Examining the Effect of Corn Price Risk on Import Source Diversification*

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corn, import demand, source diversification, price risk, risk-augmented AIDS

Abstract
This study examines how South Korea diversifies corn import sources with a focus on price and risk effects. A risk-augmented almost ideal demand system is employed to investigate the extent to which import demand system responds to a change in price levels and volatilities. The estimation results indicate that the total expenditure for corn imports is more likely to depend on diverse country sources rather than the US, and the import demand is flexible in adjusting the import demand in response to corn price changes. A substitutable relationship exists between US and Brazilian corn, which is likely to alleviate the potential pressures of rising corn prices on the expenditure for corn imports. Furthermore, the estimation results highlight that the total risk from volatile corn prices induces a reduction in corn imported from the US but a rise from the rest of the world. The results are more attributable to the direct effect induced by a change in risk preferences rather than the indirect effect caused by a change in effective prices due to a change in price volatilities.

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1. Introduction

International corn prices have fluctuated over the past decades. According to the primary commodity prices of the International Monetary Fund (IMF), the average international corn prices have risen since 2000 and hit $317 per ton in June of 2008. The corn prices returned to $166 per ton in September of 2009, but they increased again with high volatilities, hitting the peak price of $367 per ton in July of 2012. High and volatile corn prices would be due to a variety of factors, including economic and climatic circumstances. For example, corn supply slowed down with low productivity growth due to adverse weather events, but corn demand increased with a significant rise in its usage for biofuel and livestock production (Abbott et al., 2011; Brown and Funk, 2008; Cabas et al., 2010; Chen and Khanna, 2012; Condon et al., 2015; Hao et al., 2015; Khanna et al., 2008; McCalla, 2009; McPhail and Babcock, 2012; Tokgoz et al., 2008).

The domestic corn production in South Korea is negligible only with 15 thousand hectares. However, the corn consumption amounts to about 10 million tons, consisting of about 80% of corn for feed and about 20% of feed, seed, and industrial use (USDA-FAS, 2018, 2019). Due to small domestic production, South Korea has been dependent significantly on corn imports from foreign countries under high and volatile corn prices. According to the Food and Agriculture Organization (FAO), South Korea was ranked the third-largest corn importer in the world, with the large volume of annual corn imports varying between about 9 and 10 million tons for the period between 1996 and 2018. While corn was imported mainly from the US and China between 1992 and 2008, its high and volatile international corn prices diversified import sources. Although the dependence on US corn imports is considerable, import sources became diverse to include Brazil, Argentina, Russia, and Ukraine afterward (Lee et al., 2009; Kim et al., 2016).

High and volatile import prices of corn are of great concern, particularly to corn importers

and livestock producers in South Korea. High and volatile corn prices would affect corn importers' behavior for risk management directly. When they were exposed to market risk from large fluctuations in supply and demand of corn, corn importers' response to varying corn prices might induce to find more import sources in a search for the countries exporting corn at relatively low and stable corn prices. Moreover, high and volatile corn prices might be translated into livestock producers' feed costs. Since corn was used mainly for livestock feedstock in South Korea, high corn prices would induce livestock producers to turn to corn imported from different sources, or even replace corn with alternative feed grains to reduce the pressures on feed costs (Suh and Moss, 2016, 2017). The price effects might affect food security, ultimately associated with livestock supply and prices in the future.

Against high and volatile corn prices, many corn importers in South Korea have diversified corn import sources to reduce their price risk. While individual corn importers have their strategies for source diversification, policymakers are not knowledgeable about the aggregate response to high and volatile corn prices. When it comes to policymaking at the national level, it is crucial to examine the import allocation system for corn to understand its responsiveness to price levels and volatilities. As the literature has paid no attention to the question of how South Korea reallocates corn import sources in response to a change in corn price levels and volatilities, this study fills the gap in the literature with a focus on two aspects. First, this study examines the price-induced source diversification for corn imports to understand the extent to which corn import demand varies with a change in corn prices. The results contribute to identifying the substitutable or complementary relationships among import sources. Second, this study decomposes the effect of price risk on corn import demand. According to Zhang (2015), the total effect of price risk is discomposed of direct and indirect effects; the direct effect is associated with a change in risk preferences, and the indirect effect is related to a change in effective prices caused by price volatilities. The decomposition results contribute to identifying the direct and indirect effects explicitly, which determines how South Korea respond to varying corn prices.

2. Risk-Augmented Almost Ideal Demand System

Modeling an import demand system has been developed to conduct a comprehensive analysis of the import decision-making procedure. A representative model is the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980), which has been extensively applied to analyze the import allocation decisions for diverse import sources. While the AIDS was useful to examine the source-differentiated demand analyses among separable import sources (Yang and Koo, 1994), a recent study conducted by Zhang (2015) incorporated price risk into the AIDS based on the approach of Pollak and Wales (1981). This study suggested a better import demand system to understand import allocation decisions in response to a change in price levels and volatilities.

Following Zhang's approach (2015), we assume that a country imports n source-differentiated commodities, $q=(q_1,\cdots,q_n)$, given n commodities' prices, $p=(p_1,\cdots,p_n)$, and their corresponding volatilities $v=(v_1,\cdots,v_n)$. Given that the total expenditure for n import sources is m, $s=(s_1,\cdots,s_n)$ is defined for the expenditure shares of source-differentiated commodities. For time $t=1,\cdots,T$, the risk-augmented AIDS is written

$$s_{it}=\mu_i+\theta_i \ln y_t+\sum_{j=1}^{n}\pi_{ij}\ln p_{jt}+\sum_{j=1}^{n}\phi_{ij}\ln v_{jt}+\epsilon_{it} \tag{1}$$

in which μ, θ, π, and ϕ are parameters, and ϵ is the error term that is distributed normally. In Equation (1), y_t is the modified real expenditure at time t defined as $y_t=\dfrac{m_t}{P_t}$ where

$$\ln P=\sum_{j=1}^{n}s_{jt}\ln p_{jt}+\sum_{j=1}^{n}s_{jt}\ln v_{jt} \tag{2}$$

which is the modified Stone index incorporating risk factors into the general Stone index.

The risk-augmented AIDS represents how the import demand for commodity i responds to a change in the total real expenditure, import prices, and price volatilities. In Equation (1), θ_i

measures the effect of total expenditure on the import share of commodity i, which is expected to be positive for all i. While π_{ij} measures the effect of the import price of commodity j on the import share of commodity i, its sign will be negative if $i = j$ and positive(negative) if i and j are substitutes (complements). In addition, ϕ_{ij} measures the volatility effect of commodity j's price on the import share of commodity i. The parameters in Equation (1) are assumed to obey the regularity conditions for adding-up ($\sum_{i=1}^{n}\mu_i = 1$, $\sum_{i=1}^{n}\theta_i = 0$, $\sum_{i=1}^{n}\pi_{ij} = 0$, and $\sum_{i=1}^{n}\phi_{ij} = 0$), homogeneity ($\sum_{j=1}^{n}\pi_{ij} = 0$), symmetry ($\pi_{ij} = \pi_{ji}$), and negative semi-definite π_{ij} matrix for concavity.

While the ϕ_{ij} reflects the total effect of price risk, it is decomposed into direct and indirect effects. According to Zhang (2015), the risk-augmented AIDS is also expressed as

$$s_{it} = \mu_i + \theta_i \ln y_t + \sum_{j=1}^{n}\pi_{ij}\ln p_{jt} + \sum_{j=1}^{n}(\rho_{ij} + \pi_{ij}\sigma_j)\ln v_{jt} + \epsilon_{it} \tag{3}$$

where the total effect (ϕ_{ij}) is the sum of the direct (ρ_{ij}) and indirect ($\pi_{ij}\sigma_j$) effects; the parameter σ_j is assumed to be the positive elasticity associated with the extent to which price volatility reduces import volume. The direct effect is determined by risk preferences, but the indirect effect is determined by a change in effective prices relevant to volatilities. The decomposition may induce an inconclusive total effect due to the undetermined directions of the direct and indirect effects. A negative price parameter ($\pi_{ij} < 0$) induces a negative indirect effect, but the sign of the total effect is dependent on that of the direct effect. While a negative direct effect guarantees a negative total effect, a positive direct effect may offset the negative indirect effect. That is, the relative magnitudes of the direct and indirect effects determine the sign of the total effect. For a positive price parameter ($\pi_{ij} > 0$), the sign of the total effect is also undetermined due to the countervailing powers of the direct and indirect effects. A positive direct effect guarantees a positive total effect, but a negative direct effect may offset the positive indirect effect, resulting in an inconclusive total effect.

The empirical decomposition can identify clearly which effect is more contributable to the

resulting total effect in terms of elasticities. That is, we can use the estimates of the risk-augmented AIDS to obtain the demand elasticities with respect to total import expenditure, import prices, and price volatilities. From Equations (1) and (3), we obtain

$$\zeta_i = 1 + \frac{\theta_i}{\bar{s}_{it}} \tag{4a}$$

$$\eta_{it} = \delta_{ij} + \frac{\pi_{ij}}{\bar{s}_{it}} - \theta_i \frac{\bar{s}_{jt}}{\bar{s}_{it}} \tag{4b}$$

$$\omega_{ij} = \frac{\phi_{ij}}{\bar{s}_{it}} = \frac{\rho_{ij}}{\bar{s}_{it}} = \frac{\pi_{ij}\sigma_j}{\bar{s}_{it}} \tag{4c}$$

where $\bar{s}_{it}$ is the average expenditure share of commodity i, and δ_{ij} is the Kronecker delta. Equation (4a) represents the elasticity of the ith import demand concerning the total expenditure, and Equation (4b) indicates the elasticity of the ith import demand with respect to the import price of jth commodity. Besides, Equation (4c) measures the elasticity of the ith import demand with respect to the volatility (risk) of jth import price, which is decomposed into the direct and indirect elasticities.

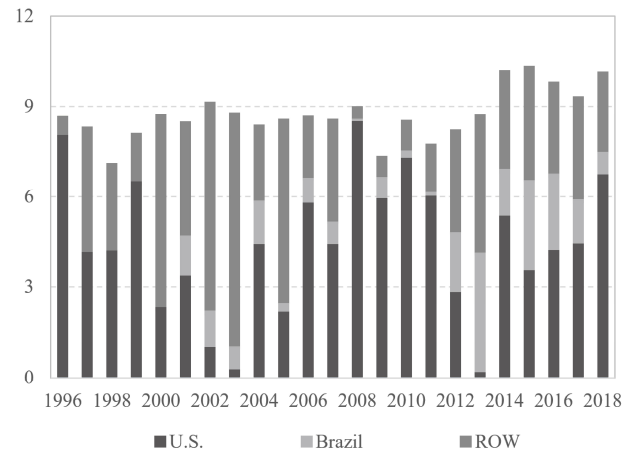
3. Empirical Results

3.1. Data and Estimation Procedure

South Korea imports, on average, about nine million tons of corn from diverse country sources; the import sources include mainly the US, Brazil, Argentina, Russia, and Ukraine. (Figure 1). While corn importers make contracts to import about nine million tons of feed and processing corn on arrival basis (USDA-FAS, 2019), the Trade Statistics of the Korea Customs

Service reports monthly data for corn imports from diverse country sources. This study converts monthly data to quarterly data due to irregular corn imports from diverse country sources. The data include the quarterly quantities and prices of corn imported from the US, Brazil, and the rest of the world (ROW). Due to the limited availability of data, the empirical analysis also covers the period between the third quarter of 2006 and the second quarter of 2018.

Figure 1. Corn Import Volumes by Source Country(Million tons)



Source: Trade Statistics, Korea Customs Service

In Table 1, import quantities are in thousand tons, and import prices in dollars per ton. The price is calculated by dividing import value by import quantity, which reflects the price of corn delivered at the territory. The price (i.e., the CIF price) includes cost, insurance, and freight charges. While the average total corn import is, on average, 2.2 million tons per quarter with variation in import prices between about 256 and 276 dollars per ton, the share of corn imported from the US is the biggest, accounting for about 56% among the selected import sources. While the share of corn imported from Brazil is the second biggest source (16%), that from the rest of the world accounts for about 28%.

Table 1. Quarterly Corn Imports by Source, 2006-2018

	Mean	Std. dev.	Min.	Max.
Quantity (1000 tons)				
US	1,232.39	673.468	5.780	2,549.04
Brazil	368.871	483.610	0.048	1,864.10
ROW	639.285	441.975	6.624	1,668.09
Price($/ton)				
US	276.422	114.013	143.678	784.409
Brazil	256.750	68.990	153.833	439.731
ROW	255.687	58.902	157.708	369.701
Import Share				
US	0.560	0.298	0.007	0.991
Brazil	0.158	0.195	0.001	0.699
ROW	0.282	0.190	0.004	0.841

Source: Trade Statistics, Korea Customs Service.

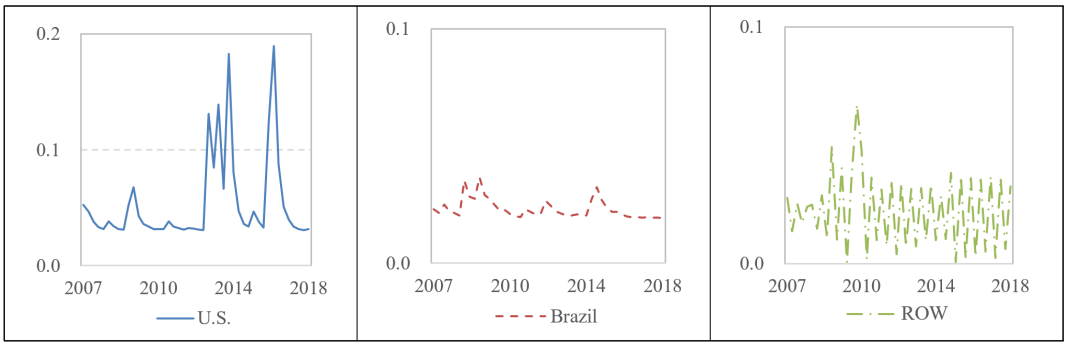
Given the quarterly data, a two-step estimation procedure is used. In the first step, the generalized autoregressive conditional heteroskedasticity (GARCH) model is employed to obtain the conditional variance used for price risk (Bollerslev, 1986; Taylor, 1986). Based on the GARCH(1,1), the conditional variance (h_t) at time t is denoted by

$$\ln p_t = \alpha_0 + \alpha_1 \ln p_{t-1} + \epsilon_t \tag{5}$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 \epsilon_{t-1}^2 \tag{6}$$

where α and β are parameters to be estimated. The predicted conditional variance of each import price is used as the proxy variable for import price risk (Figure 2).

Figure 2. Predicted Conditional Variance of GARCH Model



In the second step, the predicted conditional variance is inserted to the risk-augmented AIDS specified in Equation (3). Due to the nonlinearity, the system is estimated using the nonlinear seemingly unrelated regression (NLSUR) method. In this step, the risk-augmented AIDS is estimated with homogeneity and symmetry imposed, and the bootstrapping method is employed to obtain the theoretically valid estimates. That is, while the bootstrapping method is beneficial for a small sample size (Cameron and Trivedi, 2005), it ensures the sound import demand system satisfying its concavity (Terrell, 1996; Wolff et al., 2010). If all eigenvalues of the price parameter matrix are non-positive, we retain the estimates and continue the same procedure with 1,000 replications. Their mean and standard errors are reported in Table 2.

Table 2. Estimation Results

Parameters	Estimates
μ_1	3.479*** (0.815)
μ_2	-0.195 (0.674)
θ_1	-0.384*** (0.069)
θ_2	0.103* (0.060)
π_{11}	-0.645*** (0.114)
π_{12}	0.535*** (0.087)

(Continued)

Parameters	Estimates
π_{22}	-0.579*** (0.128)
ρ_{11}	-0.159* (0.096)
ρ_{12}	-0.179 (0.160)
ρ_{13}	-0.105*** (0.033)
ρ_{21}	-0.024 (0.077)
ρ_{22}	0.237* (0.139)
ρ_{23}	0.026 (0.030)
σ_1	0.004 (0.110)
σ_2	0.051 (0.102)
σ_3	0.170 (0.152)

Note: Bootstrapped standard errors are in parentheses.*** Denotes statistical significance at 1% level.** Denotes statistical significance at 5% level.* Denotes statistical significance at 10% level.

3.2. Import Substitution and Risk

The elasticities of import demand are obtained concerning expenditure, price, and volatility at the sample mean from Equations (4a) through (4c). In the bootstrapping procedure, we calculate the elasticities once estimates obey regularity conditions. We then retain all the elasticities during 1,000 replications and calculate their mean values and standard errors. Table 3 presents the bootstrapped estimates and standard errors for the elasticities of import demand. In the second column of Table 3, the estimated expenditure elasticities of import demand are all positive and statistically significant. The expenditure elasticity of import demand for US corn (0.31) is the most inelastic, showing that the total expenditure for corn imports is more likely to depend on diverse country sources rather than the US. While the import share of US corn is the

largest, its change is not very sensitive to a change in the total expenditure for corn imports. On the other hand, the demand for corn imported from Brazil (1.67) and ROW (1.97) are very elastic, although their import shares are relatively small. The results imply that corn importers tend to turn to countries other than the US when it increases the total expenditure for corn imports. The corn imports were dependent heavily on the US in the past, but the results are consistent with the recent importing trends with more diversified sources.

The estimated price elasticities of import demand are also presented in the third through the fifth columns of Table 3. The estimated own-price elasticities of import demand (i.e., diagonal elements) are negative and statistically significant, and their absolute values are greater than 1. The results show that the corn import demand for US (-1.78), Brazil (-4.81), and ROW (-1.81) are elastic concerning their own-price changes. While corn importers are highly dependent on corn imported from the US, import demand is the most responsive to a change in Brazilian corn prices. The results reveal that corn importers are very flexible in adjusting corn import demand in response to an import price change. In addition, the estimated cross-price elasticities of import demand (i.e., off-diagonal elements) represent a substitutable relationship between US and Brazilian corn. With a focus on the response of corn import demand to US corn prices, a 1% increase in the import price of US corn raises the demand for Brazilian corn by 3.06%. While the increased import price of Brazilian corn also raises the import demand for US corn (1.07), the import demand for Brazilian corn is more responsive to a change in US corn prices than the reverse. In addition, an asymmetric response exists when ROW corn prices change. The import demand for US corn increases in response to a rise in ROW corn prices (0.40), but the reverse does not. The results reveal that corn importers are responsive to a rise in US corn prices, replacing US corn with Brazilian corn, but it turns to US corn when it faces a rise in Brazilian and ROW corn prices. While most corn imports are delivered from the US and Brazil, corn importers are more likely to rely on the substitution between the US and Brazil rather than other country sources against high corn price levels.

Table 3. Elasticities of Import Demand for Corn

	Expenditure Elasticities	Price Elasticities			Volatility Elasticities		
		US	Brazil	ROW	US	Brazil	ROW
US	0.307** (0.125)	-1.778*** (0.238)	1.073*** (0.155)	0.399*** (0.153)	-0.292*** (0.099)	-0.272 (0.289)	-0.159*** (0.047)
Brazil	1.663*** (0.383)	3.061*** (0.669)	-4.812*** (0.811)	0.088 (0.645)	-0.143 (0.314)	1.318 (0.832)	0.204 (0.139)
ROW	1.971*** (0.192)	-0.159 (0.356)	-0.001 (0.342)	-1.812*** (0.364)	0.637*** (0.145)	(0.189 (0.426)	0.196*** (0.072)

Note: Bootstrapped standard errors are in parentheses.*** Denotes statistical significance at 1% level.** Denotes statistical significance at 5% level.* Denotes statistical significance at 10% level.

More interesting results in Table 3 are in the volatility elasticities of the import demand for corn presented in the sixth through the eighth columns. The diagonal and off-diagonal elements indicate the elasticities with respect to own- and cross volatilities. Unlike the own-price elasticities, the response of corn import demand to its own volatility is not always negative. It shows that a rise in the volatility of US corn price reduces its own import demand (-0.29), but that of ROW corn price raises its own import demand (0.20). Furthermore, the increased volatility of US corn prices induces corn importers to raise the import demand for ROW corn (0.64), while that of ROW corn prices induces a reduction in the import demand for US corn (-0.16). The results show that a rise in the price volatility leads corn importers to diversify further corn import sources by directing from US corn to ROW corn. While corn importers depend heavily on the imports from the US, they tend to seek more diverse source countries rather than the US, which reduces the imports from the US but raises those from other countries against highly volatile corn prices.

For understanding how price volatilities induce the reallocation of corn imports, the total effect of price volatility is decomposed into the direct and indirect effects. As in Table 4, the decomposition explains the behavior of reallocating corn import sources. The direct effect measures the extent to which risk preference influences corn demand directly. In contrast, the indirect effect measures the extent to which the price volatility itself affects corn import demand

indirectly through a change in the effective price (Zhang, 2015). Interestingly, the results indicate that the total effect is more attributable to the direct effect rather than the indirect effect. The decomposition results show that corn importers diversify country sources in response to price volatilities mainly due to their preferences for ROW corn (i.e., direct effect). Specifically, due to the risk preferences, corn importers are more likely to reduce the demand for US corn (-0.29) but raise that for ROW corn (0.63) in response to high volatile US corn prices. The risk preferences also induce to reduce US corn (-0.19) but raise ROW corn (0.28) against high volatile ROW corn prices. The results imply that corn importers are inclined to increase ROW corn to reduce import price risk facing high volatile US and ROW corn prices.

Table 4. Decomposition of Volatility Elasticities

	Total Effects			Direct Effects			Indirect Effects		
	US	Brazil	ROW	US	Brazil	ROW	US	Brazil	ROW
US	-0.292*** (0.099)	-0.272 (0.289)	-0.159*** (0.047)	-0.286* (0.172)	-0.323 (0.289)	-0.190*** (0.060)	-0.005 (0.129)	0.050 (0.101)	0.031 (0.046)
Brazil	-0.143 (0.314)	1.318 (0.832)	0.204 (0.139)	-0.153 (0.494)	1.521* (0.891)	0.164 (0.191)	0.009 (0.378)	-0.202 (0.388)	0.04 (0.147)
ROW	0.637*** (0.145)	-0.189 (0.426)	0.196*** (0.072)	0.631*** (0.160)	-0.202 (0.432)	0.276** (0.121)	0.005 (0.053)	0.013 (0.042)	-0.081 (0.112)

Note: Bootstrapped standard errors are in parentheses.*** Denotes statistical significance at 1% level.** Denotes statistical significance at 5% level.* Denotes statistical significance at 10% level.

However, corn importers are not responsive to a change in the effective prices induced by price volatilities (i.e., indirect effect). Rather than reallocating import sources in response to a change in the effective prices, they are more likely to reallocate them due to its risk preference for ROW corn. In effect, corn importers' risk preferences are a main driver of adjusting corn import allocation in response to price volatilities, which reflects the precautionary behavior against price risk determines the import allocation in the future. Given the high dependence on US corn, corn importers seek for more diverse import sources to prepare for potential price risk in the future, which results in source diversification to ROW corn away from US corn. Corn importers respond to price changes through reallocation mainly between the US and Brazil, but

they respond to volatility changes through reallocation from the US to ROW with precautionary purposes.

4. Conclusions

South Korea has a long history of importing corn from foreign countries with a significant dependence on US corn. However, due to high and volatile international corn prices, the source diversification for corn imports becomes necessary to reduce the exposures of corn importers to fluctuating corn prices. Accordingly, this study examines South Korea's risk-augmented import demand system to understand how the levels and volatilities of corn import prices are associated with the import demand for corn. The contribution of this study is 1) to identify the substitutable relationships among import sources against varying price levels and 2) to identify the driving factors determining the diversification strategies against price volatilities.

With the rigorous estimation of the risk-augmented model, the estimation results provide critical information about source diversification behavior. While South Korea is flexible to adjust corn import demand in response to a change in the US, Brazilian and ROW corn prices, it substitutes Brazilian corn for US corn facing high US corn prices, or vice versa. Given the high dependence on US corn, the findings imply that Brazilian corn is a primary source to reduce potential pressures on the expenditure for corn in response to increasing US corn prices. Moreover, South Korea is responsive to price volatilities, showing that high volatile US and ROW corn prices induce to reduce corn imports from the US but raise them from ROW. The results are more attributable to risk preferences (direct effect) rather than the effective price changes associated with price volatilities (indirect effect). The results are relevant to the precautionary demand for ROW corn, which increases the degree of import source diversification. The results reveal that an increase in import prices makes corn importers

reallocate their imports, mainly between the US and Brazil. However, an increase in price volatilities induces them to seek other import sources in the rest of the world due to precautionary behavior.

The findings are informative to policymakers concerned about the impact of price risk on trade flows. While the price-induced source diversification occurs between US and Brazilian corn, South Korea needs to secure more diverse sources for corn imports to respond to price risk. Policymakers may help corn importers find more import sources to reduce further the pressures on expenditure for corn if there is an unexpected rise in US and Brazilian corn prices. Moreover, the volatility-induced source diversification should be associated with reactions to a change in the effective prices as well as a change in risk preferences because adjusting corn imports properly to volatile corn prices is also essential along with the precautionary corn demand. Policymakers need to provide corn importers with price outlook information effectively to help them react appropriately to a change in the effective prices induced by price volatilities.

Admittedly, there are limitations to this study. First, the findings may not reflect the trading activities of all individual corn importers because the analysis in this study is conducted for the import allocation decisions at the national level with quarterly data. A better dataset covering daily or weekly trading activities of all individual corn importers may provide more robust results about corn import allocations. Second, the analysis does not consider exchange rates, freight costs, and the time lags between contract and delivery dates. A future study may conduct a dynamic analysis for the import demand system to reflect exchange rates and freight costs separately from import prices. Lastly, this study does not consider the linkage between corn imports and livestock production. Promising new research may focus on the transmission of corn price risk into livestock producers' feedstock allocation or livestock production and prices.

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