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Optimal hedging decisions for Taiwanese corn traders on the way to liberalisation

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Abstract

This paper examines the impacts of exchange rate risk on Taiwanese traders' decisions to hedge corn imports on US futures markets. The results yield the conclusion that, in the absence of a market that provides proper tools to hedge against exchange rate risk, the Taiwanese economy is incurring an observable social loss. Thus, further liberalisation is essential. Taiwan's experiences can serve as an example for developing countries, as the world economy is becoming increasingly integrated.

JEL classification: G10

Keywords: Exchange rate risk; Forward contract; Cross-hedging; Taiwan; Corn industry

1. Introduction

As per capita income has been rising, Taiwan's consumers have shifted away from cereal-based diets in favour of high-protein items such as meat and poultry products. For instance, during the period from 1975 to 1994, the per capita consumption of pork increased from 17.5 to 46.1 kg, and that of poultry increased from 8.4 to 23.6 kg. Meanwhile, the aggregate demand for feed grains has been increasing rapidly. With very high production costs of field crops due to poor resources conditions, Taiwan has to import large quantities of feed grains, especially corn. Even though policies have been undertaken to encourage domestic production, corn imports have increased by more than 300% from 1.4 million tonnes in 1975 to 5.6 million tonnes in 1994 (Table 1). Self-sufficiency ratios range from 3.5 to 9.1% during the period 1972–1994, and average only 5.9%. It has become obvious that, in terms of liberalisation, the question of how to mitigate costs due to risks in agricultural trade is of critical importance.

The US is the only source of Taiwan's corn imports. Hence, fluctuations in US cash prices will be transmitted to the prices of final products such as pork and corn oil in Taiwan. To stabilise the costs of corn imports, many of Taiwan's traders have begun to participate in US futures markets such as the Chicago Board of Trade. This was illegal prior to 1993. However, Taiwan's traders have to measure their terminal costs (or returns) in terms of Taiwanese currency rather than in US dollars (US$), and the exchange rate can change between the time a futures' position is initiated and the time the position is liquidated, which has an obvious impact on traders' costs. Therefore, both risks arising from the fluctuation of US corn prices and the volatility of the exchange

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Table 1
Corn production and consumption in Taiwan, 1972–1994[a]

Year	Planted area (1000 ha)	Production λ (million t)	Imports (million t)	Domestic consumption β (million t)	Self-sufficiency λ/β (%)
1972	25.76	0.07	1.32	1.39	5.07
1973	30.67	0.08	1.26	1.34	6.27
1974	40.74	0.11	1.11	1.21	8.82
1975	49.72	0.14	1.39	1.53	9.03
1976	41.42	0.11	1.86	1.98	5.78
1977	36.24	0.10	2.00	2.09	4.54
1978	37.14	0.11	2.17	2.28	4.70
1979	33.95	0.10	2.60	2.69	3.66
1980	40.37	0.12	2.60	2.61	4.42
1981	35.78	0.10	2.61	2.70	3.57
1982	39.13	0.12	2.55	2.67	4.44
1983	43.69	0.14	3.46	3.60	3.97
1984	52.60	0.19	2.96	3.15	6.03
1985	62.54	0.23	3.02	3.24	6.97
1986	76.76	0.27	3.07	3.34	8.13
1987	79.33	0.31	3.71	4.01	7.65
1988	82.16	0.32	4.46	4.78	6.72
1989	82.86	0.33	4.35	4.68	7.02
1990	81.77	0.34	5.07	5.41	6.27
1991	76.68	0.32	5.47	5.79	5.55
1992	77.22	0.34	5.36	5.69	5.95
1993	77.32	0.41	5.47	5.87	6.91
1994	77.22	0.40	5.60	6.00	6.62

[a] Source: Department of Agriculture and Forestry, 2001.

rate are relevant to the hedging decisions of corn traders.

Thompson and Bond (1987) have demonstrated that persistent differences between US and Australian wheat traders' hedging decisions may exist on US futures markets, and thus they conclude that covering exchange rate risk via forward contracts affects the optimal hedging decisions of offshore commodity traders. According to Thompson and Bond's conclusions, managing exchange rate risk by either forward contract or currency futures is very important to commodity futures traders such as Taiwan's corn importers. However, Taiwan has not yet fully liberalised the forward exchange market and there is no US dollar-denominated Taiwanese currency futures trading in Taiwan or in the US. In order to analyse Taiwan's situation, we need to specify a different model by incorporating substitutes for US dollar-denominated Taiwanese currency futures using the concept of a cross-hedging strategy (Anderson and Danthine, 1981).

The objective of this study is to examine, when confronted with the two sources of risk, the optimal decisions of Taiwanese traders, who hedge corn imports on the Chicago Board of Trade in order to stabilise terminal returns in domestic currency terms. In addition to analysing the effect of exchange rate risk on optimal commodity hedging, this study intends to show the differences in commodity hedging performance with and without proper tools such as forward currency contracts and foreign currency futures to hedge the exchange risk. Our empirical results reveal that some liberalisation measures undertaken have been very beneficial to Taiwan, but further liberalisation is still needed. This can also serve as a promising example to many developing countries.

In the following section, theoretical derivations of models for various scenarios are provided, while the simulations and results are reported in the third section. The final section concludes the findings and policy implications.

2. Derivation of the optimal hedge ratios

A mean-variance framework is used to derive optimal hedging strategies for commodity traders such as Taiwan's corn importers. To examine the effect of exchange rate risk on optimal commodity hedging, four scenarios regarding the existence of a floating exchange rate and the management of exchange rate risk are entertained: (I) without exchange rate risk, (II) with exchange rate risk but without corresponding hedging tools, (III) forward currency contracts used to cover exchange rate risk, and (IV) foreign currency futures used to hedge exchange rate risk.

In a mean-variance model, the decision maker is assumed to maximise the following objective function:

$$\max E_{t-1}(\pi_t) - \left(\frac{\lambda}{2}\right) \mathrm{var}_{t-1}(\pi_t) \qquad (1)$$

where E_{t-1} and var_{t-1} denote the conditional expectation operator and the conditional variance operator, respectively, π_t is the end-of-period return, and λ is the decision maker's coefficient of risk aversion.

2.1. Scenario I: without exchange rate risk

Assume the importer measure his net cost of imports and terminal return in US dollar, so that the hedging decision is not influenced by exchange rate risk. The agency chooses the import quantity, Q_{t-1}, and the futures quantity, B_{t-1}, to protect it from an unfavourable cash price change. The end-of-period cost (or return) is given by

$$\pi_t = -i_t Q_{t-1} + (f_t - f_{t-1}) B_{t-1} \qquad (2)$$

where i and f are import and futures prices in US dollars, respectively. From Eq. (2), $E_{t-1}(\cdot)$ and $var_{t-1}(\cdot)$ are given by

$$E_{t-1}(\pi_t) = -\mu_i Q_{t-1} + (\mu_f - f_{t-1}) B_{t-1} \qquad (3)$$

$$\mathrm{var}_{t-1}(\pi_t) = \sigma_i^2 Q_{t-1}^2 + \sigma_f^2 B_{t-1}^2 - 2 Q_{t-1} B_{t-1} \sigma_{i,f} \qquad (4)$$

where μ_i is the expected import price, μ_f is the expected futures price, σ_i^2 is the import price variance, σ_f^2 is the futures price variance, and $\sigma_{i,f}$ is the covariance between the import and futures prices. Substituting (3) and (4) into (1) and maximising (1) with respect to the decision variables Q_{t-1} and B_{t-1}, the optimal hedge ratio (HR) is

$$\mathrm{HR} = \frac{B_{t-1}}{Q_{t-1}} = \frac{\mu_i \sigma_{i,f} + \sigma_i^2(-\mu_f + f_{t-1})}{\mu_i \sigma_f^2 + \sigma_{i,f}(-\mu_f + f_{t-1})} \qquad (5)$$

The hedge ratio depends on the expected import price, the expected return on futures contracts, and the variances and covariance of import and futures prices.

2.2. Scenario II: with exchange rate risk but without hedging tools for the risk

It is assumed that the importer, by undertaking commodity hedging, tries to stabilise profits in Taiwanese dollars (Taiwan$) rather than in US dollars. The terminal return is then given as

$$\pi_t = -i_t e_t Q_{t-1} + (f_t - f_{t-1}) e_t B_{t-1} \qquad (6)$$

where e_t is the exchange rate of Taiwan's currency in US dollar terms. As above, the optimal hedge ratio is

$$\mathrm{HR} = \frac{T_1}{T_2} \qquad (7)$$

in which

$$T_1 = \mu_{ie}(f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe}) + (\mu_{fe} - f_{t-1}\mu_e)\sigma_{ie}^2$$

and

$$T_2 = -\mu_{ie}(\sigma_{fe}^2 + f_{t-1}^2 \sigma_e^2 - 2 f_{t-1} \sigma_{fe,e}) + (\mu_{fe} - f_{t-1}\mu_e)(f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe})$$

where μ_{ie} and μ_{fe} are the expected values of import and future prices in Taiwanese currency, $i_t e_t$ and $f_t e_t$ respectively, and σ_{ie}^2 and σ_{fe}^2 are the corresponding variances. Because of interactions among corn prices, futures prices, and the exchange rate, the optimal hedge ratio in (7) is more complex than in (5). Clearly, exchange rate risk has a substantial effect on the hedging decision of Taiwan's corn traders.

2.3. Scenario III: forward contracts used to cover exchange rate risk

The importer undertakes simultaneous commodity hedging and forward currency contracting to cover both types of risk. He is assumed to buy forward currency contracts of an amount C_{t-1} at a price w_{t-1}

which will be sold in time t at the prevailing cash exchange rate e_t. With the introduction of forward currency transactions, the terminal return function is

$$\pi_t = -i_t e_t Q_{t-1} + (f_t - f_{t-1}) e_t B_{t-1} + (e_t - w_{t-1}) C_{t-1} \quad (8)$$

and the optimal hedge ratio of corn futures is

$$\mathrm{HR} = \frac{T_3}{T_4} \quad (9)$$

where

$$T_3 = \begin{vmatrix} \mu_{fe} - f_{t-1}\mu_e & \sigma_{fe,e} - f_{t-1}\sigma_e^2 & f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe} \\ \mu_e - w_{t-1} & \sigma_e^2 & -\sigma_{ie,e} \\ -\mu_{ie} & -\sigma_{ie,e} & \sigma_{ie}^2 \end{vmatrix}$$

and

$$T_4 = \begin{vmatrix} \sigma_{fe}^2 + f_{t-1}^2\sigma_e^2 - 2f_{t-1}\sigma_{fe,e} & \sigma_{fe,e} - f_{t-1}\sigma_e^2 & \mu_{fe} - f_{t-1}\mu_e \\ \sigma_{fe,e} - f_{t-1}\sigma_e^2 & \sigma_e^2 & \mu_e - w_{t-1} \\ f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe} & -\sigma_{ie,e} & -\mu_{ie} \end{vmatrix}$$

2.4. Scenario IV: foreign currency futures used to cover exchange rate risk

Cross-hedging is defined as using futures on a product other than the deliverable grade of the particular commodity being hedged to hedge that commodity's price risk (Anderson and Danthine, 1981). Since there is no US dollar-denominated Taiwanese currency futures trading in any exchange, the importer uses US dollar-denominated futures contracts, the prices of which should be highly correlated with the Taiwan dollar–US dollar exchange rate to hedge against exchange rate risk. He is assumed to buy foreign currency futures, trading an amount D_{t-1} of country M's currency at a price x_{t-1} to be sold in time t at the prevailing futures price x_t. Taiwan dollar–US dollar and Taiwan dollar–M currency exchange rates are assumed to be highly correlated. With the introduction of currency futures transactions, the terminal return is given by

$$\pi_t = -i_t e_t Q_{t-1} + (f_t - f_{t-1}) e_t B_{t-1} + (x_t - x_{t-1}) e_t D_{t-1} \quad (10)$$

and the optimal hedge ratio of corn futures is

$$\mathrm{HR} = \frac{T_5}{T_6} \quad (11)$$

where

$$T_5 = \begin{vmatrix} \mu_{fe} - f_{t-1}\mu_e & \sigma_{fe,xe} - f_{t-1}\mu_{xe,e} - x_{t-1}\sigma_{fe,e} + f_{t-1}x_{t-1}\sigma_e^2 & f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe} \\ \mu_{xe} - x_{t-1}\mu_e & \sigma_{xe}^2 + x_{t-1}^2\sigma_e^2 - 2x_{t-1}\sigma_{xe,e} & x_{t-1}\sigma_{ie,e} - \sigma_{ie,xe} \\ -\mu_{ie} & x_{t-1}\sigma_{ie,e} - \sigma_{ie,xe} & \sigma_{ie}^2 \end{vmatrix}$$

and

$$T_6 = \begin{vmatrix} \sigma_{fe}^2 + f_{t-1}^2\sigma_e^2 - 2f_{t-1}\sigma_{fe,e} & \sigma_{fe,xe} - f_{t-1}\mu_{xe,e} - x_{t-1}\sigma_{fe,e} + f_{t-1}x_{t-1}\sigma_e^2 & \mu_{fe} - f_{t-1}\mu_e \\ \sigma_{fe,xe} - f_{t-1}\mu_{xe,e} - x_{t-1}\sigma_{fe,e} + f_{t-1}x_{t-1}\sigma_e^2 & \sigma_{xe}^2 + x_{t-1}^2\sigma_e^2 - 2x_{t-1}\sigma_{xe,e} & \mu_{xe} - x_{t-1}\mu_e \\ f_{t-1}\sigma_{ie,e} - \sigma_{ie,fe} & x_{t-1}\sigma_{ie,e} - \sigma_{ie,xe} & -\mu_{ie} \end{vmatrix}$$

The optimal hedge ratios in (9) and (11) involve many variance and covariance terms and hence, are even more complex than the optimal hedge ratio in (7). This is because the commodity hedging decision must be integrated with the decision to cover exchange rate risk, which generates more interacting terms. The implication of the theoretical results obtained in Scenarios III and IV are quite similar to that of Thompson and Bond in that the management of exchange rate risk will influence commodity futures trading strategies.

The above results yield the expectation that commodity hedging behaviour will vary whenever exchange rate risk and coverage of risk exist, depending on the actual levels of risk, correlations of risks, expected price levels, etc. In search of empirical evidence for the case of Taiwan's corn imports, the following section presents simulations and results.

3. Simulations and results

For the empirical analysis, it is assumed that the decision-maker selects a futures position in one of the contracts and re-evaluates this position on a monthly basis. At the end of each hedging period, the portfolio may be adjusted to reflect changing information and economic conditions. The next available nearby month contracts are used to hedge corn import price and/or exchange rate risk.

The cash price data used in the simulation analysis is C&F (cost and freight) on corn imports. Futures prices data for corn are quoted on the Chicago Board of Trade. Futures prices on German deutschmarks, Japanese yen, Swiss francs, British pounds, Canadian dollars, and Australian dollars quoted on the Chicago Mercantile Exchange are collected and used to calculate correlations between the Taiwan dollar–US dollar exchange rate and the prices of these particular US dollar-denominated currency futures. The deutschmark futures is the most highly correlated of these. Thus, of US dollar-denominated foreign currency futures, the deutschmark futures is the best choice with which to cross-hedge Taiwan dollar–US dollar exchange rate risk. The cash exchange rate and the 30-days forward exchange rate are measured as monthly market quotations. The data set covers the period from July 1987 to November 1993.

To simulate optimal hedge ratios from January 1991 through December 1993, optimal hedge ratios for each month based on Eqs. (5), (7), (9) and (11) are calculated using data of the previous 42 months. For example, to obtain the optimal hedge ratio for January 1991, the expectations, variance and covariance terms are computed ex ante using the data from July 1987 through December 1990, while for January 1992, data from July 1988 through December 1991 is used. All the expectations, variance and covariance terms are obtained using SHAZAM 7.0. The simulated optimal hedge ratios under various scenarios are presented in Table 2.

The hedging effectiveness (HE) depicts the gain or loss (of terminal return variance) due to price changes incurred in an unhedged position relative to that incurred in a hedged position as defined in Johnson (1960, p. 215):

$$\mathrm{HE} = \frac{(\mathrm{var}^{\mathrm{u}}(\pi_t) - \mathrm{var}^{\mathrm{h}}(\pi_t))}{\mathrm{var}^{\mathrm{u}}(\pi_t)} \tag{12}$$

where $\mathrm{var}^{\mathrm{u}}(\pi_t)$ is the level of risk for the unhedged position, and $\mathrm{var}^{\mathrm{h}}(\pi_t)$ is the level of risk for hedged position.

In Table 2, the annual average hedge ratios in Scenario I are 0.61, 0.51, and 0.56 for 1991, 1992, and 1993, respectively. The corresponding average hedge ratios in Scenario II are 0.66, 0.65, and 0.70, respectively, where the agency measures the terminal returns in Taiwan dollar. The differences in hedge ratios between these two scenarios demonstrate that exposure to exchange rate risk does have a substantial effect on the commodity hedging decisions of Taiwanese corn traders. However, in Scenario III, as the corn importer covers the exchange rate risk by means of forward currency contracts, the optimal hedge ratios (0.64, 0.56, and 0.57 for 1991, 1992, and 1993, respectively), are smaller than in Scenario II and closer to the values in Scenario I. This indicates that the trader in Scenario II over-hedges commodity price risk, and that tools for hedging the two particular sources of risk are substitutes for each other in Taiwan's case.

The average optimal hedging levels are 0.63, 0.59, and 0.65 for 1991, 1992, and 1993, respectively, in Scenario IV where the corn importer hedges exchange rate risk using the deutschmark futures. These magnitudes are smaller than those in Scenario II and differ from Scenario III. These results from Scenarios III and IV confirm Thompson and Bond's conclusion that the utilisation of US futures markets by offshore traders is influenced in part by their strategies for coping with exchange rate risk.

As to the hedging effectiveness, compared to Scenario II, the HE increases as exchange rate risk is covered by forward currency contracts in Scenario III, meaning that the level of risk has been reduced. The differences are quite substantial for 1992 and 1993 according to the annual averages of effectiveness. It is obvious that a well-established forward currency market can benefit Taiwanese traders. However, as the

Table 2
Comparison of hedge ratios (HR) and hedging effectiveness (HE) among the four scenarios, 1991–1993[a]

Month	Scenario							
	I		II		III		IV	
	HR	HE (%)	HR	HE (%)	HR	HE (%)	HR	HE (%)
1991								
January	0.89	53.91	0.74	54.12	0.68	55.06	0.75	52.53
February	0.91	50.85	0.78	53.39	0.73	54.65	0.80	51.76
March	0.89	47.06	0.80	51.64	0.75	53.47	0.83	50.73
April	0.88	43.05	0.82	49.37	0.79	51.23	0.81	49.40
May	0.80	37.69	0.79	45.16	0.78	47.20	0.77	45.24
June	0.72	32.21	0.74	40.62	0.75	42.30	0.71	40.70
July	0.54	24.20	0.61	33.31	0.64	35.18	0.56	33.01
August	0.56	18.53	0.65	28.44	0.67	28.90	0.62	28.74
September	0.44	13.63	0.57	24.03	0.59	24.09	0.53	24.43
October	0.34	9.18	0.52	20.02	0.53	19.86	0.49	20.46
November	0.22	4.19	0.46	15.34	0.44	15.77	0.30	15.97
December	0.10	1.78	0.38	13.39	0.30	15.46	0.35	14.30
Average	0.61	28.08	0.66	35.58	0.64	36.83	0.63	35.58
1992								
January	0.47	15.38	0.78	31.82	0.69	34.59	0.79	31.50
February	0.60	24.22	0.89	35.82	0.73	45.71	0.85	37.23
March	0.74	43.37	0.99	43.86	0.76	67.31	0.92	47.95
April	0.62	38.63	0.80	37.94	0.65	61.95	0.73	42.05
May	0.51	33.52	0.63	36.18	0.55	55.92	0.58	41.28
June	0.51	34.23	0.60	35.81	0.55	55.16	0.55	42.84
July	0.51	33.40	0.56	30.43	0.53	52.83	0.49	40.58
August	0.50	35.68	0.56	34.24	0.52	54.90	0.49	45.64
September	0.49	35.60	0.55	34.63	0.51	54.18	0.47	47.15
October	0.47	36.20	0.53	36.73	0.49	54.91	0.45	48.18
November	0.33	23.10	0.44	30.58	0.37	48.27	0.36	40.47
December	0.38	27.14	0.50	34.14	0.41	52.20	0.44	40.84
Average	0.51	31.67	0.65	35.25	0.56	53.17	0.59	42.17
1993								
January	0.40	28.30	0.55	34.96	0.43	54.69	0.50	38.53
February	0.50	37.27	0.64	41.67	0.51	60.37	0.60	43.00
March	0.52	41.17	0.66	44.92	0.53	62.73	0.62	45.64
April	0.56	42.39	0.70	43.93	0.57	63.15	0.66	44.85
May	0.57	42.94	0.72	44.45	0.58	63.26	0.66	45.92
June	0.55	41.26	0.69	43.72	0.56	62.13	0.63	45.29
July	0.55	42.46	0.69	44.49	0.56	62.81	0.62	45.13
August	0.58	44.06	0.72	44.72	0.58	63.57	0.67	44.92
September	0.58	44.32	0.71	45.74	0.59	62.90	0.68	45.92
October	0.60	43.28	0.73	43.44	0.61	62.61	0.70	43.86
November	0.63	41.80	0.78	41.96	0.64	62.02	0.75	42.31
December	0.62	37.32	0.76	34.99	0.63	57.89	0.73	35.37
Average	0.56	40.33	0.70	42.50	0.57	61.58	0.65	43.42

[a] Source: Own calculations.

market has not been fully deregulated and does not admit free participation in Taiwan, the traders' choice of hedging tools is quite limited. This, of course, implies a social loss.

As traders cover the exchange rate risk using other tools such as deutschmark futures in Scenario IV, hedging effectiveness becomes smaller compared with Scenario III, meaning that the deutschmark futures does not lead to a reduction of risk. Hence, a social loss occurs. In all, if, for any reason the exchange rate risk cannot be taken into account or managed properly, the trader's best decision would lead to over-hedging and to higher levels of risk.

4. Conclusions

The theoretical derivations in this study indicate the potential effects of exchange rate risk on commodity hedging decisions due to the interaction of commodity prices and exchange rates. Our empirical results, via simulations, confirm the hypothesis that the hedging behaviour of Taiwan's corn importers has tended to overlook the role of exchange rate risk. The results also reveal the fact that Taiwan's importers can manage commodity price risks even better if exchange rate risk is covered either by forward currency contracts or by US dollar-denominated futures contracts.

While Scenario I shows that simple hedging could have lessened the risk by 28 to 40% between 1991 and 1993, the introduction of additional instruments in Scenarios II, III and IV would have further reduced risk. Scenario III had the greatest effect in this regard dominating the others in every year, and in nearly every month.

Apparently, the legalisation of futures trading in Taiwan has been favourable for traders, which, in turn, should have benefited consumers. However, even though such liberalisation policies have been beneficial to the economy, it should be noted that in the absence of fully deregulated forward exchange and Taiwan dollar-denominated currency futures markets, the economy has been incurring an observable social loss. The hedging effectiveness in Scenario III is apparently better than in Scenario II, suggesting that further liberalisation is necessary. Permitting the trading of Taiwan dollar-denominated futures contracts appears to be desirable and essential for economic development.

Taiwan's experience provides interesting lessons for developing countries. As the world economy has become more and more integrated through international trade, markets that provide tools for hedging against exchange risk are desirable in all countries.

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