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Foreign exchange operating exposure and pass-through in a homogeneous product market

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Abstract

Purpose – Operating exposure to foreign exchange risk and exchange rate pass-through are investigated in the context of a Cournot model of equilibrium in a homogeneous product market, i.e. an industry populated by N firms, which compete exclusively on the basis of quantities produced/marketed and where each firm optimizes its decision based on expectations regarding the actions of its rivals that in fact eventuate. Whereas one firm sources its product domestically, the remaining $N-1$ firms source their product in a foreign country. The paper aims to discuss these issues.

Design/methodology/approach – By invoking two simplifying assumptions, namely, constant marginal cost functions and a linear inverted demand curve, and then deriving the Cournot equilibrium, this paper obtains clear implications regarding the effect of a currency devaluation on the competitive positions of the industry's N constituent firms as well as the pass-through effect on the industry price.

Findings – The $N-1$ firms that source the homogeneous product from a foreign country, which experiences a devaluation, gain, while the single competing firm that sources domestically loses, both market share and profit. Formulas are derived which elucidate this intuitive result. The extent of exchange rate pass-through on the resulting equilibrium price is gauged to be incomplete, consistent with extant empirical evidence. As the number of firms increases, the extent of exchange rate pass-through likewise increases, approaching a limiting situation of complete pass-through.

Originality/value – This paper is the first to examine the issues of exchange rate operating exposure and pass-through in the context of a Cournot model of competition, under the indicated two simplifying assumptions.

Keywords Cournot model, Exchange rate pass-through, Foreign exchange risk, Homogeneous product market, Operating exposure

Paper type Conceptual paper

1. Introduction

In the taxonomy of foreign currency risk management, the critical distinction between, on the one hand, transactions or contractual exposure vs, on the other hand, operating or non-contractual exposure is delineated. Shapiro's (2013) treatment is a case in point. While transactions exposure is easier to measure and hedge against due to the presence of contracts that explicitly detail the amount of foreign currency involved, operating exposure is a more troublesome phenomenon due to the non-existence of such contracts. As Flood and Lessard (1986), Lessard and Lightstone (1986), von Ungern-Sternberg and Weizsacker (1990), and O'Brien (1998) have emphasized, the latter is highly problematic due to the fact that an entity's operating risk exposure can be correctly gauged only by assessing the situation of both the entity itself as well as all of that entity's competitors. In succinct terms, operating exposure pertains to changes in a firm's competitive position occasioned by exchange rate volatility, notwithstanding the absence of foreign currency denominated contracts in that firm's dossier.

Standard international financial management textbooks vet the topic of operating exposure via the use of either extended case studies, as exemplified by Eitemann *et al.* (2013)

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and Shapiro (2013), or analytical models of monopoly, as illustrated in Bekaert and Hodrick (2009). Case studies suffer from their high situation specificity, i.e. general conclusions are difficult to glean from them. Similarly, although monopolies provide a useful starting point for analysis, globalization has rendered them arcane, i.e. of marginal relevance to the overwhelming majority of firms.

Analytical models that embrace the more realistic situation of imperfect competition are eschewed in textbook discussions. The reason for the latter practice can be gleaned from the conclusion of a comprehensive effort to model situations of imperfect competition, employing the techniques of microeconomics and industrial organization, found in Marston (2001), to wit, "[…] exposure depends on demand and cost parameters which are difficult to estimate." In the same vein, Bodnar and Wong (2003) criticize Marston's use of constant elasticity demand functions which require "[…] significant amounts of firm-specific and competitor-specific information that is available, if at all, only to those inside the firm." Stated another way, studies that attempt to model real world complexity founder on the opacity and the onerous informational requirements of the derived conclusions. Another paper that arrived as a similar impasse is that of Krupp and Davidson (1996).

This paper takes a different tack via the aggressive use of simplifying assumptions. Adopting the model first articulated by Dornbusch (1987), a bare-bones situation of imperfect competition is considered, i.e. a market populated by only two types of firms where an undifferentiated product is sold. The market demand curve is assumed to be linear and both types of firms exhibit constant marginal costs. Although both types of firms are assumed to be locally domiciled, one type of firm sources its product domestically, whereas the second type of firm sources its product in a foreign country. The number of firms that pertain to the second type equals $N-1$, while there is only one of the first type of firm. Thus, N firms comprise the industry. The market then experiences an economic shock in the form of a devaluation of the foreign currency. The resulting effects on industry sales, market shares, and product price are explored via an exercise in comparative statics where the paradigm of a Cournot equilibrium is exploited, i.e. the two types of firms compete solely on the basis of quantity produced and marketed and each firm optimizes its actions based on expectations as regards the competitors that in fact eventuate.

The focus on a market with a homogeneous product where firms compete on the basis of quantity produced/marketed, i.e. Cournot competition, distinguishes this paper from earlier efforts that considered a market with differentiated products where firms compete on the basis of price, i.e. Bertrand competition. The latter are exemplified by Friberg (1998), Friberg and Ganslandt (2007), and Bodnar *et al.* (2002). To deal with the added complexity and yet derive clear conclusions, these authors are forced to invoke additional consumer utility-theoretic assumptions or resort to simulation experiments. This paper avoids such assumptions and simulations.

2. Cournot model

To minimize verbosity and without loss of generality, consider N firms domiciled in the USA that populate an industry. The firms sell an undifferentiated product in the USA. However, whereas the first firm, labeled firm U, sources its product in the USA, the remaining $N-1$ firms, labeled the K-firms, source their product from Korea. Whereas firm U supplies quantity q_U, each of the $N-1$ K-firms supplies quantity q_K of the homogeneous product.

The inverted industry demand curve is assumed to be linear, being denoted $P(Q) = a - bQ$, where Q refers to the sum of the quantities supplied by the alluded N firms, i.e., $Q = q_U + (N-1)q_K$.

The constant marginal cost of supplying the product equals c_U and c_K for firm U and the K-firms, respectively. It should be emphasized that all financial quantities considered in this paper are denominated in dollars. Thus, although the K-firms source their product in Korea, c_K is not denominated in Korean won but in US dollars, i.e. c_K is the dollar equivalent of the won cost per unit incurred by the K-firms, where conversion occurs at the prevailing spot exchange rate. Clearly, a devaluation of the won would result in a reduction in c_K, an eventuality that will be considered later in this paper.

Each firm maximizes its individual profit, denoted Π_U and Π_K for firm U and the K-firms, respectively. Firm U's profit is formulated as $\Pi_U = [P(Q) - c_U]q_U$. Similarly, each of the K-firms' profit is formulated as $\Pi_K = [P(Q) - c_K]q_K$.

The first-order conditions for the maximization of these two profit functions are given by the following two equations for firm U and each of the K-firms, respectively:

$$\frac{\partial \Pi_U}{\partial q_U} = a - b[q_U + (N-1)q_K] - c_U - bq_U = 0 \tag{1}$$

$$\frac{\partial \Pi_K}{\partial q_K} = a - b[q_U + (N-1)q_K] - c_K - b(N-1)q_K = 0 \tag{2}$$

Equation (1) may be reformulated to yield firm U's reaction function, which yields firm U's optimal decision regarding the quantity it will supply given a conjecture about each of the K-firms' quantity decision:

$$q_U = \frac{a - c_U}{2b} - \left(\frac{N-1}{2}\right)q_k \tag{3}$$

By the same token, Equation (2) may be reformulated to yield each of the K-firms' reaction function, which generates each of the K-firms' optimal decision regarding the quantity it will supply given a conjecture about firm U's quantity decision:

$$q_K = \frac{a - c_K}{Nb} - \frac{qU}{N} \tag{4}$$

In their textbook discussions of the Cournot model of competition, Besanko and Braeutigam (2001), Carlton and Perloff (1990), and Varian (1999) emphasize that the resulting equilibrium pertains to a Nash type. Thus, the firms have no motivation to deviate from the equilibrium, i.e. the equilibrium is self-enforcing. Furthermore, at such a Nash equilibrium, for all firms the quantities conjectured to be supplied by the others firms in the industry do, in fact, transpire.

3. Pre-devaluation situation

In the pre-devaluation situation, the dollar values of the constant marginal costs incurred by both firm U and the K-firms are equal, i.e. no firm enjoys a comparative advantage *vis-à-vis* the other firms. Thus, $c_U = c_K = c$. Substituting this common value of marginal cost into the two reaction functions, defined by Equations (3) and (4), and then solving for the solution of the system of two linear equations results in the following:

$$q_U = q_K = \frac{1}{N+1}\left[\frac{a-c}{b}\right] \tag{5}$$

Clearly, each firm garners $1/N$ of industry sales. Thus, industry sales, denoted Q, equals N times the quantity defined by Equation (5), i.e. $(N/N+1)[a-c/b]$. By substituting this value of industry sales into the inverted demand function defined earlier, the resulting market price is obtained as the following:

$$P = \frac{a+Nc}{N+1} \tag{6}$$

Equations (5) and (6) may be substituted into the profit functions that pertain to firm U and the K-firms to calculate the following common value of profit achieved by each of the two types of firms:

$$\Pi_U = \Pi_K = \frac{1}{b}\left(\frac{a-c}{N+1}\right)^2 \tag{7}$$

4. Post-devaluation situation

Assume that the won experiences a percentage devaluation denoted d. To provide a numerical illustration, assume that before the devaluation the exchange rate that prevails equals \$0.01 per won whereas after the won devaluation the prevailing exchange rate drops to \$0.008 per won. Then the resulting devaluation percentage of 20 percent may be calculated as $(0.008/0.01)-1$.

As a result of the won devaluation, the constant marginal costs incurred by firm U and the K-firms are no longer equal. Specifically, in the post-devaluation situation, $c_U = c$ whereas $c_K = c(1-d)$. Substituting these values of marginal cost into the two reaction functions given by Equations (3) and (4) and then simultaneously solving them yields the following:

$$q_U = \frac{a-c-(N-1)d}{(N+1)b} \tag{8}$$

$$q_K = \frac{a-c+2cd}{(N+1)b} \tag{9}$$

Comparing Equations (8) with (5) and (9) with (5), observe that the won devaluation occasions a drop in firm U's sales volume and a concomitant rise in the sales volumes attained by each of the K-firms. Consistent with intuition, $q_k > q_U$, i.e. each of the K-firms gains market share *vis-à-vis* firm U as a result of the devaluation of the currency of the country from which the K-firms source their product.

Summing Equations (8) and (9), industry sales are calculated as follows:

$$Q = \frac{1}{(N+1)b}[N(a-c)+(N-1)cd] \quad (10)$$

Taking the derivative of Equation (10) with respect to the devaluation percentage yields the following:

$$\frac{\partial Q}{\partial d} = \frac{(N-1)c}{(N+1)b} > 0 \quad (11)$$

Consistent with intuition, inequality (11) states that the steeper the won devaluation, the greater the stimulative effect on industry sales. Furthermore, the greater the presence of Korean importers in the US market, i.e. the higher is N, the greater is the stimulative effect of a won devaluation. The veracity of the preceding assertion is attested to by considering the sign of the following second derivative:

$$\frac{\partial^2 Q}{\partial N \partial d} = \frac{2bc}{[(N+1)b]^2} > 0 \quad (12)$$

Substituting Equation (10) into the inverted demand curve defined earlier, the following post-devaluation market price is derived:

$$P = \frac{a+Nc-(N-1)cd}{N+1} \quad (13)$$

The profit level achieved by firm U may be obtained by substituting Equations (8), (10), and (13) into the definition of Π_U, which results in the following:

$$\Pi_U = \frac{1}{b}\left[\frac{a-c-(N-1)cd}{N+1}\right]^2 \quad (14)$$

To determine the effect of the won devaluation on firm U's profit level, Equation (7) is subtracted from Equation (14). The resulting change in firm U profit is calculated as the post-minus the pre-devaluation profit achieved, which is given by the following:

$$\Delta\Pi_U = \frac{1}{b}\left[\frac{a-c-(N-1)cd}{N+1}\right]^2 - \frac{1}{b}\left(\frac{a-c}{N+1}\right)^2 < 0 \quad (15)$$

Visual inspection of expression (15) suffices to establish that firm U suffers a reduction in the profit it achieves as a result of the won devaluation. This phenomenon of profit impairment on the part of firm U captures the essence of what the literature on international financial management refers to as operating exposure. Notwithstanding the fact that firm U exhibits no contracts denominated in the won, the won devaluation is prejudicial to firm U because it enhances the competitive position of firm U's competitors, i.e. the N–1 K-firms. An adequate assessment of firm U's risk exposure thus demands more than a myopic focus on firm U alone as its competitors' situation must likewise be assessed.

5. Gauging the extent of exchange rate pass-through

In the context of the scenario envisioned in this paper, exchange rate pass-through refers to the extent by which the won devaluation is reflected in the dollar price of the homogeneous product considered here. Assume that the won-related costs incurred by the K-firms amount to 80 percent of the industry price. If a 20 percent devaluation of the won results in a 20 × 80 percent or 16 percent reduction in the dollar price of the undifferentiated product, the exchange rate pass-through is said to be complete. However, if the resulting price reduction is <16 percent, the pass-through is classified as being merely partial or incomplete. The empirical evidence in this regard, as summarized in Menon (1995) and Hellerstein (2006), overwhelmingly reflects incomplete pass-through, a phenomenon that has piqued the interest of numerous international economists.

As Bodnar *et al.* (2002) have emphasized, an intimate nexus exists between the superficially disparate concepts of operating exposure to foreign exchange risk and exchange rate pass-through. Whereas the former subject is of more recent vintage, the latter topic is a long-standing academic cause *célèbre* in the literature on international finance commencing with Dornbusch (1987). An early paper by Venables (1990) demonstrates that, under conditions of perfect competition, exchange rate pass-through should be complete. Thus, to explain the observed regularity of partial pass-through, various models of imperfect competition have been entertained. What does the Cournot equilibrium model considered in this paper imply about the extent of pass-through?

To formulate a response to the preceding question, the derivative of Equation (9) with respect to the won devaluation percentage is obtained as follows:

$$\frac{\partial P}{\partial d} = -\left(\frac{N-1}{N+1}\right)c \tag{16}$$

The metric for exchange rate pass-through adopted here is the percentage change in product price induced by a percentage devaluation of the won, i.e. $(\partial P/\partial d)(1/P)$. The question to be broached here is the extent to which the value of the suggested metric falls short of the cost percentage of price, thus demonstrating partial pass-through.

Evaluating the postulated measure yields the following:

$$\frac{\partial P}{\partial d}\frac{1}{P} = -\left(\frac{N-1}{N+1}\right)\frac{c}{P} \tag{17}$$

Observe that the extent of pass-through for the industry considered here is only a fraction, i.e. $(N-1/N+1)$, of the cost percentage of price. This analytical result indicating partial pass-through is thus consistent with the empirical literature cited earlier. Furthermore, as the number of firms in the industry increases, i.e. the industry approximates one characterized by perfect competition, the cited fraction approaches unity. Stated another way, as N approaches infinity, the extent of exchange rate pass-through becomes complete. This is in conformity with an early theoretical result demonstrated by Venables (1990) who arrived at the same conclusion employing graphical supply and demand analysis.

The intuition for the incomplete exchange rate pass-through observed here for finite values of N may be gleaned by noting that although firm U loses competitive advantage due to the won devaluation, it is not expelled from the market. Firm U persists in the market, albeit with a diminished sales volume, as demonstrated earlier.

The remaining $N-1$ K-firms, which directly experience and gain from the won devaluation, must take account of firm U's competitive reaction when they determine their post-devaluation quantity decision. Thus, the resulting industry price continues to reflect the costs structures of both firm U and the K-firms, i.e. the won devaluation pass-through is only partial. As N increases, the influence of firm U on the market diminishes, resulting in a concomitant reduction in the partiality of the exchange rate pass-through.

6. Conclusion

This paper broaches operating exposure to foreign exchange risk and the associated topic of exchange rate pass-through in the context of a Cournot model, where N firms choose optimizing production/marketing quantities that embody valid expectations regarding the rivals' competitive actions. The novel feature of this investigation is the aggressive use of simplifying assumptions that render the requisite algebraic conclusions easy to interpret. A linear inverted demand curve and constant marginal production costs are assumed. The intent is to remedy the equivocal conclusions derived in earlier theoretical investigations, as the resulting ambiguity is an apparent artifact of model complexity.

In succinct terms, the scenario investigated is as follows. Two types of firms, that number N, compete in the same domestic market. The firms differ solely in one respect, one firm, labeled firm U, sources domestically, whereas the remaining $N-1$ firms, labeled the K-firms, source in a foreign country. The industry experiences an economic shock when the foreign currency devalues. The foregoing is shown algebraically to redound to the benefit of the K-firms and to the detriment of firm U in terms of both market share and profit. The latter depicts the essence of what the literature on international financial management refers to as operating exposure. The extent of exchange rate pass-though is assessed to be partial for finite values of N, consistent with extant empirical evidence. Within the context of the Cournot industry model posited here, the partial nature of the exchange rate pass-through is demonstrated to make intuitive sense. However, as N approaches infinity, i.e. the industry approaches one characterized by perfect competition, the extent of exchange rate pass-through becomes complete.

Employing this paper as a starting point, it is hoped that future theoretical research will progressively introduce more realistic assumptions to corroborate whether and to what extent the operating exposure and pass-through conclusions derived here remain valid.

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