DO FUTURES BENEFIT FARMERS WHO ADOPT THEM?

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Abstract

The present study shows how to use a simulation approach to quantify the effects of making a futures market available on adopting farmers' behavior and welfare, and its impact on market variables such as spot prices. Relevant constraints often faced by commodity producers, such as credit restrictions or lack of markets for staple crops, are explicitly considered. Aggregate market effects associated with the adoption of futures by a group of producers are also incorporated. Under the chosen parameterizations, futures availability affects various aspects of adopters' behavior. Futures availability renders consumers better off and non-adopting producers worse off. Farmers who adopt futures gain if their market share is small, but lose if their market share is large. However, the magnitudes of adopters' gains or losses are quite small, especially when compared to the welfare effects resulting from alternative changes in the market environment faced by farmers, such as the relaxation of credit restrictions or the opening of a market for food crops. The impact of making futures available on the spot market is quite modest, regardless of whether the share of adopters is small or large.

Keywords: Commodity markets, futures, storage model, welfare analysis, rational expectations.

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I. Introduction

It has long been widely perceived that vulnerability to risks is among the most important problems faced by commodity producers in developing (e.g., Roumasset, Boussard, and Singh) and developed economies (e.g., Just and Pope) alike. Historically, concerns with price risks led many countries to adopt a wide variety of schemes aimed at, among other purposes, stabilizing prices (Newbery and Stiglitz). Similarly, governments have often underwritten crop insurance policies in an effort to curb producers' yield risks (Hazell, Pomareda, and Valdez; Coble and Knight).

For a variety of reasons, most (if not all) of the large-scale government-led price stabilization schemes have proven to be unsustainable in the long run. Further, the adoption of such schemes in the future is likely to be greatly hampered by agreements to liberalize agriculture under the auspices of the World Trade Organization (World Trade Organization). These facts may explain the recent interest in promoting the use of institutional markets, such as futures markets, to manage the price risks affecting commodity producers (United Nations Conference on Trade and Development, 1994 and 1998). Such interest is well exemplified by the International Task Force on Commodity Risk Management in Developing Countries (ITF) convened by the World Bank. The ITF includes international institutions, producers' and consumers' organizations, major commodity exchanges, and commodity trading firms (ITF, Annex 5). Succinctly, the ITF recommends facilitating the use of market-based risk-management instruments by commodity producers in developing countries (ITF, Preface).

The promotion of instruments to manage commodity producers' price risks, such as futures, is based on the implicit assumption that they are conducive to improvements on the well-being of their adopters. This assumption is clearly valid from the standpoint of a single producer who adopts futures, as he would simply not use them if they made him worse off. However, the assumption need not hold when many competitive producers adopt futures simultaneously. This is true because the aggregation of individual responses may adversely affect the commodity market as a whole (e.g., spot prices may be lower as a result). Turnovsky, Kawai, and Britto were the first theoretical studies to specifically address this issue in the context of forward (as opposed to futures) markets.

Conceptually, two approaches may be used to quantify the impact of futures on adopters' welfare, taking into account the aggregate effect of adopters' decisions on the market. The first approach is to perform econometric estimation with historical data. Unfortunately, this method is unlikely to have much power due to the high volatility of many of the series involved (e.g., price and output) and the likely existence of structural changes (e.g., changes in production technology) in the past. Further, it requires data that are usually not available (e.g., long time series on individual producers' behavior before and after adoption). Not surprisingly, there are no studies pursuing this line of research.

The second approach consists of building economic models of the market(s) under analysis in terms of "deep parameters," and simulating their behavior with and without futures markets. Deep parameters are those unaffected by the policy intervention being studied. For example, in the case of futures markets weather variability is a deep parameter, but the variance of spot prices is not (because the latter will be affected by producers' optimal production responses to the availability of futures).[1] Disadvantages of the simulation approach are that its results are model-specific, and that they apply to real-world problems insofar as the latter are realistically represented by the underlying economic model. To the best of our knowledge, Turnovsky and Campbell is the only previous attempt to use the simulation approach to analyze welfare effects of introducing a forward market.

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[1]Otherwise, if some of the model's parameters depended on the policy regimes under consideration, the analysis would be subject to the famous "Lucas' critique" (Lucas).

In summary, economic theory indicates that, due to aggregate market effects, producers need not benefit from the use of market-based instruments to manage price risks if many producers adopt them simultaneously. But, with the notable exception of Turnovsky and Campbell, there are no studies quantifying the associated impact on producers' welfare.[2] Therefore, the main objective of the present study is to contribute to filling this notorious gap in the literature.

The main contributions of the present analysis are as follows. First, a model based on the rational storage paradigm (Williams and Wright, Deaton and Laroque 1992 and 1996, Chambers and Bailey) is advanced to incorporate many realistic features not considered in previous related studies. For example, the model involves futures rather than forward markets, and accounts for the fact that futures need not be made available to (or be adopted by) all producers. The model also assumes that producers make optimal intertemporal decisions, and explicitly ensures that stocks never achieve negative levels. Further, borrowing constraints and other restrictions are explicitly incorporated to represent situations often faced by producers in less developed economies. Second, the study shows how to solve the advocated model numerically, and how to use it to quantify the impact of futures availability on welfare, producers' behavior, and market variables. Finally, the study illustrates such impacts for alternative scenarios characterized by reasonable parameterizations. Briefly, such an exercise yields the following findings:

- Adopters gain when their market share is small, but lose when their market share is large.
- The welfare effect of making futures available is relatively small, compared to the impact on welfare of relaxing credit market constraints or other market restrictions.
- Making futures available has little impact on the level and variability of market variables such as prices, output, and storage.

II. A Theoretical Model for the Spot Market of a Storable Cash Crop

The present study focuses on the impact of making futures contracts available to some of the farmers who produce a storable cash crop. Hence, output by farmers for whom futures are made available (q_{ct}^{A}) is distinguished from output by other farmers (q_{ct}^{N}). For lack of a better and simple label to identify them, throughout the study the former producers are labeled "adopters" and the latter "non-adopters." It must be noted, however, that this labeling convention does not mean that non-adopting farmers are not allowed to use futures. More specifically, the scenarios explored below analyze the difference in the behavior of adopting farmers <u>before</u> and <u>after</u> futures markets are made available to them. Non-adopting farmers are allowed to either (a) use futures in both scenarios, or (b) not use futures in either of the two scenarios. That is, the crucial feature of non-adopters is that they are not allowed to switch from not using futures <u>before</u> to using futures <u>after</u>, or vice versa.

Total supply of cash crop at date t is given by total output plus initial stocks (I_{ct}):

(1) Total Supply of Cash Crop at Time $t = n^A\ q_{ct}^{A} + n^N\ q_{ct}^{N} + I_{ct}$,

where n^A (n^N) is the number of adopters (non-adopters), and q_{ct}^{A} (q_{ct}^{N}) is the average output per adopting (non-adopting) farmer. The cash crop can be used to satisfy demand for current consumption (D_{ct}), or it can be purchased by speculators to store and resale it in the future (I_{ct+1}):

(2) Total Demand for Cash Crop at Time $t = D_{ct} + I_{ct+1}$.

Market equilibrium at time t requires that total supply be equal to total demand. That is,

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[2]One recent example of a welfare analysis of futures assuming no aggregate effects of adopters' decisions is Zant.

(3) $I_{ct+1} = n^A\ q_{ct}^A + n^N\ q_{ct}^N + I_{ct} - D_{ct} \geq 0.$

where the inequality in (3) follows from the fact that stocks cannot be negative.

Solving for market equilibrium (3) requires specifying the different components of market demand and supply. Such components are described in the next subsections.

II.1. Demand for Current Consumption

Aggregate demand for current consumption (D_{ct}) is postulated to be a well-behaved random function of the current "world" price for the cash crop (P_{ct}) (e.g., $\partial D_{ct}/\partial P_{ct} < 0$). The specific functional form adopted here is

(4) $D_{ct} = \delta_{c0}\ P_{ct}^{-\delta_{c1}} + \varepsilon_{D_c t}$,

where the δ_cs are parameters and $\varepsilon_{D_c t}$ is a random shock (e.g., a disturbance to income). Ignoring $\varepsilon_{D_c t}$, (4) denotes a standard isoelastic demand function with price elasticity equal to δ_{c1}.

II.2. Demand for Speculative Stocks

Demand for speculative purposes is driven by the expectation to make profits from storage. Under perfect competition, speculators' (discounted) expected profits from buying one unit of the cash crop at time t, storing it, and selling it at $t + 1$ must satisfy condition (5) in equilibrium:

(5) $E_t(P_{ct+1})/(1 + r) - P_{ct} - \phi \leq 0,$

where $E_t(\cdot)$ is the expectation operator conditional on information available at time t, r denotes the interest rate, and ϕ represents the cost of storing one unit of cash crop for one period. If (5) does not hold, speculators will buy more units of the cash crop at time t with the purpose of selling them at time $t + 1$, which is inconsistent with equilibrium.

When storage is expected to be unprofitable (i.e., $[E_t(P_{ct+1})/(1 + r) - P_{ct} - \phi] < 0$), speculators will reduce their commodity holdings, thereby exerting downward pressure on current prices P_{ct} and causing an upward revision in next-period's price expectations $E_t(P_{ct+1})$. However, such a process need not drive the left-hand side of (5) all the way up to zero because storage cannot be reduced below zero. It follows that equilibrium also implies that (6) must hold for speculative storage demand:

(6) $[E_t(P_{ct+1})/(1 + r) - P_{ct} - \phi] \times I_{ct+1} = 0,\ I_{ct+1} \geq 0.$

Together, (5) and (6) define the demand for speculative storage (e.g., Deaton and Laroque 1992).[3]

[3]Implicit in (5) and (6) is the assumption that speculators are risk-neutral. The reasons for adopting this assumption are twofold. First, it simplifies the computations needed to solve the problem. Second and more important, it allows us to better isolate the effects of making futures available to adopting farmers. This is true because risk-neutral speculators are indifferent to hedging, so their hedging activity remains unchanged when futures become available to adopting farmers. Hence, all market effects are due exclusively to the latter's adoption of futures.

II.3. Supply by Non-Adopting Farmers
Average cash-crop output per non-adopting farmer is assumed to be a well-behaved random function of the previous period's expected world price $E_{t-1}(P_{ct})$ (e.g., $\partial q_{ct}^N / \partial E_{t-1}(P_{ct}) > 0$). For simulation purposes, a functional form analogous to (4) is used here:

$$(7) \qquad q_{ct}^N = \sigma_{c0} \, [E_{t-1}(P_{ct})]^{\sigma_{c1}} + \varepsilon_{q_c^N t} ,$$

where the σ_cs are supply parameters and $\varepsilon_{q_c^N t}$ is a zero-mean random shock (e.g., a weather shock).[4] That is, the first term on the right-hand side of (7) is expected output per non-adopting farmer. It is also assumed that the latter quantity has some upper bound $\bar{q}_c^N$:

$$(8) \qquad \sigma_{c0} \, [E_{t-1}(P_{ct})]^{\sigma_{c1}} \leq \bar{q}_c^N .$$

Restriction (8) is imposed to account for potential acreage and/or capital constraints limiting non-adopters' expected output response to market signals.

II.4. Supply by Adopting Farmers
Adopting farmers are the main object of our study, so their supply is derived from their underlying preferences and production technologies. Unfortunately, modeling an entire heterogeneous population of adopting farmers is intractable from a computational standpoint. Hence, the analysis relies upon the characterization of a "representative" adopting farmer. To capture a distinguishing feature of crop production in less developed economies, the representative farmer is allowed to plant not only the cash crop, but also a food crop. The cash crop is planted solely to generate income from its sale in the market, whereas the food crop may be used for the farmer's own consumption (e.g., Sadoulet and de Janvry, Fafchamps).

At each period t, the farmer derives utility from consuming food (x_{ft}) and a marketable good (e.g., clothing) (x_{mt}), such that his felicity function is represented by $U(x_t)$, where $x_t \equiv [x_{mt}, x_{ft}]$. For simulation purposes, the widely used (multiplicative) power felicity function is adopted here:

$$(9) \qquad U(x_t) = \kappa \times u(x_{mt}; \gamma_m) \times u(x_{ft}; \gamma_f),$$

where $u(x_{it}; \gamma_i \neq 1) \equiv x_{it}^{1-\gamma_i} / (1 - \gamma_i)$ and $u(x_{it}; \gamma_i = 1) \equiv ln(x_{it})$, for $i = m$ and f. Parameter $\gamma_i \geq 0$ may be interpreted as the coefficient of relative risk aversion to consumption of good i. Relative risk aversion increases with γ_i, with the polar case of risk-neutrality being represented by $\gamma_i = 0$. Parameter κ ensures that marginal utility is positive, and equals –1 if $\gamma_i > 1$ and $\kappa = 1$ if $\gamma_i \leq 1$.[5]

At each period t, the farmer may also plant a certain number of acres with food and cash crops (a_{ft} and a_{ct}, respectively). By doing so, the farmer can harvest such crops one period later. But because of random weather conditions, pests, diseases, etc., the size of the date-(t + 1) crops are random from the perspective of the corresponding planting time t. Holding growing conditions constant, a crop's output increases

[4]Non-adopting farmers are assumed to behave as if they were risk-neutral for the same reasons storage speculators are assumed to be risk neutral (see preceding footnote). In addition, this assumption allows us to abstract from the effects on non-adopters' output of potential changes in the distribution of prices (other than changes in the first moment) induced by the use of futures by adopters.
[5]Note that $\partial U(x_t)/\partial x_{it} > 0$ requires that either $\gamma_m > 1$ and $\gamma_f > 1$, or that $\gamma_m \leq 1$ and $\gamma_f \leq 1$.

with the number of acres planted with it, albeit at a decreasing rate.[6] Given the aforementioned technology specifications, the following (power) production function is used for the numerical simulations:

$$(10) \qquad q_{it}^{A} = a_{it-1}^{\alpha_i} \; \varepsilon_{q_i^A t} ,$$

for $i = f$ and c. In (10), α_i is the elasticity of crop-i output with respect to the number of acres planted with such crop, and $\varepsilon_{q_i^A t}$ is the corresponding output (e.g., weather) shock. It must be noted, however, that in each period the farmer's plantings are constrained by his total acreage $\bar{a}$:

$$(11) \qquad a_{ft} + a_{ct} \leq \bar{a} .$$

That is, the number of acres devoted to crops cannot exceed the farmer's land availability.

Scenario with No Futures Markets Available

Assuming well-functioning markets for the food crop, at time t the adopting farmer may purchase ($x_{ft} > q_{ft}^{A}$) or sell ($x_{ft} < q_{ft}^{A}$) the food crop at price p_{ft}. Since the behavior of the food-crop price p_{ft} is not of central interest for the present study, to alleviate the computational burden p_{ft} is simply assumed to be an exogenously determined random variable,[7] negatively correlated with the food-crop output shocks. The adopting farmer may also borrow ($b_t > 0$) or lend ($b_t < 0$) money at the per-period interest rate r. However, since unlimited borrowings ($b_t \to \infty$) are unrealistic, it is postulated that his borrowings cannot exceed some amount $\bar{b}$:

$$(12) \qquad b_t \leq \bar{b} .$$

Therefore, if <u>no futures markets are available</u> to the adopting farmer, his budget constraint at period t is represented by (13):

$$(13) \qquad x_{mt} + p_{ft}\, x_{ft} + (1 + r)\, b_{t-1} \leq p_{ft}\; q_{ft}^{A} + p_{ct}\; q_{ct}^{A} + b_t + y_t,$$

where p_{ct} denotes the "local" cash-crop price received by the farmer, and y_t represents possibly random off-farm income ($y_t > 0$) or expenses ($y_t < 0$). Note that in (13) the price of the marketable good is set equal to one, i.e., all monetary values are normalized so that they are expressed in units of the marketable good.

The local cash-crop price p_{ct} in (13) is related to, but different from, the world cash-crop price P_{ct} referred to in (4) through (8). The difference between the two prices is usually known as the cash-crop "basis," $\pi_{ct} \equiv p_{ct} - P_{ct}$. The basis would be zero if the cash crop could be instantaneously transported from (to) the local market to (from) the world market at no cost. In the real world, however, the basis is typically nonzero and fluctuates from period to period. Hence, the basis (π_{ct}) is taken to be an exogenous

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[6]One would expect the total production of a crop to increase with the number of acres planted with it at a decreasing rate because, for example, the land best suited for that crop will be devoted to it first (i.e., each additional acre planted will be less suited to the crop). Also, planting more acres means that the planting operation may have to be extended beyond the optimal planting period (i.e., the period leading to the highest average yields).
[7]Otherwise, one would have to model the whole food-crop market in terms of "deep" parameters and exogenous shocks, and solve for the endogenously-determined equilibrium random price to obtain p_{ft}.

random variable, so that at time t the local cash-crop price is determined by the world cash-crop price and the actual realization of the basis:

(14) $p_{ct} = P_{ct} + \pi_{ct}$.

The representative farmer's optimization problem at time t consists of selecting the levels of consumption (x_t), the land allocations ($a_t \equiv [a_{ct}, a_{ft}]$), and the amount of borrowings (b_t) that maximize his lifetime expected utility, subject to his budget, borrowing, production, and resource constraints ((13), (12), (10), and (11), respectively). Mathematically, the optimization problem can be stated as:

(15) $V(a_{t-1}, b_{t-1}, \omega_t) = \max_{x_t, a_t, b_t} \{U(x_t) + \beta E_t[V(a_t, b_t, \omega_{t+1})]\}$,

subject to (10) through (13), with $U(x_t)$ given by (9). In (15), β ($0 < \beta < 1$) is the farmer's discount factor per period, and ω_{t+1} is a vector of exogenous variables that cannot be controlled by him and become known at time $t + 1$, but are random from the standpoint of time t. More specifically, vector ω_{t+1} consists of demand and output shocks, the cash-crop basis, and food-crop prices (i.e., $\varepsilon_{D_c t+1}$, $\varepsilon_{q_c^N t+1}$, $\varepsilon_{q_c^A t+1}$, $\varepsilon_{q_f^A t+1}$, π_{ct+1}, and p_{ft+1}, respectively). Although the model contains many more random variables (e.g., P_{ct+1}, p_{ct+1}, q_{ct+1}^N, q_{ct+1}^A, q_{ft+1}^A, etc.), they are not included in vector ω_{t+1} because they are endogenous. That is, endogenous random variables are determined by the model's deep parameters and by the vector of exogenous random variables ω_{t+1}.

Under standard regularity conditions on the felicity and production functions, and on the probability density functions (pdfs) of the underlying shocks, optimization problem (15) is well defined. Solution of (15) yields optimal decision variables as functions of state variables and parameters underlying preferences and pdfs for each particular date. The date-t outputs of cash and food crops are determined by the optimal acreage planted with such crops at time $t - 1$, along with the realization of the respective date-t production shocks (see (10)). In other words, cash-crop supply by adopters in (1) subsumes intertemporally optimal behavior by such farmers.

Scenario with Futures Markets Availability

The benchmark scenario just discussed implicitly assumes that cash-crop futures markets are not available for the adopting farmer, because his optimization problem (15) does not allow for futures trading.[8] To analyze the impact of making futures available to him, a futures availability scenario is defined as one in which the adopting farmer can costlessly trade futures contracts. That is, at time t the adopting farmer may hedge his $t + 1$ cash crop by selling h_t units at the known futures price P_{ht}. By doing so, at time $t + 1$ he receives the amount $[(P_{ht} - P_{ct+1})\, h_t]$.[9] Note that the relevant price in the futures market is the world cash-crop price P_{ct+1}, as opposed to the local cash-crop price p_{ct+1}. The smaller the farmer's uncertainty about the basis (14) (i.e., the smaller the basis risk), the greater is the potential to reduce his price risk through hedging. To prevent the unrealistic possibility of unlimited long or short futures positions, hedging is bounded both above and below:

(16) $\underline{h} \le h_t \le \overline{h}$,

[8]Alternatively, the benchmark scenario is also consistent with futures availability, but with futures trading costs high enough to make it optimal for adopting farmers not to participate in the futures market.

[9]Note that if $P_{ht} < P_{ct+1}$, the farmer must pay the amount $(|P_{ht} - P_{ct+1}|\, h_t)$.

where $\underline{h}$ and $\bar{h}$ are respectively the minimum and the maximum futures positions that adopters are allowed to take.

When cash-crop futures are available to adopters, solving the model requires specifying the formation of futures prices. To this end, futures prices are assumed to be equal to the current expectations of next period's prices:

(17) $P_{ht} = E_t(P_{ct+1})$.

Condition (17) rules out the possibility of adopters trading futures for speculative purposes. That is, (17) implies that the only incentive for adopters to trade futures contracts is to hedge their exposure to cash-crop price risk. This is a desirable restriction, given the present study's aim of analyzing the risk-reduction benefits (as opposed to the speculative gains) of futures for adopters. Otherwise, adopting farmers could be made arbitrarily better off by allowing them to trade in futures to exploit (expected) speculative profitable opportunities.

The time-*t* budget constraint corresponding to the scenario allowing for trading in cash-crop futures contracts is (18) instead of (13):

(18) $x_{mt} + p_{ft}\, x_{ft} + (1 + r)\, b_{t-1} \le p_{ft}\, q^{A}_{ft} + p_{ct}\, q^{A}_{ct} + (P_{ht-1} - P_{ct})\, h_{t-1} + b_t + y_t,$

and the corresponding objective function is given by (19):

(19) $V(a_{t-1}, b_{t-1}, h_{t-1}, \omega_t) = \max_{x_t, a_t, b_t, h_t} \{U(x_t) + \beta\, E_t[V(a_t, b_t, h_t, \omega_{t+1})]\},$

subject to (10), (11), (12), (16), and (18), with $U(x_t)$ given by (9).

Scenarios with Credit Restrictions and Food-Crop Market Failure

As pointed out by many studies (e.g., Sadoulet and de Janvry, ch. 6, and references therein), it is often the case that farmers face failures in some markets. Major market failures discussed in the literature and relevant to the present setting are those corresponding to the markets for credit and for the food crop. As explained in connection with (12), all scenarios analyzed here imply credit market failure in the sense that adopters' borrowings cannot exceed a limit $\bar{b}$. However, to investigate the effect of differential credit market conditions, simulations are performed for both relatively high and relatively low credit limits $\bar{b}$.

The impact of food-crop market failure is assessed by looking at the extreme situation of nonexistence of such a market. Since this implies that the farmer may neither buy nor sell the food crop, his food-crop consumption is limited to his own produce. Further, given that the farmer's felicity function (9) exhibits non-satiation and that whatever amount of food crop not consumed cannot be sold (as no food-crop market exists), it follows that (20) must hold:

(20) $x_{ft} = q^{A}_{ft}$.

Thus, for simulation purposes, scenarios characterized by food-crop market failure are modeled by adding constraint (20) into the relevant optimization problem (i.e., either (15) or (19)).

II.5. Expectations and Cash-Crop Market Equilibrium

It has already been pointed out that cash-crop market equilibrium at time t requires (3) to hold. Given the planting decisions made by adopting and non-adopting farmers at $t - 1$, the respective actual output shocks at t, and the storage decision made by speculators at $t - 1$ (I_{ct}), total supply at t is determined by (1). That is, total supply at t is (pre) determined by agent's decisions made at $t - 1$ and by date-t output shocks. Given date-t current consumption shock $\varepsilon_{D_c t}$ and expectations about next-period's cash-crop price $E_t(P_{ct+1})$, the current cash-crop price P_{ct} adjusts so that demand for current consumption and speculative storage satisfy equilibrium condition (3).

Clearly, the equilibrium values of prices, current consumption, and ending stocks (P^*_{ct}, D^*_{ct}, and I^*_{ct+1}, respectively) are affected by the current expectations about next-period's cash-crop price $E_t(P_{ct+1})$. This is true because speculative storage demand (5) and (6) is a function of $E_t(P_{ct+1})$. Further, next period's equilibrium values (i.e., P^*_{ct+1}, D^*_{ct+1}, and I^*_{ct+2}) are also functions of $E_t(P_{ct+1})$, because next-period's output from both adopters and non-adopters depends on current plantings of the cash-crop, which are determined by $E_t(P_{ct+1})$ as well (e.g., see (7)). Hence, the market equilibrium cannot be solved for unless one specifies how decision makers (farmers and speculative storers) form their expectations.

Here, decision makers are assumed to be *rational*, in the sense that their *subjective* expectations of the random variables are equal to the *objective* expectations of such variables implied by the model (see discussion in the "Numerical Methods" section below). As in Newbery and Stiglitz (ch. 10), the reasons for postulating rational expectations are threefold. First, from a practical standpoint, hypothesizing non-rational expectations poses a significant challenge. This is true because there is an infinite number of ways in which expectations can be rendered non-rational, and one would be forced to arbitrarily choose one among them. Second, from an analytical perspective, assuming rational expectations allows one to focus on the benefits of futures for adopting farmers arising from risk reduction, rather than from informational gains.[10] Finally, rational expectations together with (17) dispense with the possibility of obtaining arbitrarily large (expected) speculative gains by exploiting informational inefficiencies in the futures market.

III. Numerical Methods

To analyze the behavior of prices, production, storage, etc., one must first solve for the market equilibrium conditions under each possible state of the world. This is a difficult task, because the model has no closed-form solution and is highly nonlinear. There are several methods to solve the present kind of model (Judd, ch. 12 and 17). Here, we adopt Williams and Wright's approach.

The intuition behind Williams and Wright's approach is best seen by simplifying the model to its bare essentials. Hence, assume for the moment that there are zero non-adopters ($n^N = 0$), there is a single adopting farmer ($n^A = 1$) with zero output elasticity ($\alpha_c = 0$), there are no consumption shocks ($\varepsilon_{D_c t} = 0$ $\forall\, t$), and current-consumption demand parameter δ_{c0} equals 1. Then from (3), (4), and (10), the equilibrium price at time t can be expressed as

$$(21) \qquad P_{ct} = D_{ct}^{-1/\delta_{c1}} = (\varepsilon_{q_c^A t} + I_{ct} - I_{ct+1})^{-1/\delta_{c1}} .$$

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[10]As explained before, the scenarios where futures are unavailable for adopters need not imply that futures do not exist. If futures do exist, making them available to adopters need not convey any informational gains, because adopters may use the information conveyed by futures markets even if they do not trade in futures. Under the adopted assumptions, the entire impact of futures' availability stems from their risk-reduction properties.

Rational expectations means that the current expectations about next period's price are consistent with the model. Hence, using (21) and the fact that in this highly simplified setting the only exogenous source of uncertainty is the adopter's output shock:

$$(22) \qquad E_t(P_{ct+1}) = \sum_s Prob(\varepsilon_{q_c^A t+1} = \varepsilon_s) \times \{\varepsilon_s + I_{ct+1} - I_{ct+2}[\varepsilon_s, I_{ct+1}, \psi(\cdot)]\}^{-1/\delta_{c1}},$$

where $Prob(\varepsilon_{q_c^A t+1} = \varepsilon_s)$ is the "true" probability that next-period's output shock equals ε_s, and $I_{ct+2}[\varepsilon_s, I_{ct+1}, \psi(\cdot)]$ is the equilibrium ending stock at $t + 1$ given adopter's output shock realization ε_s, beginning stock I_{ct+1}, and rational price expectations $\psi(\cdot)$ (to be discussed below).

Two things must be noted about (22). First, $E_t(P_{t+1})$ can only depend on information available at time t. That is, the conditional price expectation can be expressed as (23):[11]

$$(23) \qquad E_t(P_{t+1}) = \psi(I_{ct+1}),$$

where the specific form of function $\psi(\cdot)$ depends on the probability density function (pdf) of the output shocks. Second, the equilibrium $t + 1$ ending stock $I_{ct+2}[\varepsilon_s, I_{ct+1}, \psi(\cdot)]$ is obtained by substituting (21) and (23) into (5) and (6), and rolling forward one period.

Succinctly, the problem of solving for this model's equilibrium at any time t is that the rational conditional expectation function $\psi(\cdot)$ is unknown. However, substituting (23) into the left-hand side of (22) reveals that $\psi(\cdot)$ appears on both sides of the equation. In practice, solving for the unknown $\psi(\cdot)$ consists of estimating a function $\hat{\psi}(\cdot)$ that satisfies the functional equation:

$$(24) \qquad \hat{\psi}(I_{ct+1}) = \sum_s Prob(\varepsilon_{q_c^N t+1} = \varepsilon_s) \times \{\varepsilon_s + I_{ct+1} - I_{ct+2}[\varepsilon_s, I_{ct+1}, \hat{\psi}(\cdot)]\}^{-1/\delta_1}.$$

The function approximation $\hat{\psi}(\cdot)$ used here consists of a Chebychev polynomial interpolated at Chebychev nodes. In addition, the pdfs of the exogenous random shocks (e.g., $Prob(\cdot)$) are approximated by Gaussian quadrature, which allows exact calculation of the desired number of moments of the random variables with maximum efficiency. The Chebychev interpolation and Gaussian quadrature schemes are calculated by means of the programming language MATLAB version 5.2, using the computer routines developed by Miranda and Fackler.[12]

Once function $\hat{\psi}(\cdot)$ is estimated, the properties of the model can be explored by generating sequences of the endogenous random variables of interest (e.g., prices, output, stocks) via Monte Carlo simulations. For example, given a value of time-t beginning stock I_{ct} and a randomly-generated output shock $\varepsilon_{q_c^A t}$, the

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[11]Note that I_{ct+1} is period-t's ending stock, so its magnitude is known at t.

[12]Details about Chebychev interpolation and Gaussian quadrature are provided in Judd. In the interest of brevity, the full description of the computer algorithm is omitted, but its essence is sketched in Chapter 3 of Williams and Wright. Because of the large dimensions of the present problem, the Chebychev interpolation was based on ten nodes for each state variable and the Gaussian quadrature relied on four nodes for each exogenous random variable. The number of nodes is chosen to obtain an acceptable level of accuracy, while maintaining computational feasibility. To give an idea of the large magnitude of the problem at hand, the key step in the solution for most of the scenarios requires solving over one million nonlinear equations in as many unknowns.

model's equations (along with the function $\hat{\psi}(\cdot)$) can be solved simultaneously for the market equilibrium price P_{ct}, consumption D_{ct}, ending stock I_{ct+1}, and conditional price expectations $E_t(P_{ct+1})$. Taking the solved-for I_{ct+1} as the $t + 1$ beginning stock and generating a random observation on the output shock $\varepsilon_{q_c^A t+1}$, one can proceed similarly to solve for the market equilibrium P_{ct+1}, D_{ct+1}, I_{ct+2}, and $E_{t+1}(P_{ct+2})$. This process may be repeated in the same manner for $t + 2$, $t + 3$, ..., to obtain simulated series of the model's endogenous random variables. If the simulated series are sufficiently long (and some initial observations are dropped to render ineffectual the initial choice of I_{ct}), one can use them to estimate the respective *unconditional* pdfs.[13] Alternatively, one can use the same initial stock level I_{ct} with many randomly-generated observations on output shock $\varepsilon_{q_c^A t}$, and solve for the corresponding equilibrium values of P_{ct}, D_{ct}, I_{ct+1}, and $E_t(P_{ct+1})$. The simulated sample thus obtained, if sufficiently large, provides an estimate of the respective *conditional* (on I_{ct}) pdfs.

As mentioned in connection with (21), (24) is based on extreme simplifications to facilitate explaining how the model works. The actual models used in the present study involve much more complex calculations than are implied by (24) for at least three reasons. First, the actual model entails six exogenous random variables ($\varepsilon_{D_c t}$, $\varepsilon_{q_c^N t}$, $\varepsilon_{q_f^A t}$, $\varepsilon_{q_c^A t}$, π_{ct}, and p_{ft}), instead of only one in (24).[14] Second, solving the full model requires approximating not only the conditional expectation of world cash-crop prices $\hat{\psi}(\cdot)$, but also the adopters' marginal utility of the market good $\partial U(x_t)/\partial x_{mt}$ as a function of the state variables.[15] Finally, the actual model has three state variables, instead of only one in (24).[16]

IV. Model Initialization

The postulated model is highly stylized. Its purpose is to analyze the impact of the adoption of futures by producers of a "generic" agricultural commodity, but it is clearly not meant to represent the market of any agricultural commodity in particular. Hence, the parameterization chosen for the reported simulations does not accurately depict any specific market. Instead, it is intended to capture stylized facts common to commodity markets in general.

Another important issue related to parameterization is the accuracy of the numerical solution. In the present kind of problem, accuracy is greatly enhanced by normalizing the system so as to avoid variables of considerably different orders of magnitude (Judd, ch. 2). Given that the simulations do not refer to a specific real-world commodity, the system is normalized around the unit value by choosing appropriate magnitudes for the model's scaling parameters (e.g., n^A, n^N, δ_{c0}, σ_{c0}, $\bar{a}$, and the means of the exogenous

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[13]In the present study, unconditional pdfs are based on the Monte Carlo simulation of 1,000 series of 1,150 observations each. To avoid dependence on initial conditions, the first 1,000 observations from each series are discarded, so unconditional pdfs are estimated from a total of 150,000 simulated observations. To improve efficiency, antithetic acceleration is used (Geweke). In addition, all scenarios are based on the same simulated series of exogenous random variables (i.e., "common random numbers" are used), to enhance accuracy in the comparison across alternative scenarios.

[14]It must be noted, however, that the food-crop price (p_{ft}) is rendered irrelevant in the food-crop market failure scenario because of constraint (20), so this scenario effectively consists of five exogenous random variables.

[15]The approximation to $\partial U(x_t)/\partial x_{mt}$ is used in the recursive solution to the adopter's optimization problem (15) or (19).

[16]That is, the approximations of the conditional price expectations and the marginal utility are functions of three variables. Namely, the ending stocks of the cash crop (I_{ct+1}), adopters' borrowings (b_t), and adopters' "initial wealth." Roughly speaking, adopters' initial wealth consists of crop revenues minus initial liabilities (note, however, that food-crop revenues are not considered in the food-crop market failure scenario, because in this instance they are not well defined).

random variables). This is achieved as follows. First, the numbers of adopting and non-adopting farmers are normalized so that $n^A + n^N = 1$. Second, scaling parameters δ_{c0}, σ_{c0}, $\bar{a}$, and the means of the exogenous random variables are chosen so that equilibrium values of cash-crop adopter's output, non-adopter's output, current consumption, and prices equal one when all exogenous random variables are fixed at their mean values for all dates t. That is, if all exogenous random variables were fixed at their mean values at all dates, equilibrium in the normalized model would be characterized by $q_{ct}^A = q_{ct}^N = D_{ct} = P_{ct} = p_{ct} = 1$ for all t. Under such non-stochastic equilibrium, total cash-crop output would also equal one ($n^A q_{ct}^A + n^N q_{ct}^N = 1$ for all t), and storage would be zero (i.e., $I_{ct+1} = 0$ for all t).

Besides being important to improve the numerical accuracy of the solutions, the advocated normalization has the advantage of facilitating interpretation of results. For example, all of the results in Tables 1 through 6 correspond to stochastic scenarios. Hence, comparing them with the non-stochastic benchmark allows one to easily infer the impact of introducing randomness into the system.

The values of the behavioral and technological (as opposed to scaling) parameters, such as the coefficients of relative risk aversion (γ_m and γ_f) and the own-price elasticity of demand (δ_{c1}), are chosen to be consistent with the literature (e.g., Newbery and Stiglitz, Williams and Wright, Kocherlakota, Cochrane). The same criterion is used for selecting the standard deviations of the exogenous random variables. In addition, adopted parameterizations are such that various results are consistent with the literature or with historical data.[17] Results for other parameterizations are available from the authors upon request.

Finally, the vector of date-t exogenous random variables (i.e., $[\varepsilon_{D_c t}, \varepsilon_{q_c^N t}, \varepsilon_{q_f^A t}, \varepsilon_{q_c^A t}, \pi_{ct}, p_{ft}]$) is assumed to be identically and independently six-variate normally distributed. The normality assumption is adopted because (a) it may be considered a reasonable approximation to the distribution of most of the variables of interest (e.g., Just and Weninger), (b) it requires specifying a relatively small number of parameters (i.e., means, variances, and correlations), and (c) it greatly simplifies the task of imposing desired correlations among random variables. The specific means, standard deviations, and (nonzero) correlations used in the simulations are reported below. Because of the normalization to unity, in most instances standard deviations are either equal to or well approximated by the respective coefficients of variation.[18] Correlations are assumed zero, except for the pairs ($\varepsilon_{q_f^A t}, \varepsilon_{q_c^A t}$), ($\varepsilon_{q_f^A t}, \varepsilon_{q_c^N t}$), ($\varepsilon_{q_c^A t}, \varepsilon_{q_c^N t}$), and ($\varepsilon_{q_f^A t}, p_{ft}$).

Total Supply of Cash Crop (1): As mentioned above, the numbers of adopters and non-adopters are normalized so that $n^A + n^N = 1$. In this manner, n^A and n^N can be interpreted as market shares. The scenario with relatively low number of adopters is represented by $n^A = 0.2$ and $n^N = 0.8$, whereas the case of a high number of adopters is characterized by $n^A = 0.8$ and $n^N = 0.2$.

Demand for Current Consumption of Cash Crop (4): The own-price demand elasticity for the cash crop is set at $\delta_{c1} = 0.5$. The adopted normalization to unity implies that $\delta_{c0} = 1$. Demand shocks ($\varepsilon_{D_c t}$) have a mean of zero and a standard deviation of 0.08.

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[17]For example, the coefficients of variation of cash-crop prices resulting from the model are well within the range of historical values (see Table 20.4 in p. 291 of Newbery and Stiglitz).

[18]For example, the standard deviations of 0.15 for output shocks reported below can be interpreted as coefficients of variation of crop yields equal to 15%.

Demand for Speculative Storage (5) and (6): Annual per-unit storage costs are hypothesized to be 2% of the non-stochastic equilibrium price (i.e., $\phi = 0.02$) (e.g., Newbery and Stiglitz, p. 295), and the annual interest rate is set at r = 5%.

Supply by Non-Adopting Farmers (7) and (8): Own-price elasticity of supply is set equal to $\sigma_{c1} = 0.1$. As it is the case for current-consumption demand, the adopted normalization to unity implies that $\sigma_{c0} = 1$. The upper bound on expected output is fixed at $\overline{q}_c^N = 1.05$. Non-adopters' output shocks ($\varepsilon_{q_c^N t}$) have zero mean and a standard deviation equal to 0.15. They are positively correlated with adopters' output shocks ($\varepsilon_{q_f^A t}$ and $\varepsilon_{q_c^A t}$), with correlations of 0.5 and 0.1 for the pairs ($\varepsilon_{q_c^N t}$, $\varepsilon_{q_c^A t}$) and ($\varepsilon_{q_c^N t}$, $\varepsilon_{q_f^A t}$), respectively.

Adopting Farmer's Specification (9) through (20): Preferences are characterized by a discount factor of $\beta = 0.95$ and coefficients of relative risk aversion equal to four for both the market good and food ($\gamma_m = \gamma_f = 4$). Production technology and constraints are parameterized by elasticities of output with respect to acreage equal to 0.7 for both crops ($\alpha_f = \alpha_c = 0.7$), and a maximum acreage of $\overline{a} = 2$. The values of the coefficient of relative risk aversion are close to the upper end of the range considered "normal" for such parameter (e.g., Kocherlakota, Cochrane), and the opposite is true for the elasticities of output with respect to acreage. This implies that, if anything, the reported results are biased toward finding a large (rather than a small) welfare effect from introducing futures.

It is assumed that the adopters do not have off-farm income or expenses ($y_t = 0\ \forall\ t$).[19] Annual interest rate is r = 5%, and credit constraints are fixed at $\overline{b} = 1$ and $\overline{b} = 0$ for the high- and low-credit-availability scenarios, respectively. Since total crop revenues equal two for the non-stochastic benchmark scenario,[20] a credit constraint of $\overline{b} = 1$ means that adopters can borrow roughly up to half of their annual average revenues. Obviously, $\overline{b} = 0$ means that adopters cannot borrow at all. Consistent with using futures to reduce adopter's risk (as opposed to speculating), when cash-crop futures are available the lower limit on his futures position is set at $\underline{h} = 0$, and the upper limit is set equal to the (conditional) expectation of his next-period's cash-crop output (i.e., $0 \le h_t \le E_t(q_{ct+1}^A)$).

Adopters' output shocks ($\varepsilon_{q_f^A t}$ and $\varepsilon_{q_c^A t}$) have means of one and standard deviations of 0.15 for both the food crop and the cash crop, and a correlation between them of 0.8. As reported above, adopters' output shocks $\varepsilon_{q_f^A t}$ and $\varepsilon_{q_c^A t}$ are also positively correlated with non-adopters' output shocks $\varepsilon_{q_c^N t}$, with correlations of 0.1 and 0.5, respectively. The cash-crop basis (π_{ct}) has mean zero and standard deviation equal to 0.05. Finally, the local food-crop price (p_{ft}) has mean equal to one, standard deviation equal to 0.15, and a correlation of –0.3 with the food-crop output shock.

V. Results

The simulations provide insights on the impact of futures adoption at two different levels, namely, the effect on the "world" market for the cash crop, and the influence on adopters' behavior. Both levels of

[19]Assuming that $y_t = 0\ \forall\ t$ is more likely to yield large rather than small welfare effects from making futures available. This is true because random y_t would usually "diversify" adopters' portfolio.
[20]Recall that adopters' quantities and local prices equal unity for each crop under the non-stochastic benchmark scenario.

analysis are relevant, but they are conceptually different. Hence, they are addressed separately in the next subsections.

V.1. Effects on the Cash-Crop Market

Steady-state results regarding the "world market" for the cash crop are summarized in Tables 1 through 3. Table 1 contains data for the scenario with food-crop markets and relatively unconstrained credit markets. Table 2 deals with the scenario with food-crop markets but constrained credit markets. Finally, Table 3 addresses the scenario where there are no food-crop markets and credit markets are relatively unconstrained. In each table, the no-futures scenario with a small (large) share of adopters is displayed in the first (third) column. This column reports the means, coefficients of variation, medians, and the 5% and 95% quantiles of the endogenous random variables. The second (fourth) column shows results for the futures-availability scenario assuming a small (large) share of adopters. This column depicts percentage changes with respect to the corresponding amounts under no futures. For example, the first column in Table 1 indicates that with no futures availability and n^A = 20%, the world cash-crop price has a mean of 1.02, a coefficient of variation of 0.24, and a median of 0.96. According to the corresponding figures in the second column, futures availability causes the cash-crop price mean, coefficient of variation, and median to decline by 0.4% (to 1.016), 0.6% (to 0.239), and 0.3% (to 0.957), respectively.

Recall that calibration is performed so that in the non-stochastic benchmark scenario total output, total supply, total consumption, and price all equal unity, and storage is zero. Hence, the first and third columns in Tables 1 through 3 show that the introduction of randomness into the hypothetical economy leaves mean output and consumption virtually unchanged, while increasing total supply by about 11%. The latter occurs because mean storage increases from zero to about 11% of mean total output. In addition, random shocks lead to increases of 2% to 5% in mean world prices, while inducing drops of 2% to 4% in median world prices (note that median world prices equal one in the benchmark non-stochastic scenario). The noticeable divergence in means versus medians, and the location of the 5% and 95% quantiles, point to highly skewed price pdfs.

The figures in the first and third columns of Table 1 are much more similar to the corresponding values in Table 2 than to those in Table 3. In other words, the impact of introducing randomness depends much more on whether there is a market for the food-crop than on whether the market for credit is constrained. As evidenced by the first and third columns of Tables 1 and 3, the lack of food-crop markets is associated with higher means and volatility of world cash-crop prices. Despite higher mean cash-crop prices, however, if n^A = 20% mean total cash-crop production when there is no food-crop market is the same as when such a market exists. This apparent paradox is explained by the composition of output. More specifically, adopters' mean cash-crop output is 2% lower when there is no food-crop market.[21] Therefore, the mean production of non-adopters rises (induced by higher mean prices) enough to leave mean total output almost unchanged. When n^A = 80%, mean world cash-crop output is 1% lower in the absence of food-crop markets. This occurs because non-adopters' share is too small for their higher output to offset the smaller production by adopters.

Turning to the market changes induced by the availability of futures, it is readily apparent from the second and fourth columns of Table 1 that such changes are quite modest when there is a food-crop market and the credit market is relatively unconstrained. In the scenario with a small share of adopters (n^A = 20%), the means of the endogenous random variables change by less than half of a percent. The means of total output, total supply, current consumption, and storage all increase by 0.2%. In contrast, the mean of world price decreases by 0.4%. Coefficients of variation are also little changed, the most

[21] Adopters' cash-crop production with (without) food-crop markets is reported in the third row of Table 4 (6).

Table 1. Steady-state results for cash-crop market, assuming that there is a food-crop market and credit constraints are low ($\bar{b} = 1$).[a]

	Small Share of Adopting Farmers ($n^A = 0.20$)		Large Share of Adopting Farmers ($n^A = 0.80$)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Total Output ($n^A q_{ct}^A + n^N q_{ct}^N$)	1.00 (0.14)	**0.2 (0.1)**	1.00 (0.14)	**0.1 (0.2)**
	[0.77, 1.00, 1.23]	**[0.2, 0.2, 0.2]**	[0.77, 1.00, 1.24]	**[0.0, 0.1, 0.1]**
Total Supply ($n^A q_{ct}^A + n^N q_{ct}^N + I_{ct}$)	1.11 (0.15)	**0.2 (–0.4)**	1.11 (0.14)	**0.1 (–0.2)**
	[0.85, 1.11, 1.38]	**[0.2, 0.2, 0.1]**	[0.86, 1.11, 1.36]	**[0.2, 0.1, 0.0]**
Current Consumption (D_{ct})	1.00 (0.09)	**0.2 (–0.4)**	1.00 (0.08)	**0.1 (–0.2)**
	[0.85, 1.01, 1.14]	**[0.2, 0.2, 0.1]**	[0.85, 1.01, 1.13]	**[0.1, 0.1, 0.0]**
Storage (I_{ct+1})	0.11 (0.97)	**0.2 (0.0)**	0.11 (0.96)	**0.2 (–0.1)**
	[0.00, 0.09, 0.32]	**[–, 0.3, 0.1]**	[0.00, 0.09, 0.31]	**[–, 0.4, 0.1]**
World Price (P_{ct})	1.02 (0.24)	**–0.4 (–0.6)**	1.02 (0.22)	**–0.2 (–0.5)**
	[0.83, 0.96, 1.49]	**[–0.2, –0.3, –0.5]**	[0.86, 0.96, 1.45]	**[0.0, –0.1, –0.3]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

Table 2. Steady-state results for cash-crop market, assuming that there is a food-crop market and credit constraints are high ($\bar{b}$ = 0).[a]

	Small Share of Adopting Farmers (n^A = 0.20)		Large Share of Adopting Farmers (n^A = 0.80)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Total Output ($n^A q^A_{ct} + n^N q^N_{ct}$)	1.00 (0.14)	**0.2 (0.1)**	1.00 (0.14)	**0.1 (0.3)**
	[0.77, 1.00, 1.23]	**[0.2, 0.2, 0.2]**	[0.77, 1.00, 1.24]	**[0.0, 0.1, 0.2]**
Total Supply ($n^A q^A_{ct} + n^N q^N_{ct} + I_{ct}$)	1.11 (0.15)	**0.2 (–0.5)**	1.11 (0.14)	**0.1 (–0.3)**
	[0.85, 1.11, 1.38]	**[0.3, 0.2, 0.1]**	[0.86, 1.11, 1.36]	**[0.2, 0.1, 0.0]**
Current Consumption (D_{ct})	1.00 (0.09)	**0.2 (–0.5)**	1.00 (0.08)	**0.1 (–0.3)**
	[0.84, 1.01, 1.14]	**[0.3, 0.2, 0.2]**	[0.85, 1.01, 1.13]	**[0.2, 0.1, 0.1]**
Storage (I_{ct+1})	0.11 (0.97)	**0.2 (0.0)**	0.11 (0.96)	**0.3 (–0.1)**
	[0.00, 0.09, 0.32]	**[–, 0.3, 0.1]**	[0.00, 0.09, 0.31]	**[–, 0.6, 0.1]**
World Price (P_{ct})	1.03 (0.24)	**–0.5 (–0.7)**	1.02 (0.22)	**–0.2 (–0.6)**
	[0.83, 0.96, 1.49]	**[–0.2, –0.4, –0.6]**	[0.86, 0.96, 1.45]	**[–0.1, –0.2, –0.4]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

Table 3. Steady-state results for cash-crop market, assuming that there is no food-crop market and credit constraints are low ($\bar{b} = 1$).[a]

	Small Share of Adopting Farmers ($n^A = 0.20$)		Large Share of Adopting Farmers ($n^A = 0.80$)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Total Output ($n^A q_{ct}^A + n^N q_{ct}^N$)	1.00 (0.14)	**0.0 (0.1)**	0.99 (0.14)	**0.1 (0.1)**
	[0.77, 1.00, 1.22]	**[0.0, 0.0, 0.0]**	[0.76, 0.99, 1.22]	**[0.0, 0.1, 0.1]**
Total Supply ($n^A q_{ct}^A + n^N q_{ct}^N + I_{ct}$)	1.11 (0.15)	**0.1 (–0.3)**	1.10 (0.15)	**0.2 (–0.5)**
	[0.84, 1.10, 1.39]	**[0.1, 0.1, 0.0]**	[0.84, 1.09, 1.37]	**[0.3, 0.2, 0.0]**
Current Consumption (D_{ct})	1.00 (0.09)	**0.0 (–0.5)**	0.99 (0.09)	**0.1 (–0.8)**
	[0.84, 1.00, 1.14]	**[0.1, 0.0, –0.1]**	[0.83, 1.00, 1.12]	**[0.3, 0.1, 0.0]**
Storage (I_{ct+1})	0.11 (0.97)	**0.5 (–0.3)**	0.11 (0.97)	**0.8 (–0.5)**
	[0.00, 0.09, 0.31]	**[–, 0.8, 0.3]**	[0.00, 0.09, 0.31]	**[–, 1.3, 0.4]**
World Price (P_{ct})	1.04 (0.25)	**0.0 (–0.7)**	1.05 (0.24)	**–0.2 (–1.1)**
	[0.82, 0.97, 1.52]	**[0.2, 0.0, –0.3]**	[0.84, 0.98, 1.54]	**[0.2, –0.1, –0.5]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

noticeable impacts being a 0.4% decrease in the coefficients of variation of total supply and current consumption, and a 0.6% decrease in the coefficient of variation of world cash-crop prices.

Comparison of the second and fourth columns of Table 1 reveals that futures availability exerts the same qualitative effects when the share of adopters is large (n^A = 80%) as when that share is small (n^A = 20%). Somewhat counterintuitively, however, the magnitudes of the changes in means induced in the large-adopter-share scenario are almost always smaller (around half) than in the small-adopter-share scenario. The reason for this finding is that futures trading allows adopters to gain market share at the expense of non-adopters, and adopters' gains outweigh non-adopters' losses. This is confirmed by the data in the third row of Table 4, which shows that adopters' output increases by 1% when their initial share is n^A = 20%, but it goes up by only 0.1% when their share is n^A = 80%. For non-adopters, production decreases by 0.04% when n^A = 20% and by 0.02% when n^A = 80%.[22] In other words, the relatively small increase in total production is made up of gains in adopters' output that more than offset losses in production by non-adopters.

Consumers are the clear winners from the availability of futures, as average current consumption goes up (by 0.2% when n^A = 20% and by 0.1% when n^A = 80%) and the coefficient of variation of current consumption goes down (by 0.4% when n^A = 20% and by 0.2% when n^A = 80%). Non-adopters are the unambiguous losers, as their average revenues decline due to both lower prices and lower sales.[23] More specifically, average non-adopters' revenues decrease by 0.44% when n^A = 20% and by 0.22% when n^A = 80%. These figures provide good approximations of the average losses in non-adopters' producer surplus as percentages of their initial revenues, because most of non-adopter's revenue losses stem from lower prices rather than lower output. Calculation of the impact of futures availability on adopters' welfare is more complex and its discussion will be deferred until a later subsection.

When the credit market is relatively restrictive ($\bar{b}$ = 0), the impact of futures availability is quite similar, both quanti- and qualitatively, to the effect found under less restrictive credit markets (compare Tables 2 and 1). The only minor difference is that the former tends to be slightly greater than the latter. This is consistent with intuition, because both borrowings and hedging allow for consumption smoothing over time, i.e., they are substitutes for risk-reduction purposes. Hence, adopters' hedging is larger when credit is more constrained (compare the "hedging" row in Tables 5 and 4), which translates into a larger effect from the availability of futures.

Comparison of Tables 1 and 3 indicates that in almost all instances, the impact of futures availability on the world cash-crop market is qualitatively the same whether there is a market for the food crop or not. Unlike the scenario with a food-crop market, if such a market does not exist futures availability has a greater impact when adopters' share is large than when adopters' share is small. For example, when n^A = 20% futures availability leaves the world cash-crop price mean unchanged and reduces its coefficient of variation by 0.7%. But when n^A = 80%, futures availability reduces the world cash-crop price mean by 0.2% and its coefficient of variation by 1.1%.

V.2. Effects on Adopters' Behavior

Adopters' behavior is summarized in Tables 4 through 6, which are the counterparts of Tables 1 through 3, respectively. Except for the hedging figures, data in the former tables are reported in the same format

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[22]To save space, tables with production changes by non-adopters are omitted. However, the aforementioned figures can be easily estimated from the mean percentage changes in world prices and non-adopters' supply elasticity.

[23]Changes in volatility exert no welfare effects on non-adopters, because their supply is unaffected by volatility.

as in the latter. For hedging, levels rather than percentage changes are reported in the futures availability scenario.[24]

Table 4 shows adopters' results for the scenarios with a food-crop market and low credit constraints. If futures are not available, average local cash-crop prices and mean acreage and output for both crops are the same for small and large adopters' shares. However, the respective coefficients of variation are larger when adopters' share is small than when adopters' share is large. Acreage is less variable when adopters' share is large because the same percentage increase (decrease) in acreage induces a larger price fall (rise) when n^A = 80% than when n^A = 20%. That is, acreage response tends to be "self-defeating" as adopter's share goes up.

Given the more volatile crop revenues when adopters' share is small, and the fact that borrowings have an upper ceiling at $\bar{b}$ = 1, in order to smooth consumption savings are larger for n^A = 20% than for n^A = 80% (mean savings are 0.68 versus 0.48, respectively).[25] Greater savings yield more revenues from interest payments, which together with higher mean crop revenues lead to greater mean consumption of market good and food crop when n^A = 20%. However, consumption smoothing through borrowings/savings is far from perfect, and the volatility of consumption when n^A = 20% exceeds the volatility found when n^A = 80%.

When futures are available and adopters' share is small (large), their mean hedge is 0.46 (0.10), or roughly half (10%) of the mean output of the cash-crop. As discussed in the preceding paragraphs, when futures are not available the environment is more volatile for n^A = 20% than for n^A = 80%. Therefore, because of futures' capability to reduce risk, and because futures trading is much greater when n^A = 20%, it is not surprising that making futures available exerts a considerably greater effect when adopters' share is small. When n^A = 20% (n^A = 80%), futures availability leads to a 1% (0.1%) increase in the mean production of cash crop, accompanied by a reduction of the same magnitude in mean food-crop output.

Futures availability makes adopters more responsive to market signals, as evidenced by the greater variability in crop acreage. The ensuing increase in output volatility tends to offset the reduction in cash-crop price risk resulting from hedging. The difference in the relative magnitudes of such effects is what induces adopters to increase savings (by 14.9%) when n^A = 20%, but to decrease savings (by 0.6%) when n^A = 80%. As a result, futures availability leads to substantially higher interest revenues if n^A = 20%, as opposed to lower interest revenues when n^A = 80%. Mean crop revenues are slightly reduced by futures availability, and their volatility is substantially reduced when n^A = 20%. Hence, futures adoption translates into higher mean consumption when n^A = 20%, and lower mean consumption when n^A = 80%. However, the volatility of consumption is reduced by the adoption of futures, regardless of adopters' share.

Comparison of Tables 4 and 5 shows that, if futures are not available, adopters' production behavior does not change much when credit availability is reduced from $\bar{b}$ = 1 to $\bar{b}$ = 0. Unsurprisingly, the major impact is on borrowings, as mean savings about double under the more constrained scenario. When borrowings are not allowed, adopters resort to larger savings to smooth consumption. Even though mean crop revenues are unchanged, mean consumption is greater under $\bar{b}$ = 0 because higher savings result in larger interest revenues.

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[24]Percentage changes are uninformative for hedging, because futures trading equals zero when futures are not available.

[25]Recall that savings equal negative borrowings.

Table 4. Steady-state results for adopting farmer, assuming that there is a food-crop market and credit constraints are low ($\bar{b} = 1$).[a]

	Small Share of Adopting Farmers ($n^A = 0.20$)		Large Share of Adopting Farmers ($n^A = 0.80$)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Cash-Crop Acreage (a_{ct})	1.00 (0.11) [0.80, 1.01, 1.13]	**1.4 (6.7) [0.2, 1.2, 1.7]**	1.00 (0.08) [0.86, 1.01, 1.09]	**0.1 (2.4) [–0.1, 0.1, 0.4]**
Food-Crop Acreage (a_{ft})	1.00 (0.11) [0.87, 0.99, 1.20]	**–1.4 (9.8) [–2.3, –1.2, –0.1]**	1.00 (0.08) [0.91, 0.99, 1.14]	**–0.1 (2.7) [–0.4, –0.1, 0.1]**
Cash-Crop Production (q_{ct}^A)	1.00 (0.17) [0.73, 1.00, 1.28]	**1.0 (1.5) [0.5, 0.9, 1.3]**	1.00 (0.16) [0.74, 1.00, 1.27]	**0.1 (0.3) [0.0, 0.1, 0.2]**
Food-Crop Production (q_{ft}^A)	1.00 (0.17) [0.73, 0.99, 1.29]	**–1.0 (2.2) [–1.6, –1.1, –0.4]**	1.00 (0.16) [0.74, 1.00, 1.27]	**–0.1 (0.4) [–0.2, –0.1, 0.0]**
Market-Good Consumption (x_{mt})	1.02 (0.09) [0.88, 1.02, 1.16]	**0.1 (–7.4) [0.7, 0.2, –0.4]**	1.01 (0.07) [0.89, 1.02, 1.13]	**–0.1 (–0.6) [0.0, –0.1, –0.2]**
Food-Crop Consumption (x_{ft})	1.04 (0.11) [0.88, 1.02, 1.23]	**0.1 (–4.8) [0.6, 0.2, –0.4]**	1.03 (0.10) [0.89, 1.02, 1.20]	**–0.1 (–0.4) [–0.1, –0.1, –0.1]**
Borrowings (b_t)	–0.68 (–1.09) [–1.86, –0.69, 0.54]	**14.9 (–16.0) [0.8, 19.3, –17.4]**	–0.48 (–1.47) [–1.66, –0.45, 0.64]	**–0.6 (–0.1) [–0.6, –0.1, –0.2]**
Hedging (h_t)		0.46 (0.26) [0.25, 0.48, 0.64]		0.10 (0.84) [0.00, 0.09, 0.23]
Local Cash-Crop Price (p_{ct})	1.02 (0.24) [0.80, 0.96, 1.49]	**–0.4 (–0.5) [–0.2, –0.3, –0.5]**	1.02 (0.22) [0.83, 0.96, 1.46]	**–0.2 (–0.4) [0.0, –0.1, –0.3]**
Crop and Hedging Revenues [$p_{ft}\, q_{ft}^A + p_{ct}\, q_{ct}^A + (P_{ht-1} - P_{ct})\, h_{t-1}$]	2.01 (0.17) [1.50, 1.99, 2.59]	**–0.2 (–5.8) [0.0, 0.5, –1.5]**	2.00 (0.14) [1.57, 1.99, 2.47]	**–0.1 (–0.3) [–0.2, 0.0, –0.1]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

Table 5. Steady-state results for adopting farmer, assuming that there is a food-crop market and credit constraints are high ($\bar{b} = 0$).[a]

	Small Share of Adopting Farmers ($n^A = 0.20$)		Large Share of Adopting Farmers ($n^A = 0.80$)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Cash-Crop Acreage (a_{ct})	1.00 (0.11) [0.81, 1.01, 1.13]	**1.8 (9.1)** **[0.2, 1.5, 2.3]**	1.00 (0.08) [0.86, 1.01, 1.09]	**0.2 (3.2)** **[–0.1, 0.1, 0.5]**
Food-Crop Acreage (a_{ft})	1.00 (0.11) [0.87, 0.99, 1.19]	**–1.8 (13.2)** **[–3.0, –1.6, –0.1]**	1.00 (0.08) [0.91, 0.99, 1.14]	**–0.2 (3.6)** **[–0.6, –0.1, 0.1]**
Cash-Crop Production (q_{ct}^A)	1.00 (0.17) [0.73, 0.99, 1.28]	**1.2 (1.9)** **[0.7, 1.2, 1.8]**	1.00 (0.16) [0.74, 1.00, 1.27]	**0.1 (0.4)** **[0.0, 0.1, 0.2]**
Food-Crop Production (q_{ft}^A)	1.00 (0.17) [0.74, 0.99, 1.29]	**–1.3 (2.8)** **[–2.1, –1.5, –0.5]**	1.00 (0.16) [0.74, 1.00, 1.27]	**–0.1 (0.4)** **[–0.2, –0.2, 0.0]**
Market-Good Consumption (x_{mt})	1.04 (0.09) [0.89, 1.03, 1.18]	**–0.1 (–9.4)** **[0.6, 0.1, –0.8]**	1.03 (0.08) [0.90, 1.03, 1.15]	**–0.1 (–0.9)** **[–0.1, –0.1, –0.2]**
Food-Crop Consumption (x_{ft})	1.05 (0.11) [0.89, 1.04, 1.25]	**–0.1 (–6.6)** **[0.5, 0.1, –0.7]**	1.04 (0.10) [0.90, 1.03, 1.22]	**–0.1 (–0.6)** **[–0.1, –0.1, –0.2]**
Borrowings (b_t)	–1.16 (–0.44) [–1.99, –1.18, –0.30]	**3.5 (–6.8)** **[–0.7, 4.6, 16.3]**	–1.05 (–0.46) [–1.85, –1.05, –0.26]	**–0.2 (–0.4)** **[–0.5, 0.0, 0.0]**
Hedging (h_t)		0.50 (0.22) [0.30, 0.52, 0.66]		0.11 (0.84) [0.00, 0.10, 0.24]
Local Cash-Crop Price (p_{ct})	1.03 (0.24) [0.80, 0.96, 1.50]	**–0.5 (–0.7)** **[–0.2, –0.4, –0.7]**	1.02 (0.23) [0.83, 0.96, 1.46]	**–0.2 (–0.6)** **[–0.1, –0.2, –0.4]**
Crop and Hedging Revenues $[p_{ft}\ q_{ft}^A + p_{ct}\ q_{ct}^A + (P_{ht-1} - P_{ct})\ h_{t-1}]$	2.01 (0.17) [1.50, 1.99, 2.59]	**–0.2 (–5.8)** **[–0.1, 0.4, –1.6]**	2.00 (0.14) [1.57, 1.99, 2.46]	**–0.1 (–0.2)** **[–0.2, 0.0, –0.1]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

Table 6. Steady-state results for adopting farmer, assuming that there is no food-crop market and credit constraints are low ($\bar{b}$ = 1).[a]

	Small Share of Adopting Farmers (n^A = 0.20)		Large Share of Adopting Farmers (n^A = 0.80)	
	Futures Unavailable (level)	Futures Available (% change)	Futures Unavailable (level)	Futures Available (% change)
Cash-Crop Acreage (a_{ct})	0.97 (0.05) [0.88, 0.97, 1.05]	**0.0 (5.6) [–0.8, 0.1, 0.3]**	0.98 (0.05) [0.90, 0.98, 1.05]	**0.1 (2.5) [–0.1, 0.2, 0.2]**
Food-Crop Acreage (a_{ft})	1.03 (0.05) [0.95, 1.03, 1.12]	**0.0 (5.7) [–0.4, –0.1, 0.6]**	1.02 (0.04) [0.95, 1.02, 1.10]	**–0.1 (2.8) [–0.3, –0.2, 0.1]**
Cash-Crop Production (q_{ct}^A)	0.98 (0.15) [0.73, 0.98, 1.23]	**0.0 (0.3) [0.0, 0.0, 0.1]**	0.99 (0.15) [0.74, 0.98, 1.24]	**0.1 (0.1) [0.0, 0.1, 0.1]**
Food-Crop Production (q_{ft}^A)	1.02 (0.15) [0.76, 1.02, 1.28]	**0.0 (0.4) [–0.1, –0.1, 0.1]**	1.01 (0.15) [0.76, 1.01, 1.27]	**–0.1 (0.1) [–0.2, –0.1, –0.1]**
Market-Good Consumption (x_{mt})	1.03 (0.14) [0.84, 1.02, 1.27]	**1.0 (–13.4) [2.5, 1.5, –0.9]**	1.04 (0.13) [0.84, 1.03, 1.29]	**–0.1 (–5.8) [0.7, 0.1, –1.0]**
Food-Crop Consumption (x_{ft})	1.02 (0.15) [0.76, 1.02, 1.28]	**0.0 (0.4) [–0.1, –0.1, 0.1]**	1.01 (0.15) [0.76, 1.01, 1.27]	**–0.1 (0.1) [–0.2, –0.1, –0.1]**
Borrowings (b_t)	–0.68 (–1.09) [–1.88, –0.70, 0.55]	**27.1 (–26.4) [1.6, 33.9, –33.2]**	–0.52 (–1.42) [–1.75, –0.50, 0.64]	**–0.8 (–1.8) [–1.9, –0.6, –3.4]**
Hedging (h_t)		0.53 (0.18) [0.35, 0.55, 0.65]		0.22 (0.36) [0.10, 0.22, 0.34]
Local Cash-Crop Price (p_{ct})	1.04 (0.25) [0.79, 0.97, 1.53]	**0.0 (–0.7) [0.2, 0.0, –0.3]**	1.05 (0.25) [0.82, 0.99, 1.54]	**–0.2 (–1.1) [0.1, –0.1, –0.6]**
Crop and Hedging Revenues $[p_{ct}\, q_{ct}^A + (P_{ht-1} - P_{ct})\, h_{t-1}]$	1.00 (0.22) [0.72, 0.97, 1.38]	**0.1 (–19.3) [–0.2, 2.8, –6.0]**	1.02 (0.17) [0.78, 1.00, 1.30]	**–0.1 (–13.5) [–0.2, 1.2, –3.0]**

[a]Stand-alone numbers denote means, numbers within parentheses are coefficients of variation, and the three numbers within brackets are, respectively, the 5 percent quantile, the median, and the 95 percent quantile. Bolded numbers are percentage changes with respect to the corresponding unbolded figures.

Tables 4 and 5 also reveal that the more restrictive the credit market, the greater the amounts hedged (e.g., for n^A = 20% mean hedging is 0.46 when $\bar{b}$ = 1 versus 0.50 when $\bar{b}$ = 0). The effect of futures availability on acreage and output is augmented by the credit constraints, while the opposite holds true for savings. For n^A = 20%, the smaller increase in savings induced by futures under $\bar{b}$ = 0 compared to $\bar{b}$ = 1 results in lower interest revenues. This is the reason why, in contrast to the futures impact found when $\bar{b}$ = 1, in the $\bar{b}$ = 0 scenario futures adoption is accompanied by lower consumption regardless of farmers' share. But when futures become available, the reduction in consumption volatility is greater under the more restricted credit-market scenario.

Tables 4 and 6 demonstrate that absence of markets for the food crop exerts a substantial impact on adopters' behavior. If futures are not available, lack of food-crop markets is associated with lower (higher) means for cash-crop (food-crop) acreage and output. Because adopters cannot resort to the market to compensate shortfalls in their harvest of the food crop, they tend to plant more of the latter and to be less responsive to the signals from the market for the cash crop. Hence, acreage and output for both crops are more stable when there is no food-crop market.

Without futures, mean crop revenues are much lower (by about one unit) because they do not include food-crop revenues, as there is no market to price the food crop. Having revenues from just one crop leads to a greater coefficient of variation of crop revenues, because there is no "portfolio diversification." Absence of food-crop markets causes mean consumption to go up for the market good and to go down for the food crop, but makes consumption of both goods substantially more volatile. The differential impact on consumption means reflects the fact that when a market for the food crop does not exist, food is relatively more expensive (in terms of resources required to produce it) than the market good.

When there are no food-crop markets and futures become available, adopters' mean hedges are 0.53 if n^A = 20% and 0.22 if n^A = 80%. Both amounts are considerably greater than the respective hedges in the presence of food-crop markets (equal to 0.46 and 0.10, respectively). In addition, hedging is less volatile without food-crop markets because cash-crop acreage fluctuates much less. In this regard, Table 6 shows that futures render adopters more responsive to cash-crop market signals, as acreage (and output) variability increases. When n^A = 20%, mean acreage and output of both crops are left unchanged by futures adoption. In contrast, when n^A = 80% mean acreage and output of the cash crop increase at the expense of the food crop.

Without food-crop markets, futures availability increases savings substantially for n^A = 20, but decreases them slightly for n^A = 80%. Because in the former scenario mean food-crop revenues are unchanged but mean interest earnings are much higher, mean consumption of the market good increases by as much as 1% (mean consumption of the food crop is unaffected because mean food-crop production remains constant). In contrast, when n^A = 80% mean market good consumption is slightly smaller if futures are available, due to lower food-crop revenues and lower mean interest revenues (mean consumption of the food crop is also smaller because mean food-crop output is lower). Regardless of the share of adopters, futures availability leads to substantial reductions in the volatilities of crop and hedging revenues and of market good consumption, and to a small increment in food-crop consumption volatility.

Effects on Adopters' Welfare

Adopters' welfare is ultimately a function of the level, volatility, and higher moments of the joint pdf of market-good consumption and food-crop consumption. Mean consumption is higher and consumption volatility is lower after futures adoption in the scenario with food-crop markets, relatively unconstrained credit markets, and n^A = 20% (see Table 4, column two). Thus, futures adoption would be expected to improve adopters' welfare in such scenario. But column four of Table 4 shows that the impact on the welfare of adopters is far less clear when their share is n^A = 80%. This is true because in such instance futures adoption not only reduces consumption volatility, but reduces mean consumption as well.

The simple example above demonstrates that Tables 4 through 6 do not contain enough information to infer the welfare effects of futures on adopters. A proper welfare analysis requires the explicit consideration of adopters' expected utility with and without futures, and of the changes in the joint pdf of the endogenous random variables (as opposed to changes in the means and variances only). To this end, consider the following thought experiments:

- Experiment 1. Assume futures are not available to begin with, but starting at a random time t futures are made available forever.
- Experiment 2. Similar to Experiment 1, but starting at time t adopters are given a certain amount of income Y in each period forever, instead of allowing them to trade in futures.

Define scalars V^* and $V^{**}(Y)$ as adopters' unconditional expected utility under experiments 1 and 2, respectively.[26] The certain per-period income Y^* defined by the equality $V^* = V^{**}(Y^*)$ represents the amount that makes adopters indifferent between adopting and not adopting futures. Thus, Y^* measures the impact of futures on the welfare of adopters. Amount Y^* is labeled "compensating income" in the following analysis.

Compensating income results associated with availability of futures are reported in the top three rows in Table 7. For example, when there are food-crop markets and credit markets are relatively unconstrained, compensating income equals 0.0015 if n^A = 20% and –0.0015 if n^A = 80%. Since the market good is the numeraire, and mean market-good consumption is 1.02 for n^A = 20% and 1.01 for n^A = 80% (see Table 4, row five), compensating income represents a gain of 0.15% in mean market-good consumption when n^A = 20%, and a loss of similar magnitude when n^A = 80%. Futures are conducive to greater welfare gains (or smaller welfare losses) when food-crop markets are absent (compare rows one and three in Table 7). When credit markets are relatively constrained, futures yield greater gains if n^A = 20%, but also lead to greater losses if n^A = 80% (compare rows one and two in Table 7).

It is clear from rows one through three in Table 7 that futures improve adopters' welfare when their share is small, but worsen it when their share is large. Although it seems counterintuitive that adopters are made worse by expanding their choice set (i.e., by relaxing the no-hedging constraint), this result is possible because of the combined assumptions of perfect competition and market clearing. Due to perfect competition, it is in each individual adopter's best interest to trade futures and to modify his/her other decisions accordingly. However, the collective impact of such decisions on the market may render every adopter worse.

A simple explanation for the negative welfare impact when n^A = 80% would be that, because futures induce adopters to increase cash-crop output and world demand is inelastic, futures adoption results in smaller crop revenues when adopters' share is large. This explanation is consistent with the data for the scenario without food-crop markets, but it is not supported by the data for the scenarios with food-crop markets (compare crop and hedging revenue means in the last row of Tables 4 through 6). This is true because Tables 4 and 5 show that futures availability cause crop and hedging revenue means to drop slightly, but more so for n^A = 20% than for n^A = 80%. Instead, the last row of Tables 4 and 5 indicates that the differential futures' welfare impact associated with adopters' shares is due to differences on revenue volatilities. Thus, for n^A = 20% the volatility drop is so large that its benefits offset the welfare losses stemming from the small decrease in revenue means. In contrast, for n^A = 80% the reduction in

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[26]Obviously, V^* and $V^{**}(Y)$ are calculated under the appropriate joint pdfs. That is, before t both experiments involve the no-futures joint pdf. After t, Experiment 2 also involves the no-futures joint pdf, but Experiment 1 uses the joint pdf corresponding to the futures-availability scenario.

Table 7. Adopting farmers' compensating income from relaxing alternative market imperfections.

Scenario	Small Share of Adopting Farmers ($n^A = 0.20$)	Large Share of Adopting Farmers ($n^A = 0.80$)
Making futures available in the presence of food-crop market, under low credit constraints ($\bar{b} = 1$).	0.0015	–0.0015
Making futures available in the presence of food-crop market, under high credit constraints ($\bar{b} = 0$).	0.0020	–0.0019
Making futures available in the absence of food-crop market, under low credit constraints ($\bar{b} = 1$).	0.0045	–0.0001
Relaxing credit market constraints in the presence of food-crop market, when futures are not available.	0.0068	0.0033
Introducing food-crop markets under low credit constraints ($\bar{b} = 1$), when futures are not available.	0.0219	0.0068

volatility is so small that its benefits are outweighed by the negative welfare impact associated with the slight reduction in means.

In summary, the introduction of futures in the presence of inelastic world demand tends to slightly reduce mean crop revenues. Futures also reduce risk, oftentimes substantially so. However, futures' effectiveness in reducing risk is greatly diminished as adopters' share goes up. The combination of these effects result in welfare gains from futures' availability for small adopters' shares, and welfare losses for large adopter's shares.

Another way of assessing the welfare impact of making futures available is to compare it with the effect of changing other market variables. Given the scenarios used in the analysis, the two most obvious welfare impacts to look at are those resulting from relaxing credit-market constraints, and from introducing food-crop markets. The compensating incomes associated with such market changes can be obtained by performing thought experiments analogous to the ones used to measure compensating income for futures availability. Results for relaxing credit market constraints and for introducing food-crop markets are respectively shown in rows four and five in Table 7.

Considering Table 7, there are two noticeable differences between rows one through three on one hand, and rows four and five on the other. First, compensating incomes from futures availability are substantially smaller than compensating incomes from either credit relaxation or food-crop market introduction. For example, in the absence food-crop markets, making futures available has a compensating income of 0.0045 for n^A = 20%, versus a compensating income of 0.0219 associated with introducing food-crop markets. Second, when adopters' share is large, compensating incomes from making futures available are negative, whereas compensating incomes from relaxing credit constraints or from introducing food-crop markets are positive. Table 4 also reveals that, of the market changes under analysis, introducing food-crop markets has the largest impact on adopters' welfare.

VI. Conclusions

Recent years have witnessed a renewed interest in market-based solutions to alleviate some of the risks faced by commodity producers. However, to date little has been done in terms of concomitant research.

The present study aims at partially filling this gap by showing how to use a simulation approach to analyze the effects of making a futures market available on adopting producers' behavior and welfare, and its impact on market variables such as spot prices. One key distinguishing attribute of the advocated model is the explicit consideration of relevant constraints faced by some commodity producers, such as credit restrictions or lack of markets for staple crops. In addition, the model incorporates the aggregate market effects associated with the adoption of futures by a group of producers. Use of the model is illustrated with parameterizations capturing generic features of commodity markets.

Under the chosen parameterizations, futures availability affects various aspects of adopters' behavior. Typically, adopters' acreage decisions become more responsive to market signals, as reflected in greater year-to-year variability in the area planted with a specific crop. Adopters' revenues from crop production (and hedging) become less volatile with the use of futures. Adopters' consumption and borrowings/savings decisions are also modified and, except for the case of no markets for the food crop, adopters' consumption volatility is clearly reduced.

In terms of welfare, futures availability renders consumers better off and non-adopting producers worse off. Farmers who adopt futures gain if their market share is small, but lose if their market share is large. However, the magnitudes of adopting farmers' gains or losses are quite small. This is particularly evident when comparing the welfare effects of making futures available with those resulting from alternative changes in the market environment faced by adopting producers, such as the relaxation of credit restrictions or the opening of a market for food crops.

The impact of making futures available on the spot market is quite modest, regardless of whether the share of adopting producers is small or large. Total output, total supply and current consumption tend to increase slightly, whereas the opposite is true of spot prices. As well, the variability of total output increases a little, while the volatilities of total supply, current consumption, and spot prices are reduced by small amounts.

Overall, the present results suggest that advocating the use of futures as a mean to improve commodity producers' well-being need not be justified.[27] The reasons for this assertion are twofold. First, adopters' welfare is changed little by futures availability. Second and more importantly, adopters may end up worse off when futures are available.

From a policy perspective, the present findings uncover at least two interesting issues. First, producers' welfare is quite difficult to measure in practice, so the degree of adoption is often used as a proxy to measure a policy's success. But in the case of policies aiming at making futures available to improve producers' welfare, measuring success by the extent of futures adoption is likely to be very misleading. This is true because the larger the share of adopting producers, the likelier it is that futures availability makes adopters worse off. Second, in the real world commodities are often produced in developing countries and consumed in developed economies. It follows that the push by international organizations (e.g., ITF) to improve the availability of futures among producers may ultimately enhance the lot of consumers in developed economies, while reducing the welfare of producers in developing countries. To many, this regressive redistributional outcome is likely to be both surprising and undesirable.

Hopefully, the issues just raised should make it clear that if one wants to prevent policy recommendations with unwelcome consequences, or to prevent the use of misleading measures of policy success, more research is needed in this area of inquiry.

[27] Unless, of course, compensating side payments are made from consumers to producers.

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