HOW LARGE IS THE COMPETITIVE EDGE THAT U.S.-BASED FUTURES PROVIDE TO U.S. FARMERS?

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Abstract

The present study advocates a simulation approach to analyze quantitatively the impact of having locally-based markets for price derivatives. A major result is that market outcomes do not appear to be sensitive to most of the underlying parameters of the model other than demand elasticity and transportation costs. For the case of inelastic demand, introduction of a futures market in a country provides domestic producers with a competitive edge if transportation costs are relatively high, but the opposite is true for relatively low transportation costs. The most important insight of the present analysis is that, under realistic scenarios it need not be the case that local producers will gain a competitive edge over foreign producers by introducing a futures market based on the local spot prices.

Keywords: Commodity markets, derivative markets, futures markets, welfare analysis, rational expectations.

Paper presented at the Annual Meeting of the American Agricultural Economics Association, Denver, CO, August 1-4, 2004.

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HOW LARGE IS THE COMPETITIVE EDGE THAT U.S.-BASED FUTURES PROVIDE TO U.S. FARMERS?

U.S. farmers have had access to futures markets for corn and other agricultural commodities for well over a century. U.S. futures for the main agricultural commodities are the most liquid in the world, and are routinely used by many foreign trader and producers to hedge their exposure to price risk. So ingrained is futures hedging in the marketing of agricultural commodities in the U.S. that the competitive edge conferred by such markets to U.S. producers has been largely neglected by the economics literature.

More specifically, the fact that the world's best functioning futures markets are for U.S. agricultural commodities allows U.S. producers to manage their price risk exposure better than foreign producers. Everything else equal, such enhanced risk-management provides U.S. producers a competitive edge over their foreign counterparts. However, to the extent that U.S. producers modify their output decisions in response to enhanced hedging opportunities, equilibrium in the spot commodity markets will be affected as well. Conceptually, since the latter aggregate market effect may have a negative impact on the revenues of U.S. producers, having local futures markets need not provide them with a competitive edge overall.

In principle, two basic approaches could be used to study the study the impact of adding a futures market to the spot market for a commodity of interest. One approach consists of performing an econometric study of the commodity market under analysis using data corresponding to the periods with and without futures market. Comparison of the estimated models for the two periods would then provide a quantitative assessment of the impact of the futures market. Despite its apparent appeal, however, the econometric approach has important limitations. First, much of the price and quantity data for commodity markets are highly volatile, thereby greatly reducing the power of the econometric tests. Second, often times other important events may occur at the same time a futures market is introduced. This leads to identification problems, as it is impossible to disentangle the effects of introducing futures from the impact of

the other events. Third, to identify the effects on producer decisions, one would need long data series regarding individual producer decisions, and such data are rarely available. For the present study, the problems are exacerbated by the fact that most of the futures markets for the major agricultural commodities have been in place for over a century. This severely hampers the availability of data previous to the introduction of such markets.

The second approach, and the one advocated here, consists of counterfactual simulations. Succinctly, this method involves constructing a simulation model based on economic theory, and calibrating its parameters to reflect as closely as possible the behavior of the market of choice. A major advantage of the simulation approach is that it avoids the famous "Lucas' critique," because the model built depends only on behavioral parameters that are not affected by shifts in policy regimes such as the one under consideration. However, as with all simulation-based research, the present results are only as accurate as the assumptions upon which the model is based. Therefore, caution must be exercised when interpreting these numbers within a policy context.

Succinctly, the present study contributes to the literature by employing a simulation approach to analyze quantitatively the impact of having locally-based markets for price derivatives on farmers' well being and on market variables of interest (e.g., production, consumption, exports, prices).

A Theoretical Model of the Commodity Market

The present study of the impact of local derivative markets is based on a standard commodity trade model. The relevant market for the commodity is assumed to consist of I countries that trade with each other until all arbitrage opportunities are exhausted. The scenario without derivatives markets in any country is laid out in the next subsection. This is followed by a discussion of the modifications that ensue when a local derivatives market is introduced in one of the countries.

The Commodity Market in the Absence of Derivatives Markets

Consumption in country i is inversely related to the contemporaneous realization of the local commodity price (P_{it}), and is also affected by other exogenous variables such as income:

(1.1) $D_{it} = d_i(P_{it}, e_{Dit})$.

In (1.1), $d_i(\cdot)$ is a demand function satisfying $\partial d_i(\cdot)/\partial P_{it} < 0$, and e_{Dit} represents the other variables that impact consumption of the commodity in country i.

Commodity production is assumed to take one period and be subject to random exogenous shocks (e.g., weather shocks). More specifically, the input choices made by a representative producer at time $t - 1$ determine the expected output at t [$Q_{it-1} \equiv E_{t-1}(S_{it})$]. The actual output at t (S_{it}) further depends on the realization of the random shock at time t (e_{Sit}):

(1.2) $S_{it} = Q_{it-1} \times e_{Sit}$.

By definition of Q_{it-1}, the random shock in (1.2) satisfies the condition $E_{t-1}(e_{Sit}) = 1$.

The representative producer is postulated to be an expected-utility maximizer, so that his objective function at time $t - 1$ consists of (1.3):

(1.3) $max_{Q_{it-1}} E_{t-1}\{U_i[\pi_{it}(Q_{it-1})]\}$.

In (1.3), $E_{t-1}(\cdot)$ denotes the expectations operator conditional on information at time t – 1, $U_i(\cdot)$ is the producer's utility function, and $\pi_{it}(\cdot)$ are profits at time t. In the absence of derivatives markets, the latter are simply revenues minus costs:

(1.4) $\pi_{it}(L_{it-1}) = P_{it}\, Q_{it-1}\, e_{Sit} - C_i(Q_{it-1})$.

Function $C_i(\cdot)$ represents the cost of planned output Q_{it-1} and satisfies standard properties (i.e., $C_i'(\cdot) > 0$ and $C_i''(\cdot) > 0$).

At period t, the commodity can be transported between countries i and j at cost T_{ijt}. Allowing for trade across countries, market clearing requires that world demand be equal to world supply, so that equality (1.5) must be met:

$$(1.5) \quad \sum_{i=1}^{I} D_{it} = \sum_{i=1}^{I} S_{it} .$$

Equilibrium implies the absence of arbitrage opportunities. Hence, given the output decisions made by producers at time $t - 1$, transportation costs, and the realizations of the demand and supply shocks at t, in equilibrium prices and net exports must satisfy condition (1.6) for all i and $j \neq i$:

$$(1.6) \quad P_{jt} - P_{it} - T_{ijt} \leq 0,\ x_{ijt} \geq 0,\ (P_{jt} - P_{it} - T_{ijt})\, x_{ijt} = 0,$$

where x_{ijt} are exports from country i to country j.

To close the model it is necessary to postulate a joint probability density function (pdf) for all of the exogenous random variables, and to determine the way by which producers form their expectations in (1.3). The exogenous pdfs used are discussed below in the "Model Initialization" section. As per the expectation formation mechanism, rational expectations are invoked. This means that expression (1.3) assumes correct expectations, in the sense that producers' subjective pdfs attach the same weights to the future states of nature as the true pdf does. Given equations (1.1) through (1.6) plus the joint pdf for the exogenous variables and the rational expectation assumption, the model can be solved. The procedure to do so is explained in later in the "Numerical Methods" section.

The Commodity Market in the Presence of a Local Derivatives Market in Country *A*

Consider now the introduction of a futures market for the commodity, and let F_{t_1,t_2} denote the futures price at time t_1 for maturity at time $t_2 \geq t_1$. Allowing producers in country i to hedge with futures, their objective function becomes (1.7) instead of (1.3), with profits defined as in (1.8) instead of (1.4):

$$(1.7) \quad max_{Q_{it-1},H^F_{it-1}} E_{t-1}\{U_i[\pi_{it}(Q_{it-1},\ H^F_{it-1})]\},$$

$$(1.8) \quad \pi_{it}(Q_{it-1},\ H^F_{it-1}) = P_{it}\ Q_{it-1}\ e_{Sit} - C(Q_{it-1}) + (F_{t-1,t} - F_{t,t})\ H^F_{it-1},$$

where H^F_{it-1} is the amount hedged in futures by the representative producer in country i. The futures hedge is the quantity of commodity sold short in the futures market at time $t-1$ for price $F_{t-1,t}$ and bought back at time t for price $F_{t,t}$.

Additionally allowing for a market in at-the-money put options on futures further expands the decision set of producers. In such an instance, the objective function consists of (1.9), and profits are given by (1.10):

$$(1.9) \quad max_{Q_{it-1},H^F_{it-1},H^O_{it-1}} E_{t-1}\{U_i[\pi_{it}(Q_{it-1},\ H^F_{it-1},\ H^O_{it-1})]\}.$$

$$(1.10) \quad \pi_{it}(Q_{it-1},\ H^F_{it-1},\ H^O_{it-1}) = P_{it}\ Q_{it-1}\ e_{Sit} - C(Q_{it-1}) + (F_{t-1,t} - F_{t,t})\ H^F_{it-1}$$

$$+ [max(F_{t-1,t} - F_{t,t},\ 0) - O_{t-1}]\ H^O_{it-1}.$$

In the above expressions, H^O_{it-1} is the put hedge and O_{t-1} is the premium for the at-the-money futures put option at time $t-1$. The term $max(F_{t-1,t} - F_{t,t},\ 0)$ is the payoff from the futures put (recall that the put is assumed to be at the money, so its strike price at time $t-1$ is equal to the futures price $F_{t-1,t}$).

To solve for the commodity market equilibrium in the presence of a futures market requires the definition of equilibrium values for futures prices $F_{t-1,t}$ and $F_{t,t}$. Note, however, that futures price $F_{t,t}$ is the spot price for the commodity in the local market of reference. Hence, if the local market of reference corresponds to country A (i.e., country A is the one with a "local" futures market), it follows that:

(1.11) $F_{t,t} = P_{At}$.

Expression (1.11) implies that country A has no basis risk, whereas all other countries face some basis risk. To identify futures price $F_{t-1,t}$ it is assumed that futures prices are unbiased, so that $F_{t-1,t} = E_{t-1}(F_{t,t})$.[1] Given (1.11), this assumption implies that:

(1.12) $F_{t-1,t} = E_{t-1}(P_{At})$.

In addition, when there is also a market for put options on futures, it is necessary to define the equilibrium premium on such options (O_{t-1}). Consistent with the assumption of unbiased futures, it is assumed that options are fairly priced:

(1.13) $O_{t-1} = E_{t-1}[max(F_{t-1,t} - F_{t,t}, 0)]$,

$= E_{t-1}\{max[E_{t-1}(P_{At}) - P_{At}, 0]\}$.

That is, the premium on the futures put equals the expected payoff of the at-the-money futures put.

[1]Recall that expectations are rational, so the expectations are taken with respect to the "true" pdf of $F_{t,t}$.

Model Initialization

For even the simplest parameterizations of interest, the postulated theoretical model does not have an analytical solution. Hence, we resort to numerical simulations to analyze the implications of the model. The numerical analysis requires specific functional forms for the demand functions, supply functions, utility functions of producers, as well as pdfs for the demand and supply shocks. The functional forms and their corresponding parameterizations are discussed next.

Functional Forms

For the demand function, we adopt the standard isoelastic form (2.1):

$$(2.1) \quad D_{it} = \delta_{0i} \; P_{it}^{\delta_{1i}} \; e_{Dit},$$

where $\delta_{0i} > 0$ is a scaling parameter and $\delta_{1i} < 0$ is the own-price elasticity of demand. On the supply side, producers' preferences are represented by a constant relative risk aversion utility function (2.2), whereas the cost function is assumed to be isoelastic as in (2.3):

$$(2.2) \quad U_i(\pi_{it}) = \frac{(\pi_{it} + \gamma_{0i})^{1-\gamma_{1i}}}{1-\gamma_{1i}},$$

$$(2.3) \quad C_i(Q_{it-1}) = \alpha_{0i} \; Q_{it-1}^{\alpha_{1i}}.$$

In (2.2), parameter $\gamma_{0i} > -min(\pi_{it})$ can be interpreted as an initial wealth level, whereas $\gamma_{1i} > 0$ denotes the coefficient of absolute risk aversion.[2] As per the cost function (2.3), $\alpha_{0i} > 0$ is a scaling factor and parameter $\alpha_{1i} > 1$ determines the own-price elasticity of supply (the latter would equal $1/(\alpha_{1i} - 1)$ in a deterministic setting).

[2]Note that the coefficient of relative risk aversion (CRRA) is defined here as CRRA = $-(\pi_{it} + \gamma_{0i}) \; U''/U' > 0$.

Without loss of generality, demand shocks (e_{Dit}) are normalized to have mean equal to one, and are assumed to be multivariate normally distributed and independent from the supply shocks:

$$(2.4)\quad \begin{bmatrix} e_{D1t} \\ \vdots \\ e_{DIt} \end{bmatrix} \text{ i.i.d. MN}\left(\begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}, \begin{bmatrix} \sigma_{D1}^2 & \cdots & \rho_{D1I}\sigma_{D1}\sigma_{DI} \\ \vdots & \ddots & \vdots \\ \rho_{D1I}\sigma_{D1}\sigma_{DI} & \cdots & \sigma_{DI}^2 \end{bmatrix}\right),$$

where $\sigma_{Di} > 0$ is the standard deviation of the demand shock in country i and ρ_{Dij} ($|\rho_{Dij}| < 1$) is the correlation between demand shocks in countries i and j.

By definition, supply shocks (e_{Sit}) have mean equal to one. Paralleling the assumed pdf for the demand shocks, supply shocks are postulated to be multivariate normally distributed:

$$(2.5)\quad \begin{bmatrix} e_{S1t} \\ \vdots \\ e_{SIt} \end{bmatrix} \text{ i.i.d. MN}\left(\begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}, \begin{bmatrix} \sigma_{S1}^2 & \cdots & \rho_{S1I}\sigma_{S1}\sigma_{SI} \\ \vdots & \ddots & \vdots \\ \rho_{S1I}\sigma_{S1}\sigma_{SI} & \cdots & \sigma_{SI}^2 \end{bmatrix}\right),$$

Parameters $\sigma_{Si} > 0$ and ρ_{Sij} ($|\rho_{Sij}| < 1$) denote respectively the standard deviation of supply shocks in country i and the correlation between supply shocks in countries i and j.

Transportation costs are also assumed to be random, following a multivariate normal distribution independent from the demand and supply shocks:

$$(2.6)\quad \begin{bmatrix} T_{12t} \\ \vdots \\ T_{I-1,I,t} \end{bmatrix} \text{ i.i.d. MN}\left(\begin{bmatrix} \tau_{12} \\ \vdots \\ \tau_{I-1,I} \end{bmatrix}, \begin{bmatrix} \sigma_{\tau 12}^2 & \cdots & \rho_{\tau;12;I-1,I}\sigma_{\tau 12}\sigma_{\tau,I-1,I} \\ \vdots & \ddots & \vdots \\ \rho_{\tau;12;I-1,I}\sigma_{\tau 12}\sigma_{\tau,I-1,I} & \cdots & \sigma_{\tau,I-1,I}^2 \end{bmatrix}\right),$$

with obvious definitions for $\sigma_{\tau ij} > 0$ and $\rho_{\tau,ij,kl}$ ($|\rho_{\tau,ij,kl}| < 1$).

Parameterization

Specific parameter values are needed for the simulations, including the number of countries making up the world market for the commodity (I). To focus on the impact of introducing a local derivatives market, we assume that countries are identical in all respects, except for the potential existence of a local derivatives market in one of them. To further simplify the analysis, we further restrict the analysis to the two-country case (i.e., $I = 2$). This procedure facilitates isolating the key factors affecting the quantitative impact of introducing a local derivatives market. In what follows, whenever it is necessary to distinguish between the country with the local derivatives market and the country facing basis risk, the former will be labeled "*A*" and the latter will be labeled "*B*."

To improve the accuracy of the numerical procedures, the demand and cost functions are normalized so as to yield equilibrium price, output and demand equal to unity for each country in the limiting case of non-stochastic shocks. This requires setting $\delta_0 = 1$ and $\alpha_0 = 1/\alpha_1$ for all of the simulations. Utility parameter γ_0 is fixed at $\gamma_0 = 2$ across all simulations to prevent numerical problems arising from a negative argument in the power utility function. For the other parameters, the values corresponding to the baseline scenario chosen are summarized in the "Baseline Value" column of Table 1.

The baseline parameter values are selected to render the simulations as realistic as possible, based on the existing literature and on available historical data. To put in perspective the magnitudes of the parameters for the transportation cost pdf and the standard deviations of the demand and supply shocks, recall that the scaling parameters are normalized to yield non-stochastic equilibrium price output and consumption equal to one in each country. Hence, the baseline transportation cost parameters amount to transportation costs of about 20% of prices, with a coefficient of variation of 20%. Similarly, the standard deviation of the demand (supply) shocks amounts to a coefficient of variation for demand (supply) in the order of 6% (18%). To explore the robustness of the results to alternative parameterizations, simulations were also conducted for the ranges of parameter values reported in the "Sensitivity Range" column of

Table 1. The sensitivity range of the production cost parameter α_1 implies (non-stochastic) supply elasticities between 0.1 and 0.9. To avoid unrealistically high transportation cost volatilities, for sensitivity purposes the coefficient of variation of transportation costs is capped at 20%, so that the range for $\sigma_{\tau AB}$ is [0, 0.2 τ_{AB}].

Numerical Methods

Solving the model amounts to calculating each country's equilibrium producer decision variables. For the scenarios with both futures and option markets, the equilibrium variables are obtained using the following algorithm:[3]

Step 1. Make an educated guess for the initial vector of producer decision variables [$Q^{(0)}_{At-1}$, $H^{F(0)}_{At-1}$, $H^{O(0)}_{At-1}$, $Q^{(0)}_{Bt-1}$, $H^{F(0)}_{Bt-1}$, $H^{O(0)}_{Bt-1}$].

Step 2. Repeat the following sub-step for each of the *N* states of nature:

Sub-step 2.1. Given $Q^{(0)}_{At-1}$ and $Q^{(0)}_{Bt-1}$, the supply and demand shocks in each country, and the transportation cost shocks in state of nature *n*, calculate the prices and exports that satisfy both the market-clearing condition (1.5) and the no-arbitrage condition (1.6) [$P^{(0)}_{At,n}$, $P^{(0)}_{Bt,n}$, $x^{(0)}_{At,n}$, $x^{(0)}_{Bt,n}$].

Step 3. Given the probability of occurrence of the *n*th state of nature w_n and the corresponding prices in country *A* ($P^{(0)}_{At,n}$), calculate the futures price from (1.12) ($F^{(0)}_{t-1,t} = \Sigma_n w_n P^{(0)}_{At,n}$) and the option premium from (1.13) ($O^{(0)}_{t-1} = \Sigma_n w_n max(F^{(0)}_{t-1,t} - P^{(0)}_{At,n}, 0)$).

Step 4. Given the probability of occurrence of the *n*th state of nature w_n, the corresponding prices $P^{(0)}_{At,n}$ and $P^{(0)}_{Bt,n}$, futures price $F^{(0)}_{t-1,t}$ and the option premium $O^{(0)}_{t-1}$, obtain the decision variables that maximize the expected utility of producers in each country (1.9):

[3]Note that the assumption that shocks are not autocorrelated greatly simplify the solution, because it implies that the equilibrium producer decision variables at *t* are also equilibrium variables for all $u \neq t$.

$$[Q_{it-1}^{(1)},\ H_{it-1}^{F(1)},\ H_{it-1}^{O(1)}] = argmax_{Q_{it-1},H_{it-1}^{F},H_{it-1}^{O}}\ \Sigma_n\, w_n\, U[\pi_{it,n}^{(0)}(Q_{it-1},\ H_{it-1}^{F},\ H_{it-1}^{O})],$$

where: $\pi_{it,n}^{(0)}(Q_{it-1},\ H_{it-1}^{F},\ H_{it-1}^{O}) = P_{it,n}^{(0)}\ Q_{it-1}\ e_{Sit} - C(Q_{it-1}) + (F_{t-1,t}^{(0)} - P_{At,n}^{(0)})\ H_{it-1}^{F}$

$$+ [max(F_{t-1,t}^{(0)} - P_{At,n}^{(0)}, 0) - O_{t-1}^{(0)}]\ H_{it-1}^{O}.$$

Step 5. Calculate the largest absolute difference between the initial and the new decision variables: $\eta \equiv max(|Q_{At-1}^{(1)} - Q_{At-1}^{(0)}|, |H_{At-1}^{F(1)} - H_{At-1}^{F(0)}|, |H_{At-1}^{O(1)} - H_{At-1}^{O(0)}|, |Q_{Bt-1}^{(1)} - Q_{Bt-1}^{(0)}|, |H_{Bt-1}^{F(1)} - H_{Bt-1}^{F(0)}|, |H_{Bt-1}^{O(1)} - H_{Bt-1}^{O(0)}|)$. If η is smaller than a prescribed tolerance level, the model is solved with equilibrium decision vector $[Q_{At-1}^{(1)},\ H_{At-1}^{F(1)},\ H_{At-1}^{O(1)},\ Q_{Bt-1}^{(1)},\ H_{Bt-1}^{F(1)},\ H_{Bt-1}^{O(1)}]$. Otherwise, repeat Steps 1 through 5 using the new decision vector $[Q_{At-1}^{(1)},\ H_{At-1}^{F(1)},\ H_{At-1}^{O(1)},\ Q_{Bt-1}^{(1)},\ H_{Bt-1}^{F(1)},\ H_{Bt-1}^{O(1)}]$ instead of the initial vector $[Q_{At-1}^{(0)},\ H_{At-1}^{F(0)},\ H_{At-1}^{O(0)},\ Q_{Bt-1}^{(0)},\ H_{Bt-1}^{F(0)},\ H_{Bt-1}^{O(0)}]$.

As shown in Step 2 of the above algorithm, the solution involves calculating the prices that satisfy simultaneously the market-clearing condition (1.5) and the no-arbitrage condition (1.6) for each state of nature. This requires an approximation, because the normal pdfs imply an infinite number of states of nature. To maximize efficiency, the approximation used to the continuous pdfs is a 6-point Gaussian quadrature for each of the five random shocks (Miranda and Fackler, Ch. 5). By adopting this procedure, the number of states of nature is reduced from infinity to a manageable $N = 15{,}625\ (= 5^6)$. For each of these states, the prices and exports that simultaneously solve conditions (1.5) and (1.6) are calculated by means of the bisection method (Miranda and Fackler, Ch. 3). The vector of optimal decision variables in Step 4 is obtained employing Newton's method (Miranda and Fackler, Ch. 3). The model is implemented in the programming language MATLAB version 6.5, using the toolbox of computer routines CompEcon Toolbox developed by Miranda and Fackler.

Results and Discussion

Results for the baseline scenario are reported in the "Inelastic Demand" columns of Table 2. The "No Futures" column shows the expected levels of the main variables of interest in the absence of futures markets. Also shown are their standard deviations, which appear within parentheses below the corresponding expected values. For example, total world output on average equals 1.974 commodity units, with a standard deviation of 0.251 units. As countries are identically parameterized for the "No Futures" scenario, the expected values and the standard deviations of production, consumption, exports, and prices are identical for both countries. Because of the market-clearing condition, expected output equals expected consumption for each country. However, consumption volatility is significantly smaller than production volatility in each country due to trade. Exports represent slightly more than 3% of production for each country. Expected prices equal \$1.088 per commodity unit in each country, and have an associated standard deviation of \$0.330/unit. Because of the absence of derivatives markets, there are no hedge ratios to speak of. The last two rows show that certainty equivalents for commodity producers are \$0.672.[4]

Under the baseline scenario, the introduction of a futures market in country *A* has a noticeable impact on the commodity market. Expected production in country *A* increases by 0.77%. However, expected production in country *B* increases by a considerably larger 1.08%. Even more interestingly, *A* expected exports decline by 1.62%, whereas *B* expected exports (i.e., *A* imports) actually increase by almost the same amount (1.58%). The reduced expected exports and larger expected imports by *A* lead to an increase in *A*'s expected consumption (0.88%) that exceeds *A*'s increase in expected output (0.77%). For *B*, the situation is reversed. As a result of the higher expected output, expected prices drop by a sizeable 1.73% in *A* and 1.90% in *B*. The bigger price decline in *A* compared to *B* is consistent with the reduction in expected exports by *A*

[4]To put in perspective the impact of random shocks on the commodity market, it is worth noting that the normalizations used imply that in the limit where all exogenous variables are nonstochastic, in equilibrium each country produces and consumes one unit of commodity, exports nothing, prices are \$1/unit of commodity, and profits are \$0.667 (i.e., certainty equivalents are \$0.667).

and the simultaneous increase in expected exports by *B*. In equilibrium, producers in *A* hedge in the futures market 38.9% of their expected output. Puzzlingly, producers in *B* hedge an even larger percentage (44.6%) of their expected production.

The percentage changes in expected output and prices indicate that producers in both countries experience a decline in expected revenues. However, the certainty equivalent figures indicate that commodity producers in both countries benefit from the introduction of a futures market in country *A*. For this to happen, it must be the case that the negative impact on revenues is outweighed by the gains in risk reduction attained by futures hedging. Interestingly, the increase in certainty equivalents for *B* producers is more than three times greater than the analogous increase for *A* producers. This is largely due to the larger expected decline in revenues for *A* producers.

The introduction of an options market when there is already a futures market in place in country *A* has a relatively minor impact on the commodity market. Expected output in A increases by a mere 0.04% of the expected output under futures, whereas expected output in *B* declines by a negligible amount (0.001%). The increase in expected exports by *A* (0.19%) is matched by the decline in *B*'s expected exports. Expected prices exhibit a tiny decline in both countries (0.04% in *A* and 0.02% in *B*).

In the presence of a put market, *A* (*B*) producers hedge 32.2% (42.6%) of their expected output in futures and an additional 19.8% (6.6%) in long puts. Interestingly, the percentage changes in certainty equivalents show that producers in both countries are worse off (albeit marginally so) by adding an options market to the existing futures market.

Except for changes in transportation costs and demand elasticities, the qualitative results just described are very robust to changes in parameters over the sensitivity ranges reported in Table 1.[5] Figures 1 through 4 are provided to illustrate the sensitivity results for expected

[5]This assertion is particularly true for the results regarding the introduction of a futures market. The additional introduction of an options market tends to be characterized by more nonlinearities, but the resulting market effects are substantially smaller than the impacts of futures alone. Therefore, the following discussion focuses on the introduction of futures markets only.

transportation costs and non-stochastic supply elasticities. Figure 1 shows that the percentage increase in expected output is greater the greater the supply elasticity. However, for a given supply elasticity, the increase in expected output is non-monotonic. For example, when the supply elasticity is 0.5, *A*'s (*B*'s) increase in expected output is minimum (maximum) for expected transportation costs of 0.15 (0.10). Figure 2 reveals that percentage changes in expected exports are not monotonic either on expected transportation costs. Thus, when transportation costs are about 0.10, *A* (*B*) exports decrease (increase) as the supply elasticity increases, but the opposite is true for expected transportation costs of 0.40. Figure 3 shows that percentage declines in expected prices are greater the greater the supply elasticity. For large expected transportation costs and supply elasticities, however, the percentage price decline is large for *A* but small for *B*. The reason for this is that large transportation costs tend make the situation closer to autarky, so a futures market in *A* is less useful to *B* producers, whose output response is diminished (see Figure 1). In turn, this means that the impact of the futures market in *A* tends to concentrate on country *A* when expected transportation costs are large.

Percentage increases in certainty equivalents are highest when supply elasticity is smallest (see Figure 4). This result is to be expected, because the inelastic demand ($\delta_1 = -0.5$) used for the simulations implies smaller expected revenues with increased expected output. Thus, in the absence of supply response, the percentage change in certainty equivalent only reflects the risk-reducing benefits stemming from the introduction of the futures market.

As pointed out earlier, the qualitative results are very sensitive to the elasticity of demand. To better highlight this point, results for an elastic demand ($\delta_1 = -1.30$) are reported in the last three columns of Table 2. In this instance, introduction of a futures market improves the well being of producers in *A* but leaves producers in *B* worse off. However, the realism of this scenario is questionable, because the model implies that producers in *A* actually buy futures (i.e., perform a "Texas hedge"). Thus, caution should be exercised when interpreting these results.

Figures 5 through 9 illustrate the sensitivity of the main variables of interest to transportation costs and demand elasticities. The most important insight from the graphs is that,

when demand is inelastic, the effect of introducing a futures market is very sensitive to the magnitude of transportation costs. For large transportation costs (e.g., expected transportation costs above 0.30) having a local futures market provides a competitive edge to producers in country *A*. In contrast, for low transportation costs (e.g. expected transportation costs below 0.20) a local futures market benefits producers in *B* far more than producers in *A*.

Concluding Remarks

The present study advocates a simulation approach to analyze quantitatively the impact of having locally-based markets for price derivatives. A major result is that market outcomes do not appear to be sensitive to most of the underlying parameters of the model other than demand elasticity and transportation costs. For the case of inelastic demand, introduction of a futures market in a country provides domestic producers with a competitive edge if transportation costs are relatively high, but the opposite is true for relatively low transportation costs. The most important insight of the present analysis is that, under realistic scenarios it need not be the case that local producers will gain a competitive edge over foreign producers by introducing a futures market based on the local spot prices.

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Table 1. Parameterizations used for the simulations.

Function	Parameter	Baseline Value	Sensitivity Range
Demand	δ_0	1	-
	δ_1	–0.5	[–1.5, –0.5]
Production cost	α_0	1/3	$1/\alpha_1$
	α_1	3	[2.11, 11]
Utility	γ_0	2	-
	γ_1	6	[2, 8]
Demand shock pdf	σ_D	0.06	[0.02, 0.16]
	ρ_{DAB}	0	[0, 0.6]
Supply shock pdf	σ_S	0.18	[0.10, 0.45]
	ρ_{SAB}	0	[0, 0.6]
Transportation shock pdf	τ_{AB}	0.2	[0, 0.40]
	$\sigma_{\tau AB}$	0.04	[0, 0.2 τ_{AB}]

Table 2. Results for baseline parameterization under inelastic and elastic demand.

	Inelastic Demand (Demand Elasticity = –0.50)			Elastic Demand (Demand Elasticity = –1.30)		
	No Futures (level)	**Futures Only (% change)**	**Futures & Puts (% change)**	No Futures (level)	**Futures Only (% change)**	**Futures & Puts (% change)**
Stochastic Variables:						
Output: *A*	0.987	**0.77**	**0.04**	0.991	**0.19**	**0.005**
	(0.178)	**(0.77)**	**(0.04)**	(0.178)	**(0.19)**	**(0.005)**
B	0.987	**1.08**	**–0.001**	0.991	**–0.01**	**0.001**
	(0.178)	**(1.08)**	**(–0.001)**	(0.178)	**(–0.01)**	**(0.001)**
World	1.974	**0.93**	**0.02**	1.983	**0.09**	**0.003**
	(0.251)	**(0.93)**	**(0.02)**	(0.252)	**(0.09)**	**(0.003)**
Consumption: *A*	0.987	**0.88**	**0.02**	0.991	**0.16**	**0.005**
	(0.136)	**(0.89)**	**(0.04)**	(0.155)	**(0.24)**	**(0.01)**
B	0.987	**0.98**	**0.01**	0.991	**0.03**	**0.002**
	(0.136)	**(1.24)**	**(–0.001)**	(0.155)	**(–0.03)**	**(0.0003)**
Exports: *A*	0.032	**–1.62**	**0.19**	0.013	**1.29**	**0.03**
	(0.061)	**(–0.35)**	**(0.10)**	(0.039)	**(0.68)**	**(0.02)**
B	0.032	**1.58**	**–0.19**	0.013	**–1.31**	**–0.03**
	(0.061)	**(1.26)**	**(–0.09)**	(0.039)	**(–0.61)**	**(–0.01)**
Price: *A*	1.088	**–1.73**	**–0.04**	1.023	**–0.12**	**–0.003**
	(0.330)	**(–1.74)**	**(–0.03)**	(0.132)	**(–0.01)**	**(–0.001)**
B	1.088	**–1.90**	**–0.02**	1.023	**–0.02**	**–0.001**
	(0.330)	**(–1.68)**	**(–0.04)**	(0.132)	**(–0.10)**	**(–0.003)**
Nonstochastic Variables:						
Futures HR: *A*	Not applic.	0.389	0.322	Not applic.	–0.328	–0.416
B	Not applic.	0.446	0.426	Not applic.	0.050	0.089
Puts HR: *A*	Not applic.	Not applic.	0.198	Not applic.	Not applic.	0.202
B	Not applic.	Not applic.	0.066	Not applic.	Not applic.	–0.091
Cert. Equiv.: *A*	0.672	**0.12**	**–0.001**	0.659	**0.16**	**0.005**
B	0.672	**0.45**	**–0.03**	0.659	**–0.02**	**0.0001**

Note: Figures bolded for "Futures Only" and "Futures and Puts" designate percentage changes with respect to the corresponding "No Futures" and "Futures Only" values, respectively. Figures not bolded for stochastic variables denote expected values (not within parenthesis) and standard deviations (within parenthesis). Figures not bolded for nonstochastic variables designated "HR" and "Cert. Equiv." denote equilibrium hedge ratios and equilibrium commodity producer certainty equivalents, respectively. Futures hedge ratios and puts hedge ratios for country *i* are defined as H^{F}_{it-1}/Q_{it-1} and H^{P}_{it-1}/Q_{it-1}, respectively. The certainty equivalent of random profit $\tilde{\pi}$ for commodity producer *i* is given by $CE_i(\tilde{\pi}) \equiv U_i^{-1}\{E_{t-1}[U_i(\tilde{\pi})]\}$.

Figure 1. Percentage change in expected output due to the introduction of a futures market.

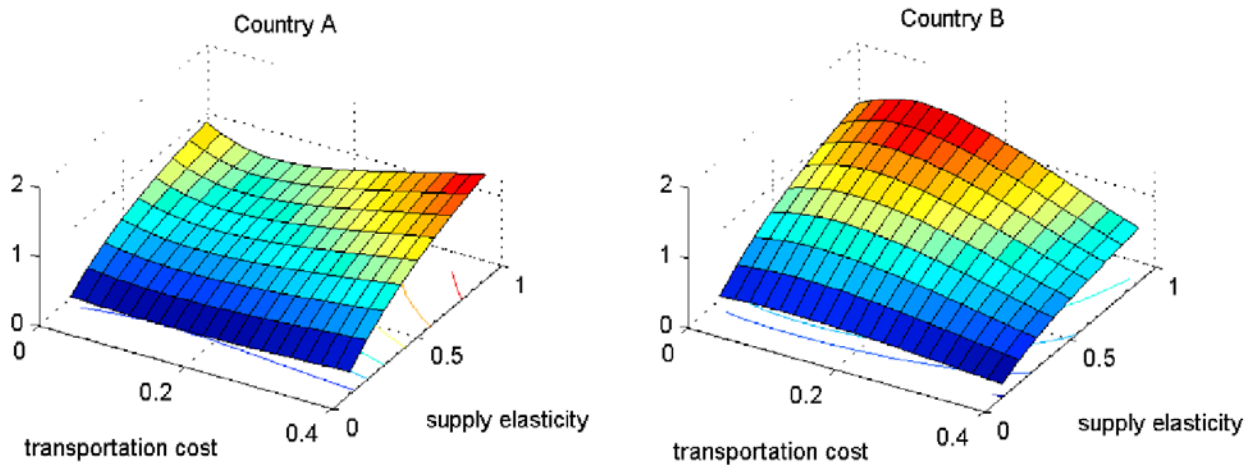
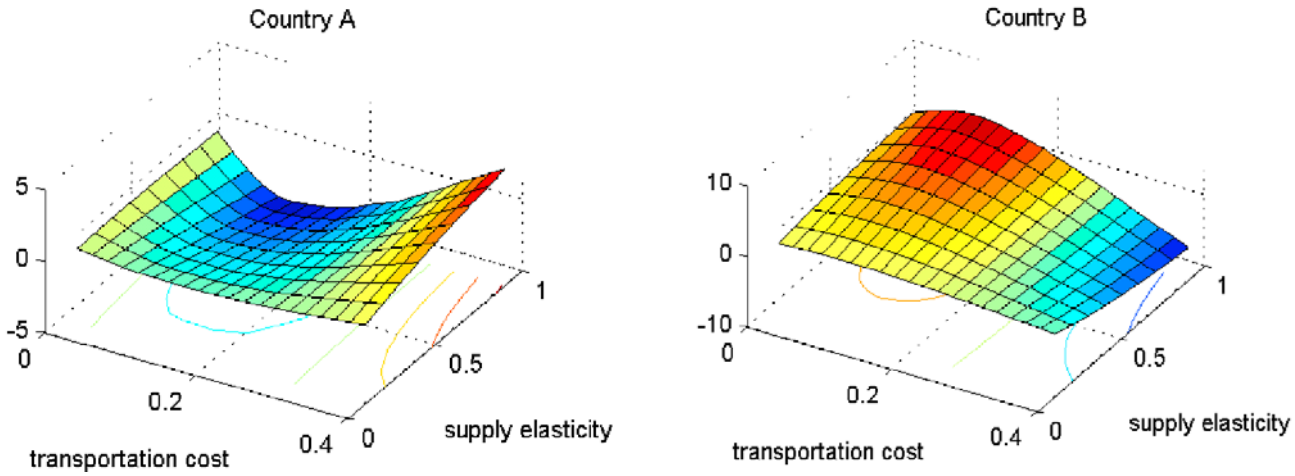
Figure 2. Percentage change in expected exports due to the introduction of a futures market.