frac{1}{P+P'Q_F}\Big)\mathrm{E}\{U''(\tilde{\Pi}_F)[\tilde{S}(P+P'Q_F)-C'_F]^2\} \\ &\quad +\Big[\frac{F(P+P'Q_F)-C'_F}{P+P'Q_F}\Big]\mathrm{E}\{U''(\tilde{\Pi}_F)[\tilde{S}(P+P'Q_F)-C'_F]\}. \end{aligned} \tag{13}$$

Clearly, the first term on the right-hand side of equation (13) is positive given risk aversion. If U exhibits constant absolute risk aversion, then $-U''(\tilde{\Pi}_F)/U'(\tilde{\Pi}_F)$ is a positive constant for all $\tilde{\Pi}_F$. It follows immediately from equation (2) that the second term in the right-hand side of equation (13) vanishes, thereby implying that $E > 0$ in this case. On the other hand, if U exhibits decreasing absolute risk aversion, then $-U''(\tilde{\Pi}_F)/U'(\tilde{\Pi}_F) = R(\tilde{\Pi}_F)$ is a decreasing function of $\tilde{\Pi}_F$. Using the covariance operator, Cov, we can write equation (2) as[3]

$$\frac{F(P+P'Q_F)-C'_F}{P+P'Q_F} = -\frac{\mathrm{Cov}[U'(\tilde{\Pi}_F),\tilde{S}]}{\mathrm{E}[U'(\tilde{\Pi}_F)]}. \tag{14}$$

Define $\hat{\Pi}_F$ as $\tilde{\Pi}_F$ evaluated at $\tilde{S} = C'_F/(P+P'Q_F)$. Using equation (2) and (14), we can write the second term in the right-hand side of equation (13) as

$$\Big\{\frac{\mathrm{Cov}[U'(\tilde{\Pi}_F),\tilde{S}]}{\mathrm{E}[U'(\tilde{\Pi}_F)]}\Big\}\mathrm{E}\{[R(\tilde{\Pi}_F)-R(\hat{\Pi}_F)]U'(\tilde{\Pi}_F)[\tilde{S}(P+P'Q_F)-C'_F]\}.$$

Since $\partial\Pi_F/\partial S = PQ_F - Z$, it follows from risk aversion that $\mathrm{Cov}[U'(\tilde{\Pi}_F),\tilde{S}]$ is positive or negative, depending on whether PQ_F is below or above Z, respectively. Likewise, under decreasing absolute risk aversion, the sign of $R(\tilde{\Pi}_F) - R(\hat{\Pi}_F)$ is the same as or opposite to that of $\tilde{S}(P+P'Q_F) - C'_F$, depending on whether PQ_F is below or above Z, respectively. Using these two observations, we know that the second term

[3]For any two random variables, $\tilde{X}$ and $\tilde{Y}$, we have $\mathrm{Cov}(\tilde{X},\tilde{Y}) = \mathrm{E}(\tilde{X}\tilde{Y}) - \mathrm{E}(\tilde{X})\mathrm{E}(\tilde{Y})$.

in the right-hand side of equation (13) must be positive, irrespective of whether PQ_F is below or above Z. Thus, $E > 0$ when U exhibits decreasing absolute risk aversion. This completes our proof. □

Proposition 2 shows that, under reasonable assumptions on the preference of the foreign firm, trading in the currency futures market by the foreign firm can act as a strategic device in that it promotes the export of the foreign firm while concomitantly deters the output of the home firm. These results are in the spirit of Bulow et al. (1985, p. 488): "A firm's action in one market can change competitors' strategies in a second market by affecting its own marginal cost in that other market." Nevertheless, the strategic link of the currency futures market and the product market in our model occurs in a far more subtle way through the income effect under risk aversion. Before illustrating the underlying intuition, we state and prove the following proposition which is an immediate corollary of Proposition 2.

Proposition 3. *If the foreign firm is risk neutral, then a change in the futures position of the foreign firm in the currency futures market has effects neither on the export of the foreign firm nor on the output of the home firm.*

Proof. Under risk neutrality, we have $U'' = 0$. It follows from equation (12) that $E = 0$. Thus, equation (11) implies that $Q'_F(Z) = Q'_H(Z) = 0$. This completes our proof. □

Proposition 3 reveals that trading in the currency futures market by the foreign firm has no strategic effects at all in the product market should the foreign firm be risk neutral. This is in stark contrast to Allaz (1992) and Allaz and Vila (1993) who show that risk-neutral quantity-setting firms would take positions in futures markets for pure strategic reasons, attempting to improve their situation in spot markets.[4] Unlike us, Allaz (1992) and Allaz and Vila (1993) consider the spot and futures markets for the same homogeneous good in which an obvious strategic link is built in through the effects of forward transactions on marginal revenues. In our model, the currency futures market has nothing to do with the homogeneous good produced by the home and foreign firms, thereby making the strategic link envisioned by Allaz (1992) and Allaz and Vila (1993) disappear.

Risk aversion on the part of the foreign firm gives rise to an income effect associated with a change in the futures position of the foreign firm in the currency futures market. As evident from equation (1), other things being equal, an increase in the futures position of the foreign firm changes its profit denominated in the foreign currency by $F - \tilde{S}$, which can be decomposed into two parts:

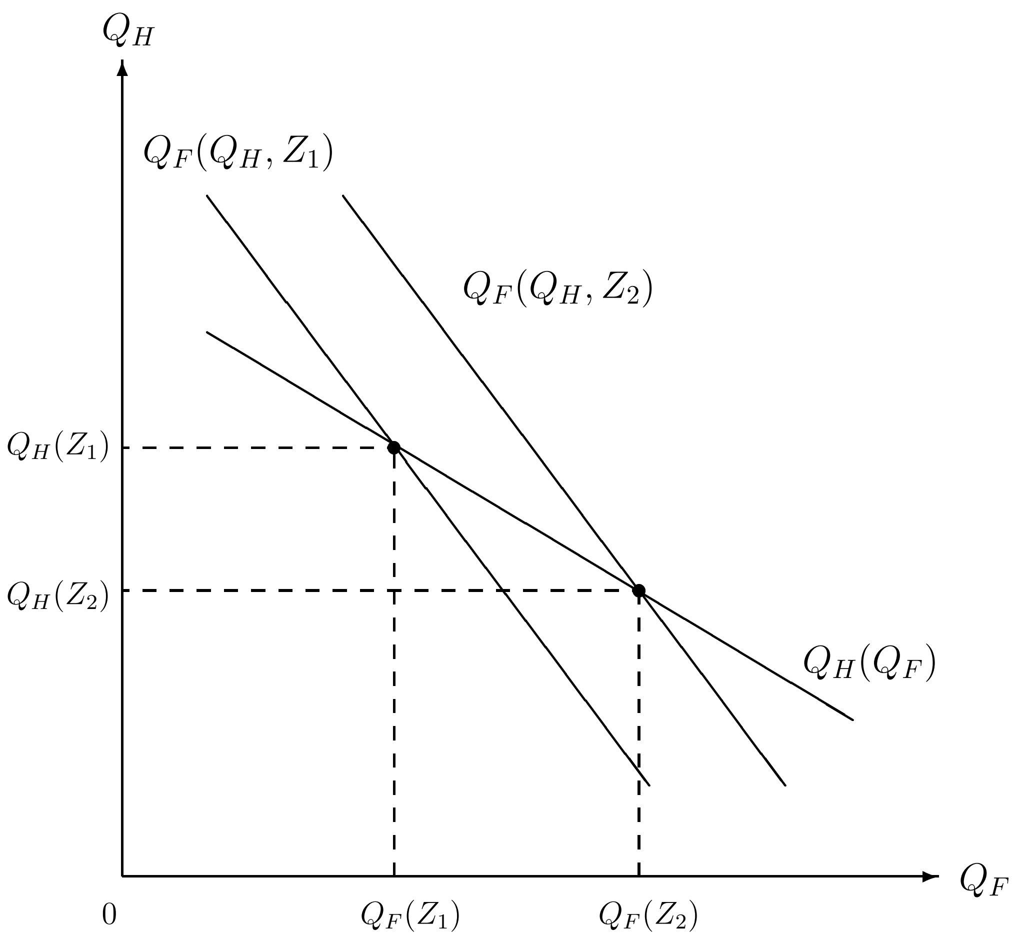
$$-\frac{\tilde{S}(P + P'Q_F) - C'_F}{P + P'Q_F} + \frac{F(P + P'Q_F) - C'_F}{P + P'Q_F}.$$

The first part provides a perfect hedge against the uncertain marginal profit of the foreign firm and, under risk aversion, renders the foreign firm to produce and export more. The second part increases or decreases the level of profit of the foreign firm, depending on whether the expected marginal revenue, $F(P + P'Q_F)$, exceeds the marginal cost, C'_F, or not, respectively, which in turn depends on whether PQ_F is above or below Z, respectively. Under constant absolute risk aversion, a change in the level of profit of the foreign firm generates no income effects. Under decreasing absolute risk aversion, an increase in the level of profit of the foreign firm encourages the firm to assume a higher exchange rate risk exposure gauged by $|PQ_F - Z|$. This

[4] In a rather different vein, Hughes and Kao (1997) show that if forward transactions are not observable and if hedging motives are not present (i.e., firms are risk neutral), then the strategic incentives identified by Allaz (1992) and Allaz and Vila (1993) no longer exist.

implies that the foreign firm should produce more or less, depending on whether PQ_F is above or below Z, respectively. Thus, the second part of $F - \tilde{S}$ always induces the foreign firm to produce and export more under decreasing absolute risk aversion.

The overall income effect associated with an increase in the futures position of the foreign firm is unambiguously positive under either constant or decreasing absolute risk aversion. Given the assumption of strategic substitutes so that the reaction functions of the home and foreign firms are downward sloping, trading in the currency futures market by the foreign firm thus promotes the export of the foreign firm and concomitantly deters the output of the home firm. This is illustrated graphically in Figure 1.



In Figure 1, the reaction function of the home firm is given by $Q_H(Q_F)$, and the reaction functions of the foreign firm are given by $Q_F(Q_H, Z_1)$ and $Q_F(Q_H, Z_2)$ for two different futures positions of the foreign firm in the currency futures market, where $Z_1 < Z_2$. An increase in the futures position of the foreign firm from Z_1 to Z_2 creates an income effect under risk aversion that shifts the reaction function of the foreign firm outward from $Q_F(Q_H, Z_1)$ to $Q_F(Q_H, Z_2)$. Since the reaction function of the home firm is downward sloping, this results in a decrease in the Cournot-Nash equilibrium output of the home firm from $Q_H(Z_1)$ to $Q_H(Z_2)$, while an increase in the Cournot-Nash equilibrium export of the foreign firm from $Q_F(Z_1)$ to $Q_F(Z_2)$. It is the income effect under risk aversion which creates a strategic link of the currency futures market and the product market in our setting.

4.2 Optimality of an over hedge

Using the covariance operator, Cov, the first–order condition (10) implies that

$$\mathrm{Cov}\Big\{U'\{\tilde{S}P[Q_H(Z^*) + Q_F(Z^*)]Q_F(Z^*) - C_F[Q_F(Z^*)] + (F - \tilde{S})Z^*\}, \tilde{S}\Big\} > 0,$$

since $P' < 0$ and, from Proposition 2, $Q_H'(Z) < 0$ if the foreign firm's preference exhibits either constant or decreasing absolute risk aversion. Given risk aversion, the above inequality holds only when $P[Q_H(Z^*) + Q_F(Z^*)]Q_F(Z^*) < Z^*$. Thus, we establish the following proposition.

Proposition 4. *If the preference of the foreign firm exhibits either constant or decreasing absolute risk aversion, then the optimal futures position of the foreign firm in the currency futures market is an over hedge, i.e.,* $Z^* > P[Q_H(Z^*) + Q_F(Z^*)]Q_F(Z^*)$.

Proposition 4 is in stark contrast to the full-hedging theorem emanated from the literature on hedging under perfect competition (see, e.g., Katz and Paroush, 1979; Benninga, Eldor, and Zilcha, 1985; Broll and Zilcha, 1992; Broll, Wong, and Zilcha, 1999), which states that a risk-averse exporting firm should eliminate its exchange rate risk exposure completely via a full hedge in an unbiased currency futures market. In our model, a full hedge is never optimal because of the strategic role of hedging identified in Proposition 2. Trading in the currency futures market by the foreign firm always benefits the foreign firm at the expense of the home firm. Had the foreign firm adopted a full hedge in the currency futures market, a small deviation to an over hedge would have had trivial effects on the foreign firm's exchange rate risk exposure but non-trivial effects on the strategic benefits in the product market as shown in Proposition 2. The foreign firm will keep on increasing its futures position in the currency futures market until the incremental exchange rate risk exposure is sufficiently large to offset the strategic benefits in the product market, rendering the optimality of an over hedge.

4.3 Export and production decisions

From Proposition 1, the Cournot-Nash equilibrium output of the home firm and export of the foreign firm, $Q_H(Z^*)$ and $Q_F(Z^*)$, depend on the optimal futures position of the foreign firm in the currency futures market, Z^*. Since Z^* is defined in equation (10), it depends on the preference of the foreign firm as well as on the probability distribution of the random spot exchange rate. From this, we establish the following proposition.

Proposition 5. *The Cournot-Nash equilibrium output of the home firm and export of the foreign firm, $Q_H(Z^*)$ and $Q_F(Z^*)$, depend on the preference of the foreign firm as well as on the probability distribution of the random spot exchange rate.*

In other words, Proposition 5 invalidates the separation theorem derived in the hedging literature (see, e.g., Katz and Paroush, 1979; Benninga, Eldor, and Zilcha, 1985; Broll and Zilcha, 1992; Broll, Wong, and Zilcha, 1998), which states that a risk-averse exporting firm's output decision is affected neither by the risk attitude of the firm nor by the incidence of exchange rate uncertainty in the presence of a currency futures market.

Finally, we want to compare the Cournot-Nash equilibrium output levels with those under certainty, i.e., in the case where $\tilde{S} \equiv F$, which we denote by Q_H^c and Q_F^c. Note first that we fix the futures position of the foreign firm in the currency futures market at $Z^c = P(Q_H^c + Q_F^c)Q_F^c$. Then, the pair, $(Q_H^c,\ Q_F^c)$, solves the system of equations (2) and (5) simultaneously. Thus, we have $Q_H(Z^c) = Q_H^c$ and $Q_F(Z^c) = Q_F^c$. Totally differentiating the objective function in program (9) with respect to Z and evaluating at $Z = Z^c$ yields

$$U'\{FZ^c - C_F[Q_F(Z^c)]\}FP'[Q_H(Z^c) + Q_F(Z^c)]Q_F(Z^c)Q_H'(Z^c) > 0, \tag{15}$$

since $P' < 0$ and, from Proposition 2, $Q_H'(Z) < 0$ if the foreign firm's preference exhibits either constant or decreasing absolute risk aversion. We state and prove the following proposition.

Proposition 6. *If the preference of the foreign firm exhibits either constant or decreasing absolute risk aversion, then (i) the Cournot-Nash equilibrium output of the home firm is smaller than that under certainty, (ii) the Cournot-Nash equilibrium* *export of the foreign firm is larger than that under certainty, and (iii) the Cournot-Nash equilibrium industry output is larger than that under certainty.*

Proof. From equations (10) and (15), we have $Z^* > Z^c$. It then follows from Proposition 2 that $Q_H(Z^*) < Q_H(Z^c) = Q_H^c$ and $Q_F(Z^*) > Q_F(Z^c) = Q_F^c$. Since the industry output, $Q_H(Z) + Q_F(Z)$, is an increasing function of Z, we have $Q_H(Z^*) + Q_H(Z^*) > Q_H(Z^c) + Q_F(Z^c)$. □

5. Concluding remarks

A simple two–stage model of an international Cournot duopoly with exchange rate uncertainty was used to analyze effects of hedging in unbiased currency futures markets on the duopoly equilibrium. Buying futures contracts to hedge against adverse realizations of the stochastic exchange rate improves the market position of the exporting foreign firm relative to the import–competing home firm, if the foreign firm's preferences exhibit constant or decreasing absolute risk aversion. Hedging can therefore be used as a strategic device shifting the exporter's reaction curve to the right due to an income effect. The full–hedging and the separation results well–known from the literature on hedging in a perfectly competitive environment are no longer valid in the oligopoly framework. There is an incentive to over hedge for strategic reasons, and the output of the exporting firm depends on its preferences and on the distribution of the random spot exchange rate.

Our analysis was focused on currency futures as hedging instruments. Clearly enough, other instruments like currency options could be used, but this would not alter the basic insights of the paper. Intuition tells us that even a non–financial hedge in the form of the foreign firm buying inputs in the home country where it also sells its output will create a strategic effect. This intution is supported by results based on a more specific model in the discussion paper by Welzel (1997).

We implicitly assumed that the exporting firm is able to commit to its position in the futures markets, thereby making a credible strategic move. Some readers might question this presumed commitment power, arguing that the foreign firm could secretly offset its hedging position by selling futures contracts without letting the competitor know about this fact. Notice, however, that this will not invalidate our main result that hedging will take place and has a strategic effect. The foreign firm has no interest in offsetting the forward sale of the revenue denominated in home currency, because by doing so it would create exposure to exchange rate uncertainty again. The expected utility loss from an uncertain profit plays the same role for commitment as sunk costs in more standard oligopoly settings, implying that there will indeed be a shift of the reaction curve. It is only the over hedge property in our model that could be become questionable due to the possibility of offsetting operations in the futures market. We note in passing that the idea of strategic hedging can also be developed in a strategic trade policy framework in the tradition of Brander and Spencer (1985), where a risk–neutral foreign government offers a hedge to the exporting firm. In such a model it is the commitment power of government that matters for the strategic effect. When in the early 1990s Daimler–Benz in Germany took over MBB, the German government offered an exchange rate guarantee for the revenue accruing in US dollars from the Airbus division of MBB.

Future work on international oligopolies with uncertain exchange rates should address the issue of non–strategic hedging which arises if hedging volume and output level are determined simultaneously. Other interesting research could involve an extension of our model to two–way trade with both firms facing exchange rate risk and considering other financial instruments such as currency swaps.

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