Economics Publications

Economics

2015

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This is a pre-copyedited, author-produced PDF of an article accepted for publication in American Journal of Agricultural Economics following peer review. The version of record is available online at: http://dx.doi.org/10.1093/ajae/aav052.

MODELING THE MARKET AND WELFARE EFFECTS OF MEXICO'S "AGRICULTURE BY CONTRACT" (A×C) PROGRAM

Sergio H. Lence*

Abstract

"Agriculture by contract" (A×C) is the main government program aimed at mitigating price risks for agricultural producers in Mexico. A×C has unique features, involving forward contracts, and the provision of basis subsidies and subsidized exchange-traded futures options for both producers and intermediaries. A simulation model is developed to analyze the market and welfare effects of A×C. When applied to corn, results show that A×C exerts substantial impacts, and causes large transfers across sectors. Even if A×C reduced intermediaries' market power to the largest extent feasible, results indicate that it would still cause important losses in aggregate welfare.

Keywords: Agricultura por contrato, agriculture by contract, farm programs, farm support, market impact, price risk, welfare analysis

JEL: C6, D6, Q11, Q18

Suggested Running Head: Mexico's Agriculture by Contract Program

Production and price risks are among the most common concerns for agricultural producers. In some instances, the private sector has devised tools to manage some of such risks without any kind of government support. This is the case of hail insurance (which involves non-systemic production risks) and futures and options markets (which can be used to manage price risks). Quite often, however, governments have intervened by designing policies aimed at curbing the production or price risks faced by farmers (Gardner 1987).

In the case of production risks, some governments provide subsidized yield insurance and/or emergency assistance when yields are extremely poor. In the United States, the Congressional Budget Office has estimated that the federal crop insurance program legislated under the 2014 Farm Bill will require subsidies of 89.8 billion U.S. dollars over 10 years (Shields 2014).[1] The public sector provides some kind of support in 16 out of the 18 Latin American countries where agricultural insurance is available (World Bank 2010). Agricultural insurance subsidies in Brazil and Mexico amounted to 294 million dollars in 2009, accounting for 90% of the region's total public support for agricultural insurance in that year (World Bank 2010). Rather than subsidizing insurance, governments in Caribbean countries, Bolivia, and Nicaragua provide post-disaster assistance (World Bank 2010). Over 1995-2005, annual payments for relief from natural disasters averaged about 1.2 billion dollars in the United States and 0.5 billion dollars in the European Union (Johnson, Hanrahan, and Schnepf 2010).

In regard to farmers' price risks, governments have intervened in a number of ways (Dana and Gilbert 2009). Price supports through government purchases or deficiency payments have been among the most common government-instituted price-risk management tools. Both mechanisms have been used by the United States over the last century, and are currently employed in Brazil (DTB Associates 2011; USDA-ERS 2012). Other types of intervention aimed at mitigating price risks have included variable tariff schemes (as in Chile and Colombia (Knudsen and Nash 1990)), the creation of government marketing boards to act as monopsonies (e.g., the Australian Wheat Board and the Canadian Wheat Board), international trade agreements (e.g., the International Cocoa Agreements and the International Coffee Agreements),

as well as complex mechanisms involving long-term storage coupled with minimum prices and production restrictions aimed at maintaining prices within certain bands (as in the United States over most of the 20th century).

Contrasting with the aforementioned schemes aimed at mitigating price risks for agricultural producers, Mexico has used a fairly unique government program since the mid-1990s called "agriculture by contracts" (translated from the Spanish "agricultura por contrato"), typically abbreviated as "A×C." As explained in the next section, A×C involves the provision of subsidized market-based risk-management tools; more specifically, derivative contracts traded at the Chicago Mercantile Exchange (CME). The magnitude of A×C has increased dramatically over time, with government expenditures exploding from about 11 million dollars in 2001 to over 700 million dollars in 2010.

Despite the significant resources devoted by the Mexican government to this novel price-risk mitigating mechanism, to the best of our knowledge it has not been the subject of standard economic welfare analysis.[2] A likely reason for the lack of studies addressing its welfare impact is that, unlike more conventional programs, it requires the specification of a model involving not only production and price uncertainty, but also more than one decision time. The explicit modeling of uncertainty and risk preferences is critical for a proper evaluation of programs aimed at mitigating risks, but imposes substantial computational challenges.

The objective of the present study is to perform an economic welfare analysis of A×C for the case of corn. In the process, we show how to build a simulation model able to incorporate key features of the program. In particular, the advocated model allows for uncertain outcomes and risk-averse producers. The model also exhibits more than one decision time, as participation in A×C requires signing forward contracts after planting but before harvest. In addition, "intermediaries"[3] are explicitly modeled, and are assumed to possess market power to better reflect the reality of agricultural markets in Mexico.[4]

Mexico's "Agriculture by Contracts" Program

In recent years, A×C has been the most important government-sponsored program aimed at mitigating price risks for crop producers in Mexico. Direct subsidies paid through A×C averaged approximately 7.55 billion Mexican pesos (about 605 million dollars) per year over 2008-2010 (SAGARPA 2010c).[5] By contrast, the second largest price-risk mitigating program (minimum price, officially called "ingreso objetivo" in Mexico) paid out only 4% as much as A×C over the same period.[6]

The A×C program covers several crops, including barley, corn, cotton, oats, rice, sorghum, soybean, and wheat. However, A×C payments are extremely concentrated among corn, sorghum, and wheat, which is not surprising because they account for most of the area planted. For example, in 2010 corn (52%), sorghum (20%), and wheat (18%) received 90% of the A×C payments, and accounted for 94% of the area planted with the eight aforementioned crops (SIAP 2015; ASERCA 2011).[7] A×C covers a significant proportion of the amount produced for such crops (e.g., 45% for corn, 62% for sorghum, and 53% for wheat in the fall/winter cycle of 2009/10) (ASERCA 2011). A×C subsidies are very heavily concentrated geographically, with the state producing most of a crop receiving an even larger share of the crop's A×C outlays: The state of Sinaloa (Tamaulipas, Sonora) produced 74% (83%, 55%) of the corn (sorghum, wheat) in the 2009/10 fall/winter cycle, and accounted for 90% (96%, 66%) of the cycle's A×C corn (sorghum, wheat) payments (SIAP 2015; ASERCA 2011).

The A×C program is a complex mechanism involving unique features. It is based on a forward contract that producers and intermediaries must sign and register at designated government offices over a specified period of time, typically shortly after the planting season for the corresponding crop (SAGARPA 2010c). Each forward contract stipulates the volume of crop that producers will deliver to intermediaries at post-harvest, and the corresponding dollar-denominated forward price for the transaction. The forward price consists of an officially-determined forward basis, plus the CME closing price on the contract registration date for futures maturing immediately after the agreed-upon delivery date. The contract also specifies that the

dollar-denominated forward price is to be converted into pesos at the official exchange rate observed at the moment of issuing the invoice for the physical transaction of the crop. Under the contract, at post-harvest intermediaries (participants) are legally obligated to receive from participants (deliver to intermediaries) the crop volume stipulated in the contract, and pay (receive from) them the forward price converted to pesos.

The A×C forward basis is determined by negotiations involving government officials and representatives of producers and intermediaries, where they discuss the estimated underlying costs (e.g., transportation, handling, and storage costs). Once an agreement is reached, the forward basis is officially announced, typically at the same time the government announces the official period over which forward contracts must be registered. There is a single forward basis for each major production region, i.e., the forward basis is identical for all of the A×C contracts corresponding to a crop produced in a particular region.

By registering the forward contracts with the government and abiding by the A×C rules, producers and intermediaries gain access to two types of subsidies, namely, subsidized futures options and compensatory basis. The subsidies involving futures options are essentially cost-free at-the-money calls for producers and cost-free at-the-money puts for intermediaries. The compensatory basis is a payment to producers or intermediaries, depending on which party experiences an unfavorable change in the dollar-denominated basis.

Upon registration of an A×C contract, the Mexican government buys at-the-money futures calls and puts at the CME for the crop volume stipulated in the contract. The futures underlying the calls and puts is the same as the one used to determine the A×C forward price. The options positions are canceled at the time the crop is delivered to fulfill the A×C contract. Gains in the call (put) position accrue to the producers (intermediaries), previous deduction of up to a maximum share of the initial premium to cover the government's cost to buy the call (put).

The compensatory basis, officially named "compensación de bases," consists of a government payment to producers (intermediaries) if the realized "official" basis at post-harvest is greater (smaller) than the forward basis. Similar to the forward basis, the realized official basis

4

is settled in a negotiated manner by government officials and representatives of producers and intermediaries, and there is a single realized basis for each major production region. The agreed-upon realized official basis is announced to the public at post-harvest.

The compensatory basis is equal to the absolute value of the difference between the realized official basis and the forward basis; it accrues to producers if the realized basis exceeds the forward basis, and to intermediaries otherwise. Since the forward basis and the realized basis are both denominated in dollars per crop unit, the total amount paid by the government equals the compensatory basis times the amount of crop involved in the forward contract, valued at the prevailing official exchange rate.

Theoretical Model

The A×C program changes the distributions of the actual payoffs received by producers and intermediaries. Such distributions are endogenous and affected by risk attitudes, because market-clearing prices and ultimately the payoffs themselves depend on the agents' responses to A×C, which in turn are driven by their risk preferences. Therefore, to evaluate A×C's market and welfare impacts, we resort to a rational expectations equilibrium displacement model that incorporates risk preferences and allows for both probabilistic and endogenous payoffs.

The closest model to the one advocated here is Lence (2009a). Agents are assumed to hold rational expectations (i.e., agents' subjective beliefs regarding the probability distributions are the same as the actual distributions). Unlike Lence, however, interannual speculative storage is not included, which enables us to incorporate two key A×C features into the model, namely, intermediaries (with market power) and a decision time between planting and post-harvest (to enter contracts). Allowing for speculative interannual storage would render the proposed model numerically intractable because of the "curse of dimensionality" (i.e., it would not be possible to solve the model due to the large number of dimensions involved). Importantly, however, the assumption of no speculative interannual storage does not seem overly restrictive for the present

5

purposes, because Mexico's historical data suggest that speculative demand is dwarfed by the demand for current consumption.[8]

To capture the essential elements of A×C, the model involves decision making and/or market-clearing conditions at three points in time, namely, "planting" ($t = 0$), "contracting" ($t = 1$), and "post-harvest" ($t = 2$). Figure 1 summarizes the notation, timing of decisions, market-clearing conditions, and occurrences of the exogenous shocks responsible for the uncertainty in the model. For clarity of exposition, farmers are called "participants" if they participate in A×C, and "non-participants" otherwise. Variables corresponding to participants, non-participants, consumers of final product, intermediaries, and the world market are identified by subscripts G, $\mathbb{G}$, D, M, and W, respectively. In addition, $E_{t_i}(x_{t_j})$ is used to represent the expectations of random variable x_{t_j} conditional on information at time $t_i < t_j$.

At planting, farmers choose the optimal expected crop output. Being rational, this decision incorporates their knowledge of the A×C program and rules as of planting time (e.g., producers know that the subsidized options will be at the money, and that the strike price won't be known until contracting). At contracting, participants and intermediaries sign contracts stipulating the volume of crop to be traded at post-harvest and the corresponding dollar-denominated forward price for the transaction, consisting of the time-1 futures price for post-harvest maturity at the CME (F_1), plus the forward basis (B_1). The dollar-denominated forward price is to be converted into pesos at the official exchange rate prevailing at post-harvest (X_2).

At post-harvest all of the uncertainties are resolved. Contractual obligations are fulfilled, and non-participants sell their output to intermediaries in the spot market. Intermediaries also import crop from the world market (which is characterized by an infinitely elastic supply at the prevailing world price), process the crop, and sell the processed product to final consumers in the spot market. Consumer demand for final product at post-harvest satisfies standard regularity conditions (e.g., it is a differentiable and negatively-sloped function of price). Domestic spot prices (and the basis) are determined by market clearing, so that in equilibrium the consumption

of final product in crop-equivalent units ($Q_{D,2}$) equals the aggregate crop output of participants ($Q_{G,2}$) and non-participants ($Q_{\bar{G},2}$), plus crop imports ($Q_{W,2}$): $Q_{D,2} = Q_{G,2} + Q_{\bar{G},2} + Q_{W,2}$.

The fundamental difference between A×C participation and non-participation is the net price received by and paid to producers. The price received by non-participants ($P_{\bar{G},2}$) is the same as the net price intermediaries pay to them ($P_{M\bar{G},2}$). In contrast, for participants the net price received ($P_{G,2}$) is greater than the net price paid by intermediaries ($P_{MG,2}$). More specifically,

(1) $P_{G,2} = (F_1 + B_1)\, X_2 + ProdCompBas_2 + CallSubsidy_2$,

(2) $P_{MG,2} = (F_1 + B_1)\, X_2 - IntCompBas_2 - PutSubsidy_2$.

That is, both the net price received by and paid to participants include the forward price ($F_1 + B_1$) converted into pesos at the prevailing exchange rate (X_2). In addition, A×C participants receive the compensatory basis ($ProdCompBas_2 \geq 0$) and the call subsidy ($CallSubsidy_2 \geq 0$), whereas intermediaries get the intermediary compensatory basis ($IntCompBas_2 \geq 0$) and the put subsidy ($PutSubsidy_2 \geq 0$). The compensatory basis and the option subsidies create a gap between the net prices received by and paid to participants.[9]

The producer compensatory basis is an additional payment that participants receive when the post-harvest basis is higher than the forward basis. It is defined as

(3) $ProdCompBas_2 \equiv max(B_2 - B_1,\, 0)\, X_2$,

where $B_2 \equiv (P_{M\bar{G},2}/X_2 - F_2)$ is the realized post-harvest basis (expressed in dollars per crop unit). Similarly, the intermediary compensatory basis $IntCompBas_2 \equiv max(B_1 - B_2,\, 0)\, X_2$ is a subsidy paid to intermediaries when the realized post-harvest basis is smaller than the forward basis.

The call and put subsidies are given by

(4) $CallSubsidy_2 \equiv max[(1 - \omega_G) \, max(F_2 - F_1, 0), \, max(F_2 - F_1 - \omega_G \, Call_1, 0)] \, X_2,$

(5) $PutSubsidy_2 \equiv max[(1 - \omega_M) \, max(F_1 - F_2, 0), \, max(F_1 - F_2 - \omega_M \, Put_1, 0)] \, X_2,$

where $\omega_G \in [0, 1]$ and $\omega_G \in [0, 1]$ are A×C cost-recovery parameters, and $Call_1$ and Put_1 are respectively the time-1 premiums for the corresponding at-the-money CME futures calls and puts. The call (put) subsidy benefits participants (intermediaries) if futures rise (fall) between contracting and post-harvest.

The next two subsections discuss domestic farmers and intermediaries in greater detail, as A×C directly affects them. The last subsection addresses the welfare impact of A×C.

Domestic Crop Production

Let g index the type of farmers (i.e., $g = G$ and $g = \mathbb{G}$ refer to participants and non-participants, respectively). Following Lence (2009a), aggregate crop output by farmers of type g is given by $Q_{g,2} = n_g \, q_{g,2}$, where n_g is the number of type-g producers and $q_{g,2}$ is the corresponding average output per farmer. The amount produced equals $q_{g,2} = q_{g,0} \, \varepsilon_{g,1} \, \varepsilon_{g,2}$, where $q_{g,0} \equiv E_0(q_{g,2})$ is the expected output as of planting, and $\varepsilon_{g,1}$ and $\varepsilon_{g,2}$ represent the exogenous output shocks occurring between planting and post-harvest. Output shocks must be positive ($\varepsilon_{g,1}, \varepsilon_{g,2} \geq 0$) because output cannot be negative.

At planting, type-g farmers choose the level of expected output $q_{g,0}^*$ that maximizes the expected utility of their post-harvest profits $\pi_{g,2}(q) \equiv P_{g,2} \, q \, \varepsilon_{g,1} \, \varepsilon_{g,2} - C_g(q)$:

(6) $q_{g,0}^* \equiv argmax_q\{E_0[U_g(P_{g,2} \, q \, \varepsilon_{g,1} \, \varepsilon_{g,2} - C_g(q))]\}.$

In this expression, $U_g(\cdot)$ and $C_g(\cdot)$ denote, respectively, the von Neumann-Morgenstern utility function and the cost function of type-g farmers, and $P_{g,2}$ represents the net price received by

8

type-*g* producers at post-harvest. Cost function $C_g(\cdot)$ satisfies standard regularity conditions (e.g., $C_g(\cdot)$ is continuous, increasing, and convex).

Intermediaries

Letting $q_{mG,2}$, $q_{m\mathcal{G},2}$, and $q_{mW,2}$ be respectively the mth intermediary's crop acquisitions from participants, non-participants, and the world market, the amount of crop processed and sold by such firm in crop-equivalent units is $q_{mD,2} = q_{mG,2} + q_{m\mathcal{G},2} + q_{mW,2}$. Intermediary *m*'s post-harvest profits can be represented as:

(7) $\pi_{m,2} = P_{D,2}\, q_{mD,2} - C_{mD}(q_{mD,2}) - P_{MG,2}\, q_{mG,2} - P_{M\mathcal{G},2}\, q_{m\mathcal{G},2} - F_2\, X_2\, q_{mW,2} - C_{mW}(q_{mW,2}),$

where $P_{D,2}$ is the price of the final product, and functions $C_{mD}(\cdot)$ and $C_{mW}(\cdot)$ respectively represent the costs of processing the crop and the costs of the logistics involved in importing and having the crop ready for processing. Cost functions $C_{mD}(\cdot)$ and $C_{mW}(\cdot)$ satisfy standard regularity conditions.

Intermediaries take world prices and exchange rates as given, but they are aware that their decisions influence the prices they receive for the final product ($P_{D,2}$) and the net prices they pay to producers ($P_{Mg,2}$). Intermediaries' power in the procurement market effectively means that they take into account their impact on the forward basis (B_1) and the realized post-harvest basis (B_2), because $P_{M\mathcal{G},2} = (F_2 + B_2)\, X_2$ and $P_{MG,2} = [F_1 + min(B_1, B_2)]\, X_2 - PutSubsidy_2$ (which is obtained by plugging $IntCompBas_2 \equiv max(B_1 - B_2, 0)\, X_2$ into expression (2)).

At post-harvest ($t = 2$), intermediary *m*'s only decisions are the purchases from non-participants $(q_{m\mathcal{G},2})$ and from the world market $(q_{mW,2})$.[10] At an interior solution, the first-order conditions (FOCs) for the maximization of profits (7) (i.e., $\partial \pi_{m,2}/\partial q_{mW,2} = 0$ and $\partial \pi_{m,2}/\partial q_{m\mathcal{G},2} = 0$) can be expressed as:[11]

(8) $\quad P_{D,2} = \dfrac{1}{(1-\mu_{mD})} \left[\dfrac{\partial C_{mD}(q_{mD,2})}{\partial q_{mD,2}} + F_2 X_2 + \dfrac{\partial C_{mW}(q_{mW,2})}{\partial q_{mW,2}} \right],$

(9) $\quad B_2 = \dfrac{1}{[1+(1+\iota_{B_2<B_1} q_{mG,2}/q_{mG,2})\mu_{mG}]} \left\{ \dfrac{1}{X_2} \left[(1-\mu_{mD})\, P_{D,2} - \dfrac{\partial C_{mD}(q_{mD,2})}{\partial q_{mD,2}} \right] - F_2 \right\}.$

In the equations above, $\mu_{mD} \in [0, 1)$ represents intermediary m's power in the final product market,[12] $\mu_{mG} \geq 0$ denotes firm m's power in the market for non-participants' crop, and $\iota_{B_2<B_1}$ is the indicator function (equal to 1 if $B_2 < B_1$, and 0 otherwise). According to (8), the greater firm m's power in the market for final product, the larger its final product markup over marginal cost. Similarly, (9) implies that the larger μ_{mG} in equilibrium, the greater firm m's non-participant crop markdown relative to m's net marginal revenue.

The term $\iota_{B_2<B_1} q_{mG,2}/q_{mG,2}\mu_{mG}$ in expression (9) implies that the forward basis (B_1), contracted with participants at $t = 1$, may have a negative impact on the acquisitions from non-participants at $t = 2$. Such term originates from the intermediary compensatory basis scheme (*IntCompBas$_2$*), which effectively allows intermediaries to pay participants the smaller of the forward or the realized basis (i.e., $min(B_1, B_2)$). Intuitively, when intermediaries with market power increase purchases from non-participants, they end up paying a higher basis (B_2). The higher basis applies only to the amount bought from non-participants if $B_2 \geq B_1$, but it applies to purchases from both participants and non-participants if $B_2 < B_1$. As a result, if intermediaries have power in the procurement market ($\mu_{mG} > 0$), the compensatory basis scheme tends to depress the actual post-harvest (B_2) basis relative to the forward basis (B_1).

Conceptually, the post-harvest Cournot-Nash market equilibrium can be computed by simultaneously solving equations (8) and (9) for all intermediaries, under the restrictions that aggregate purchases from participants and non-participants equal the respective aggregate supplies.

At contracting time ($t = 1$), the decision problem faced by the mth intermediary is to choose the amount of crop to contract with participants $q_{mG,1} \equiv E_1(q_{mG,2})$, which commits firm m

to buy at post-harvest the actual participants' output $q_{mG,2} = q_{mG,1} \, \varepsilon_{G,2}$. Assuming that

intermediaries maximize expected post-harvest profits (7),[13] the corresponding FOC

$(\partial E_1(\pi_{m,2})/\partial q_{mG,1})$ at an interior solution can be written analogously to FOC (9) as follows:

$$(10) \quad B_1 = \frac{1}{[1 + \dfrac{E_1(\iota_{B_2 > B_1} X_2 \varepsilon_{G,2})}{E_1(X_2 \varepsilon_{G,2})} \mu_{mG}]} \; \{ \frac{1}{E_1(X_2 \varepsilon_{G,2})} E_1[(1 - \mu_{mD}) \, P_{D,2} \, \varepsilon_{G,2} - \frac{\partial C_{mD}(q_{mD,2})}{\partial q_{mD,2}} \varepsilon_{G,2}$$

$$+ \, max(B_1 - B_2, \, 0) \, X_2 \, \varepsilon_{G,2} + PutSubsidy_2 \, \varepsilon_{G,2}] - F_1 \}.$$

In the above expression, $\mu_{mG} \geq 0$ denotes firm m's power in the market for participants' crop. At

the optimum, the greater the value of μ_{mG}, the larger the forward basis markdown relative to m's

expected net marginal revenue. In the perfectly competitive case where $\mu_{mG} = 0$, the markdown

is zero and the forward basis equals firm m's expected net marginal revenue.

Comparison of (9) and (10) reveals two key differences between the forward basis (B_1)

and the realized basis (B_2) -- in addition, of course, to the fact that the former is established at

contracting ($t = 1$), whereas the latter is set at post-harvest ($t = 2$).[14] First, relative to the realized

basis, the forward basis is augmented by the expected values of the payments related to the basis

compensation scheme ($E_1[max(B_1 - B_2, \, 0) \, X_2 \, \varepsilon_{G,2}]$) and the put subsidy ($E_1(PutSubsidy_2 \, \varepsilon_{G,2})$).

Second, intermediaries' procurement market power (μ_{mg}) has greater impact on the realized basis

than on the forward basis.

The preceding discussion also shows that, to the extent that intermediaries have market

power in the domestic crop market, the intermediary compensatory basis ($IntCompBas_2$)

provides an incentive for them to strategically discriminate against non-participants in favor of

participants. In the absence of such discrimination, the first term on the right-hand side of (9)

would be $1/(1 + \mu_{mG})$, and its counterpart in (10) would equal $1/(1 + \mu_{mG})$.

Best contracting responses for each intermediary can be obtained in the same manner as

previously described in connection with expressions (8) and (9), providing as many equations as

unknowns. In principle, the Cournot-Nash market equilibrium at contracting ($t = 1$) can be derived from such set of equations, plus the restriction that the total amount contracted with participants must equal their expected aggregate output $Q_{G,1} = E_1(Q_{G,2})$.

Measures of A×C's Welfare Effects

The welfare effects of A×C on participants, non-participants, intermediaries, and final consumers are measured by the respective post-harvest compensating incomes $\overline{\overline{Y}}_{i,2}$ for $i \in \{G, \mathcal{G}, D, M\}$. To calculate compensating income $\overline{\overline{Y}}_{i,2}$, compare (a) the scenario without A×C, with (b) an alternative scenario incorporating A×C, but subtracting the fixed amount $Y_{i,2}$ from the post-harvest income of agents in group i. Define scalars $\overline{U}_i$ and $\overline{\overline{U}}_i(Y_{i,2})$ as group i agents' expected utility in market equilibrium under scenarios (a) and (b), respectively.[15] Then, the post-harvest compensating income $\overline{\overline{Y}}_{i,2}$ is the certain income implied by the equality $\overline{U}_i = \overline{\overline{U}}_i(\overline{\overline{Y}}_{i,2})$. In other words, subtracting the amount $\overline{\overline{Y}}_{i,2}$ from post-harvest income under A×C leaves agents in group i indifferent between having the program and not having it.[16]

Taxpayers' direct subsidy outlays for A×C are:

(11) $T_2 = Q_{G,2} \, max(B_2 - B_1, B_1 - B_2) \, X_2$

$+ \, Q_{G,2} \, \{exp[r \, (t_2 - t_1)] \, Call_1 - \omega_G \, min[max(F_2 - F_1, 0), Call_1]\} \, X_2$

$+ \, Q_{G,2} \, \{exp(r \, (t_2 - t_1)) \, Put_1 - \omega_M \, min[max(F_1 - F_2, 0), Put_1]\} \, X_2,$

where r is the risk-free interest rate. The first term corresponds to the compensatory basis payments, whereas the terms comprising $Call_1$ and Put_1 arise from the option subsidies to participants (calls) and intermediaries (puts). Assuming taxpayers are risk-neutral, the compensating income associated with the direct subsidies (T_2) equals the negative of the mean outlays.

Importantly, A×C's total cost comprises not only the direct subsidy outlays (T_2), but also the administrative cost of operating the program, and the marginal deadweight loss of raising the

tax revenues needed to implement A×C. The latter, also called the marginal cost of public funds, is the burden on the rest of the economy arising from the distortions, due to the taxes imposed to raise the funds to support the intervention (Auerbach and Hines 2002).

Numerical Implementation for Mexico's Corn Market

The model is applied to quantify the market and welfare effects of the A×C program for corn, which is Mexico's main crop. This requires the specification of the various functions involved, including the probability density functions (pdfs) of the exogenous random shocks, and of appropriate values for the underlying parameters. To this end, it is also important to consider numerical issues, such as the choice of methods to compute optimal values and expectations, as well as practical considerations, like parameterization and workability.[17] These topics are the focus of the next subsections.

Specification of Functional Forms

Consistent with an equilibrium displacement framework, cost functions are postulated to be isoelastic, so that $C_i(x) = \kappa_i \, x^{\eta_i}$ for $i \in \{G, G, mD, mW\}$.[18] The term $\kappa_i > 0$ is a scaling parameter, and η_i is the cost elasticity. The marginal cost elasticity is given by $(\eta_i - 1)$; hence, $\eta_i > 1$ is required for increasing marginal costs, and $\eta_i \geq 2$ is necessary for marginal cost to rise at an increasing rate. Under certainty and perfect competition, the supply elasticity equals the inverse of the marginal cost elasticity, which facilitates the interpretation and parameterization of η_i.

An isoelastic function is also used to represent aggregate demand from final consumers, $Q_{D,2} = \kappa_D \, P_{D,2}^{-\eta_D} \, \varepsilon_{D,1} \, \varepsilon_{D,2}$, where $\kappa_D > 0$ is a scaling parameter and $\eta_D > 0$ is the own-price demand elasticity. Terms $\varepsilon_{D,1} > 0$ and $\varepsilon_{D,2} > 0$ are exogenous random shocks to demand (e.g., unexpected changes in consumers' income). Without loss of generality, the demand shock expectations satisfy the conditions $E_0(\varepsilon_{D,1}) = E_0(\varepsilon_{D,2}) = E_1(\varepsilon_{D,2}) = 1$.

As in Lence (2009a), farmers' utility functions are specialized to the constant absolute risk aversion (CARA) form, i.e., $U_g(\pi) = [1 - exp(-\lambda_g \pi)]/\lambda_g$ for $g \in \{G, \mathcal{G}\}$, where parameter λ_g is type-g farmers' coefficient of absolute risk aversion. Risk neutrality is a limiting case of this CARA utility, since $lim_{\lambda \to 0}\{[1 - exp(-\lambda \pi)]/\lambda\} = \pi$. Results are robust to changes in the specification of the utility function, as long as the levels of relative risk aversion (defined as $-\pi U''(\pi)/U'(\pi)$) are kept similar and the risks involved are neither too large nor too asymmetric (Černý 2004; Lence 2009b).

Futures prices and exchange rates evolve according to $F_t = F_{t-1} \varepsilon_{F,t}$ and $X_t = X_{t-1} \varepsilon_{X,t}$ for $t \in \{1, 2\}$, with F_0, X_0, and random shocks $\varepsilon_{F,t} > 0$ and $\varepsilon_{X,t} > 0$ exogenously given.[19] The exogenous shocks $\varepsilon_{F,t} > 0$ and $\varepsilon_{X,t} > 0$ represent unexpected events taking place between times t and $(t-1)$, and are identically and independently log-normally distributed. That is, letting $N(u, v^2)$ denote the normal distribution with mean u and variance v^2, $ln(\varepsilon_{i,\tau})$ i.i.d. $N(-0.5\ \sigma_i^2\ (t_\tau - t_{\tau-1}), \sigma_i^2\ (t_\tau - t_{\tau-1}))$ for $i \in \{F, X\}$ and $\tau \in \{1, 2\}$. Parameter σ_i is the volatility per unit of time (i.e., σ_i is the annual volatility if time is measured in years). Since $E(\varepsilon) = exp(u + 0.5\ v^2)$ if $ln(\varepsilon) \sim N(u, v^2)$, the assumed pdfs satisfy the conditions $E_0(\varepsilon_{i,1}) = E_0(\varepsilon_{i,2}) = E_1(\varepsilon_{i,2}) = 1$ for $i = \{F, X\}$. In other words, futures prices and exchange rates are unbiased.

Similarly, the exogenous random demand shocks, $\varepsilon_{D,t}$ ($t \in \{1, 2\}$), are identically and independently log-normally distributed. In contrast, following the seminal work by Nelson and Preckel (1989), the exogenous output shocks $\varepsilon_{g,t}$ ($g \in \{G, \mathcal{G}\}$ and $t \in \{1, 2\}$) are assumed to be conditionally beta distributed. Note that the beta distribution implies that the pdf of output shocks at $t = 2$ depends on the realized output shock at $t = 1$ (intuitively, since beta-distributed shocks have a finite support, if $\varepsilon_{g,1}$ is high, the distribution of the corresponding $\varepsilon_{g,2}$ must display higher probabilities of small shocks than if $\varepsilon_{g,1}$ is small; see, e.g., Hennessy (2011)).

Finally, consistent with the log-normally distributed futures, the at-the-money futures calls ($Call_1$) and puts (Put_1) involved in the option subsidies (see expressions (4), (5), and (11)) are assumed to be traded at "fair" values, i.e., Black's arbitrage-free premiums (Black 1976).

Parameterization and Calibration

The values used for non-calibrated parameters are reported in table 1. Such values represent estimates based on (a) historical data (e.g., length of planting/contracting and contracting/post-harvest periods, and parameters of shocks' pdfs), or (b) reasonable assumptions about the underlying objects (e.g., cost elasticities and own-price elasticity of demand for final product).

All intermediaries are assumed to have the same cost functions, so that $\kappa_{mD} = \kappa_{MD}$ and $\eta_{mD} = \eta_{MD}$ for all m. The equilibrium amounts bought, processed, and sold by individual intermediaries are the symmetric pure-strategy Nash-Cournot equilibrium responses, and the solution is unique under the stated assumptions. Since by construction the equilibrium level of market power must be identical for all intermediaries, market power is taken to be a parameter to make the numerical solution tractable, with $\mu_{mD} = \mu_{MD}$, $\mu_{m\mathbb{G}} = \mu_{M\mathbb{G}}$, and $\mu_{mG} = \mu_{MG}$ for all m.

As formulated in Section 2, the model implies that the vast majority of the years would be characterized by compensatory basis payments to intermediaries rather than participants (i.e., $B_1 > B_2$). However, this implication is contradicted by the historical record, as that there have been more years featuring $B_1 < B_2$ than $B_1 > B_2$.[20] Therefore, to reconcile the model results with the historical evidence, the constraint $B_1 \leq E_1(B_2)$ was added. This restriction ensures that, on average, the compensatory basis received by participants is at least as large as the compensatory basis received by intermediaries.

For the simulations assuming risk-averse producers, the coefficient of absolute risk aversion is standardized by setting it equal to $\hat{\lambda}_g = 3.1/E_0(\pi_{g,2}^{A \times C})$, where $\pi_{g,2}^{A \times C}$ denotes the equilibrium post-harvest profits for g-type producers in the A×C scenario.[21] This approach follows Lence (2009a) and ensures that the expected coefficient of relative risk aversion is exactly 3.1 under A×C (which is the scenario used for the calibration), and very close to 3.1 in the scenario without A×C. This value is used by Zant (2001, p. 700), and is well within the range considered typical (Gollier 2001, pp. 31 and 289; Kocherlakota 1996).

The number of farmers (n_g) can be chosen arbitrarily because, as explained in the next paragraph, production cost scaling parameters κ_g ($g \in \{G, \mathbb{G}\}$) are set by calibration.[22] Hence, to

facilitate computations, the number of farmers is set equal to the mean aggregate output used for calibration (i.e., $\hat{n}_g = \overline{Q}_{g,2}$, as shown in tables 1 and 2).[23]

To ensure that the model yields endogenous quantities consistent with the historical record, values for the scaling parameters of the demand and cost functions κ_i ($i \in \{D, G, \mathbb{G},$ $MD, MW\}$) are obtained by calibration. The five scaling parameters are calibrated to make the model's five endogenous variables listed in table 2 equal to their respective historical averages.[24] Thus, running the model under the A×C parameterization shown in table 1 yields the expected output, expected imports, and expected prices reported in table 2.

Numerical Methods to Compute the Solution

To compute the rational expectations of the model's endogenous variables (e.g., output and prices) at planting-time, one must first solve for the market equilibrium conditions under each possible state of the world at contracting and post-harvest times. This task is non-trivial, because the model has no closed-form solution and is highly nonlinear.

To compute expectations, the exogenous random shocks' pdfs are approximated by Gaussian quadrature (Judd 1998), so that each state of the world is represented by a quadrature node. Letting $\#_{i,t}$ denote the number of nodes corresponding to exogenous random variable $\varepsilon_{i,t}$ ($i \in \{G, \mathbb{G}, F, X, D\}$ and $t \in \{1, 2\}$), solving the model requires calculating $\#_t \equiv \#_{G,t} \times \#_{\mathbb{G},t} \times \#_{F,t} \times \#_{X,t} \times \#_{D,t}$ equilibrium values for each of the endogenous variables at $t \in \{1, 2\}$. Since the computational burden increases exponentially with the number of nodes, to obtain an acceptable level of accuracy while maintaining tractability, $\#_{i,t} = 3$ nodes were used for $i \in \{G, \mathbb{G}, F, X, D\}$ and $t \in \{1, 2\}$.

The model was solved numerically by function iteration (Miranda and Fackler 2002, Ch. 3), employing the programming language MATLAB version R2014a 64-bit. The iteration steps are outlined in the Online Appendix C, and the Gaussian quadrature was implemented with the computer routines developed by Miranda and Fackler (2013).

Results and Discussion

In the interest of space, we focus on the impact of introducing A×C into a scenario without government intervention, for selected parameterizations. Further, it is assumed that neither participants nor intermediaries would buy CME futures options if it weren't for the A×C subsidies.[25]

The market effects caused by the introduction of A×C are summarized in table 3. To illustrate the contents of this table, consider the cell at the intersection of the "Net Prices Received by Participants" row with the "Risk-Averse Producers" column. This cell shows that, compared to the no-program scenario, A×C increases the mean of the net corn price received by participants by 4.8%, and reduces its standard deviation by 14.5%. Analogously, the 10%, 50%, and 90% quantiles of the pdfs of the net corn price received by participants are respectively 11.1% higher, 2.4% higher, and 1.4% smaller under A×C.

The most noticeable price effects of A×C are the increase in the mean net price received by participants (4.8% to 5.3%), the even larger fall in the mean net price paid to participants (5.6% to 6.0%), and the substantial reductions in their standard deviations (14.5% to 18.5% for prices received, and 28.8% to 32.2% for prices paid). The mean and standard deviation of the net prices received by and paid to non-participants also decrease, but by smaller amounts. Since A×C reduces the mean and the standard deviations of the prices paid to both participants and non-participants, intermediaries benefit regardless of the type of farmers from whom they buy.

The quantile changes reveal that the higher (lower) mean and the lower standard deviation in the net price received by (paid to) participants stems mostly from the smaller probability of occurrence of low (high) prices. Figure 2 provides a visual representation of this effect, showing that A×C makes the pdfs of the net prices received by (paid to) participants much less skewed to the left (right).

A×C causes output to rise for participants, and fall for non-participants (see table 3). Under risk-neutrality, the resulting own-price supply elasticity is approximately 0.67 (= 3.6/5.3 for participants and = −0.3/(−0.5) for non-participants), which is the value one would obtain

under certainty given the assumed production cost elasticity (see Subsection 3.1). In contrast, output changes under risk aversion imply supply elasticities larger than 0.67 for participants and smaller than 0.67 for non-participants. Such difference in price elasticities is caused by the lower price volatility associated with A×C, which tends to increase production for both participants and non-participants under risk aversion. This volatility effect reinforces (partly offsets) the output response of participants (non-participants) to the program's higher (lower) prices.

The impact of A×C on domestic consumption is positive, but negligible. Regardless of risk preferences, imports fall due to the rise in aggregate domestic output. However, the contraction in imports is larger when farmers are risk averse, because of the aforementioned positive production response to lower price volatility.

A×C has a substantial impact on profits. Mean profits for participants and intermediaries experience a sizeable boost (of 8.5% to 9.2% and 4.0% to 5.3%, respectively), whereas mean profits for non-participants decline (by 0.7% to 1.5%).

Welfare Effects

To interpret the welfare results, it is important to note that government intervention in the present model may enhance total net surplus for two reasons. First, the scenario without A×C assumes that intermediaries have market power, i.e., it is not a first-best market outcome. Thus, A×C may increase total net surplus if it moves equilibrium outcomes closer to the intervention-free competitive equilibrium (e.g., Romano 1988). Second, when producers are risk-averse, interventions that transfer farmers' risks to risk-neutral intermediaries and/or taxpayers, like A×C does, may enhance aggregate welfare if the gains associated with the transfers outweigh the standard allocative inefficiency losses (i.e., the standard deadweight loss triangles).

A×C's welfare effects are summarized in table 4. Results are reported for two levels of intermediaries' market power to investigate its impact (recall that table 3 is computed using μ_{MD} = 0.1 and $\mu_{MG} = \mu_{M\tilde{G}} = 0.2$). The "Society" row contains the deadweight losses arising from the taxes levied to raise the revenues needed to pay for the direct subsidies and their administration

costs. Such losses are listed separately, because no information is available to allocate them among the other sectors.

Considering the lower level of market power first, table 4 shows that A×C leads to total surplus losses ranging from 56 million dollars under risk aversion to 70 million dollars under risk neutrality. The main beneficiaries are participants (who gain between 92 and 95 million dollars) and intermediaries (who gain between 84 and 110 million dollars). The biggest losses are experienced by taxpayers, who pay 202 million dollars in direct subsidies (184 million dollars) and program administration (18 million dollars). Non-participants lose between 3 million dollars under risk neutrality and 12 million dollars under risk aversion. In addition, raising taxes to fund A×C costs society 50 million dollars in deadweight losses.

Regardless of risk preferences, doubling intermediaries' procurement market power increases A×C's losses to non-participants, reduces the benefits to participants, and raises taxpayers' costs and society's deadweight losses from tax collection. Contrastingly, higher market power significantly boosts intermediaries' gains. In fact, doubling market power in the presence of risk-averse producers raises intermediaries' gains by 26 (= 136 − 110) million dollars, which exceeds the benefit reductions and/or loss increases accruing to all of the other sectors combined (22 million dollars). As a result, somewhat counterintuitively, the scenario with higher intermediaries' market power has a smaller total net surplus loss (52 million dollars vs. 56 million dollars).

Participants' welfare gains are slightly smaller under risk aversion than under risk neutrality. This result is explained by the fact that under risk aversion A×C increases participants' mean profits by less than under risk neutrality, and it slightly increases the standard deviation of participants' profits (see table 3). Non-participants also experience greater welfare losses under risk aversion compared to risk neutrality. Given the profit figures reported in table 3, this outcome implies that for non-participants, the loss in mean profits caused by A×C outweighs the benefits associated with the smaller standard deviation of profits.

Overall, risk aversion has a positive and sizeable effect on total net surplus, but not large enough to revert the program's negative impact on total welfare. If the main purpose of the government intervention is to reduce producers' risks, A×C seems an expensive and inefficient way to achieve that goal.[26]

Despite the substantial transfers across sectors associated with A×C, the standard deadweight loss triangles (i.e., the deadweight losses assuming risk neutrality, and ignoring administrative costs and the costs of raising public funds) are small. The large import cost elasticity adopted for the simulations implies that, leaving aside administrative costs and the costs of raising public funds, the main deadweight losses are due to overproduction by participants and underproduction by non-participants. Evaluated at the means, participants' standard deadweight loss triangle amounts to less than 2 million dollars, and non-participants' loss triangle is even smaller.[27] Clearly, the standard deadweight loss triangles are dwarfed by the administrative cost and the allocative inefficiencies on the general economy induced by the taxes levied to fund A×C.

Welfare Effects when A×C Reduces Intermediaries' Market Power

The preceding analysis assumes that intermediaries' market power, when procuring crops from domestic producers, is the same in the scenario with A×C ($\mu_{Mg}^{A \times C}$) as in the scenario without A×C ($\mu_{Mg}^{\overline{A \times C}}$), i.e., $\mu_{Mg}^{A \times C} = \mu_{Mg}^{\overline{A \times C}}$. However, A×C may reduce intermediaries' procurement market power, in which case $\mu_{Mg}^{A \times C} < \mu_{Mg}^{\overline{A \times C}}$.[28] For example, the negotiations to determine the A×C forward basis include government officials and representatives of participants, which may weaken intermediaries' ability to pay low prices.

If A×C does diminish intermediaries' market power, table 4 need not accurately reflect its impact on welfare. To provide insights on this issue, simulations were performed assuming that intermediaries' market power falls from $\hat{\mu}_{Mg}^{\overline{A \times C}}(\mu_{Mg}^{A \times C})$ without A×C to $\mu_{Mg}^{A \times C} < \hat{\mu}_{Mg}^{\overline{A \times C}}(\mu_{Mg}^{A \times C})$ under A×C. For a given value of $\mu_{Mg}^{A \times C}$, the no-A×C market power $\hat{\mu}_{Mg}^{\overline{A \times C}}(\mu_{Mg}^{A \times C})$ is obtained by calibration, so as to leave intermediaries indifferent about joining A×C. The rationale for

defining $\hat{\mu}_{Mg}^{A \times C}(\mu_{Mg}^{A \times C})$ in this manner is that intermediaries would (not) voluntarily take part in A×C if doing so changed their market power from $\mu_{Mg}^{A \times C} < (>) \hat{\mu}_{Mg}^{A \times C}(\mu_{Mg}^{A \times C})$ to $\mu_{Mg}^{A \times C}$, as the gains from subsidies would outweigh (be outweighed by) the losses from the reduced market power.

Assuming voluntary participation by intermediaries, the maximum reduction in market power that A×C can achieve equals ($\hat{\mu}_{Mg}^{A \times C}(\mu_{Mg}^{A \times C}) - \mu_{Mg}^{A \times C}$). More importantly, when market power under A×C equals $\mu_{Mg}^{A \times C}$, producers' gains relative to the $\hat{\mu}_{Mg}^{A \times C}(\mu_{Mg}^{A \times C})$ scenario constitute an upper bound for the producers' benefits from A×C. Therefore, if A×C's objective is to enhance producers' well-being, comparing the $\hat{\mu}_{Mg}^{A \times C}(\mu_{Mg}^{A \times C})$ and $\mu_{Mg}^{A \times C}$ scenarios is useful because it provides upper bounds on the targeted population's benefits.

Table 5 reports welfare results when A×C induces the maximum feasible cut in the market power of intermediaries. To facilitate comparisons, results corresponding to no change in market power are shown within brackets. Panel A (B) shows that if market power is $\mu_{Mg}^{A \times C} = 0.1$ (0.2) under A×C, the upper bound on intermediaries' market power without A×C equals $\hat{\mu}_{Mg}^{A \times C}(0.1) = 0.184$ ($\hat{\mu}_{Mg}^{A \times C}(0.2) = 0.321$) under risk-neutrality, and $\hat{\mu}_{Mg}^{A \times C}(0.1) = 0.207$ ($\hat{\mu}_{Mg}^{A \times C}(0.2) = 0.346$) under risk aversion. By construction, intermediaries' surplus is unchanged if A×C reduces their market power by the maximum feasible amount. Contrastingly, if market power remains the same after introducing A×C, intermediaries gain substantial amounts. For example, if producers are risk-averse and market power stays unchanged at $\mu_{Mg}^{A \times C} = \hat{\mu}_{Mg}^{A \times C}(0.2) = 0.346$, introducing A×C benefits intermediaries by 153 million dollars.

When A×C cuts market power as much as feasible, the main beneficiaries are participants, followed by non-participants; consumers benefit the least. The gains to participants, non-participants, and consumers, the taxpayers' losses, and the costs of public funds are all larger under $\mu_{Mg}^{A \times C} = 0.2$ than under $\mu_{Mg}^{A \times C} = 0.1$. Overall, however, the changes in surpluses for individual sectors are remarkably similar across the two panels.

The surplus changes computed by assuming market power is reduced, minus the surplus changes calculated under the assumption that A×C leaves market power the same, can be termed the marginal gains from reducing market power. Such gains are quite large for producers, and

greater for non-participants than for participants.[29] Marginal gains are smaller but still sizeable for consumers.

Significantly, even under the extreme assumption that A×C reduces market power as much as possible, the program causes sizeable total losses. Moreover, if producers are risk averse, the total loss is larger for the scenario with the maximum market power reduction (57 to 62 million dollars) than for the scenario where market power is unchanged (50 million dollars). In short, the efficiency gains from reducing intermediaries' market power are small relative to the cost of A×C. As a result, A×C has a substantial negative impact on total surplus, regardless of whether it reduces intermediaries' market power or not.

Conclusions

To the best of our knowledge, this is the first study to perform market and welfare effects of Mexico's A×C program. A×C not only has involved substantial government expenditures in recent years, but also exhibits unique features, like the provision of basis subsidies and subsidized CME futures options to both producers and intermediaries. To capture A×C's key characteristics, the proposed model incorporates uncertainty, and includes intermediaries possessing market power. The model also allows participants and intermediaries to sign A×C forward contracts after planting, but before harvest.

Our analysis focuses on Mexico's corn market. A×C shifts the pdf of the net price received by participants to the right and makes it more right-skewed, whereas it has the opposite effect on the pdf of the net prices paid by intermediaries to participants. Overall, the mean net price received by (paid to) participants increases by about 5% (decreases by almost 6%), and the mean net prices received by non-participants decline by approximately 1%. A×C also reduces the standard deviation of the prices received by producers and paid by intermediaries. The impact on profits is substantial: mean profits jump by around 9% for participants, and 4% to 5% for intermediaries, but shrink by about 1% for non-participants.

Assuming that A×C does not change intermediaries' market power, it is estimated to yield annual losses in aggregate welfare of about 50 (70) million dollars if producers are risk-averse (risk-neutral). If anything, such figures are likely to underestimate the actual losses, because very conservative assumptions are used to compute administration costs and the marginal cost of public funds. In addition, it is assumed that the government purchases the CME futures options for the A×C program at "fair" values and without incurring transaction costs.

Intermediaries and participants benefit the most from A×C. Taxpayers are the biggest losers, spending almost 200 million dollars in direct subsidies alone, plus the sizable administration costs. Non-participants also suffer large surplus losses. In addition, society as a whole experiences substantial inefficiency losses due to the need to collect taxes to fund A×C.

Importantly, even if A×C reduced intermediaries' market power to the largest extent feasible, it would still cause substantial losses in aggregate welfare. In such circumstances, however, introducing A×C would benefit all producers (both participants as well as non-participants) the most, while leaving intermediaries' surplus unchanged.

Some other aspects of A×C also deserve attention. For example, A×C contracts fix dollar-denominated forward prices, which leaves producers and intermediaries exposed to foreign exchange risk. More importantly, unless one is willing to assume that A×C is able to significantly curtail intermediaries' market power, the program is quite regressive, as most of its benefits are captured by intermediaries (which are typically large firms).

In summary, despite A×C's novel features, the present analysis suggests that it causes substantial losses in aggregate economic surplus for the case of corn. Neither the mitigation of price risks nor the reduction in intermediaries' market power seem capable of yielding producer surplus gains large enough to compensate for A×C's significant cost. Hence, it would seem necessary to invoke other types of benefits to justify the program from an economic standpoint. Such benefits might include, among others, fostering the development of local derivative markets by familiarizing farmers with hedging instruments commonly used in developed countries, enhancing farmers' terms of financing through intermediaries, and making farmers more willing

to switch to higher revenue crops if they are under A×C. Measuring the extent of such benefits would be an important area of inquiry for future research regarding the A×C program.

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Endnotes

1. To streamline the exposition, in the rest of the article U.S. dollars will be referred to simply as "dollars."

2. It must be pointed out, however, that numerous studies (e.g., Steffen and Echánove 2007, Fox and Haight 2010, Verteramo Chiu and Turvey 2014, and Appendini 2014) have addressed other aspects of A×C.

3. In the present study, the term "intermediaries" is used to refer generically to firms involved in the assembling, handling, and processing of raw commodities acquired from primary producers, and the distribution of processed products sold to final consumers.

4. Intermediaries' market power proved to be a recurrent theme in the numerous interviews were conducted with individuals involved in the operation of the A×C program. Anecdotal evidence (The Economist 2007, CEIA 2007) and formal econometric analysis (DGIB 2012) suggest that intermediaries possess market power in Mexico's corn market. According to DGIB (2012), the market is concentrated among very few firms importing, storing, and commercializing corn, and there are barriers to the entry of new competitors. In the case of corn flour, the market share of the two largest producers has exceeded 90%. In addition, DGIB (2012) shows that there is a large number of regulations that limit competition in many local markets.

5. For simplicity, in the remainder of the article "peso" will be used instead of "Mexican peso."

6. "Ingreso objetivo" paid out much less than A×C because market prices were typically above the set minimum prices.

7. More specifically, the areas planted with corn, sorghum, and wheat were respectively 69%, 18%, and 8% of the total.

8. The ratio of ending stocks to annual consumption for corn ranged from 0.093 to 0.163 over the period 2007-2010 (SIAP 2009, 2010). The ratio of speculative storage demand to current consumption demand must have been even smaller than such figures, because ending stocks comprise working stocks in addition to speculative stocks (Kohls and Uhl 1990). Although in

practice it is impossible to determine the share of ending stocks held for speculative purposes, it is unlikely to be high because of the deficiencies in storage infrastructure (SAGARPA 2010b). For example, a study by the World Bank (2007, p. 8) concluded that 'Mexico's storage infrastructure does not meet minimum standards, and lacks competency and instruments to finance stocks in warehouses.' (translation of ours).

9. As explained in the previous section, farmers (intermediaries) are legally obligated to deliver (receive) the crop under A×C's forward contracts. For modeling purposes, penalties for failing to fulfil the contract are considered to be high enough to eliminate the incentive to not comply.

10. Purchases from participants ($q_{mG,2}$) and sales of final product ($q_{mD,2}$) are not post-harvest choices, because the former are committed at contracting time ($t = 1$), and the latter are given by $q_{mD,2} = q_{mG,2} + q_{m\mathcal{G},2} + q_{mW,2}$.

11. Firm m's profits (7) are a function of $min(B_1, B_2)$. Therefore, under the assumption that intermediaries consider the effect of their choices at time $t = 2$ on the post-harvest basis B_2, firm m's profits are differentiable with respect to $q_{m\mathcal{G},2}$ everywhere except at the point $B_1 = B_2$. More specifically, $\partial min(B_1, B_2)/\partial B_2$ equals 0 if $B_1 < B_2$ and 1 if $B_1 > B_2$, but does not exist if $B_1 = B_2$. As a result, if the optimum $q_{m\mathcal{G},2} = q^*_{M\mathcal{G},2}$ $q^*_{M\mathcal{G},2}$ is such that $B_2(q^*_{M\mathcal{G},2}) \neq B_1$, then $\partial \pi_{m,2}/\partial q_{m\mathcal{G},2}$ evaluated at $q_{m\mathcal{G},2} = q^*_{M\mathcal{G},2}$ does exist and FOC (9) holds. In contrast, FOC (9) does not exist if $B_2(q^*_{M\mathcal{G},2}) = B_1$ (but the right- and left-hand derivatives $\partial \pi_{m,2}/\partial q_{m\mathcal{G},2}$ evaluated at $q_{m\mathcal{G},2} = q^*_{M\mathcal{G},2}$ do exist and are negative and positive, respectively). The non-existence of the derivative $\partial min(B_1, B_2)/\partial B_2$ at $B_1 = B_2$ is a technical issue that can be avoided altogether by substituting $min(B_1, B_2)$ by a smooth approximating function equivalent at the limit to $min(B_1, B_2)$ (Chen 1985, and Yang 1995). Therefore, the rest of the discussion will proceed as if $min(B_1, B_2)$ were differentiable everywhere.

12. In the standard textbook specification (e.g., Tirole 1988, p. 219), μ_{mD} is defined as firm m's market share divided by the own-price elasticity of demand. At the FOCs corresponding to the Cournot-Nash equilibrium, μ_{mD} equals firm m's Lerner index (Lerner 1934).

13. The case of risk-averse intermediaries is not analyzed because it is not workable. However, risk-neutrality is a reasonable approximation because intermediaries are much better able to diversify risks than producers.

14. In the Online Appendix A, a highly simplified version of the model is used to show the key drivers of basis risk.

15. The pdfs underlying the expectations of endogenous variables in scenarios (a) and (b) are different. Hence, $\bar{U}_i$ and $\bar{\bar{U}}_i(Y_{i,2})$ are computed by employing the pdfs corresponding to the respective scenarios.

16. Intermediaries' risk-neutrality implies that their compensating income can be calculated as simply $\bar{\bar{Y}}_{M,2} = \bar{\bar{U}}_M - \bar{U}_M$, where $\bar{\bar{U}}_M$ ($\bar{U}_M$) denotes intermediaries' mean post-harvest profits in the presence (absence) of A×C. Similarly, the isoelastic demand used in the present application (see Subsection 3.1 below) can be derived from a quasilinear utility; therefore, consumers' compensating income can be calculated as $\bar{\bar{Y}}_{D,2} = \bar{\bar{U}}_D - \bar{U}_D$, where $\bar{\bar{U}}_D$ and $\bar{U}_D$ represent, respectively, the mean consumer surpluses under scenarios (a) and (b) (Lence 2009a).

17. For example, the cost and demand functions discussed below are chosen because values for their parameters (elasticities and scaling factors) can easily set and interpreted based on actual data and previous studies. More involved functional forms can be used, but typically their parameterization is not as straightforward.

18. Cost functions are assumed to be non-stochastic to avoid the curse of dimensionality. Stochastic costs could be obtained by incorporating multiplicative exogenous random shocks $\varepsilon_{i,t} > 0$ with expectations $E_0(\varepsilon_{i,1}) = E_0(\varepsilon_{i,2}) = E_1(\varepsilon_{i,2}) = 1$.

19. In other words, the A×C program is assumed to have no effect on the world crop market or the exchange rate.

20. Uncovering the reasons why intermediaries' incentives have not materialized into larger (on average) compensatory basis payments to them instead of participants is beyond the scope of the present study. One plausible reason might be that under A×C both the forward basis as

well as the post-harvest basis are negotiated by representatives of intermediaries, participants, and government officials. Such mechanism may prevent intermediaries from setting bases so as to receive compensatory basis payments most of the years.

21. To allow for the possibility of non-participants being less risk averse than participants, we also conducted simulations assuming risk-neutral non-participants ($\hat{\lambda}_G = 0$) and risk-averse averse participants with $\hat{\lambda}_G = 3.1 / E_0(\pi_{G,2}^{A \times C})$. Results are omitted in the interest of space, but are available in the Online Appendix B.

22. The value chosen to parameterize the number of farmers is arbitrary, because any change to it will be offset by a change in the calibrated value of κ_g, so as to leave aggregate mean output $\bar{Q}_{g,2}$ the same.

23. Since in theory A×C has no downside for producers, all of them would participate if they could do so. In reality, however, participation involves registration and other costs that make the program less appealing or out of reach for small farmers (Steffen and Echánove 2007), and the scope of A×C is limited by government budget constraints (Echánove 2009). As a result, actual data indicate that participants are "commercial" producers, whereas non-participants are small farmers (Echánove 2009). The model assumes that at planting time farmers know whether they will be able to participate or not.

24. The calibration is performed under the A×C parameterization, because the historical observations correspond to a period when the A×C program was in place.

25. The merits of providing government subsidies to promote the use of risk management tools already available (such as CME futures options) are debatable. However, if the tools were not used without the subsidies, the latter would be easier to rationalize (e.g., one might argue that the subsidies help familiarize agents with hedging instruments). Hence, although it is straightforward to perform the no-A×C simulations allowing for hedging, we restrict attention to the no-A×C scenario where neither participants nor intermediaries trade derivatives. The case analyzed is also the most interesting, as it involves the largest market and welfare effects across all sectors. If one assumes that participants and intermediaries buy

options even if subsidies are not provided, A×C's market and welfare impacts are less pronounced. In the limiting no-A×C case where participants and intermediaries are fully hedged with options, introducing option subsidies would have essentially no effect in the amount produced by participants, and consequently little impact on imports, consumption, and non-participants' output. In such instance; the subsidies would simply be pure transfers from taxpayers and society to participants and intermediaries, with no consequences for non-participants or consumers.

26. An anonymous reviewer noted that Verteramo Chiu and Turvey's market-based quanto options (Verteramo Chiu and Turvey 2014), which require no taxpayers' money, could provide an alternative price hedging mechanism to A×C.

27. These triangles are computed as one-half of the product of the change in mean output times the change in the mean net price received. For participants, such calculations yield [0.5 × (3.6% × 7.14 million tn) × (5.3% × 2,815 pesos/tn)] under risk neutrality and [0.5 × (3.9% × 7.12 million tn) × (4.8% × 2,825 pesos/tn)] under risk aversion. The corresponding figures for non-participants are [0.5 × (−0.3% × 15.44 million tn) × (−0.5% × 2,815 pesos/tn)] and [0.5 × (−0.3% × 15.44 million tn) × (−1.0% × 2,825 pesos/tn)]. To facilitate interpretation, values in pesos are reported in dollars, assuming an exchange rate of 12 pesos per dollar.

28. This possibility is of more than academic interest. In personal interviews held with various stakeholders, the reduction of intermediaries' market power was often cited as a positive feature of A×C by its supporters.

29. For example, in Panel A the marginal gains for risk-averse non-participants and participants are respectively 74 (= 53 − (−21)) and 37 (= 122 − 85) million dollars.

Table 1. Values of Non-Calibrated Parameters

Planting/contracting period:[a] $(t_1 - t_0) = 1.5/12$ years

Contracting/post-harvest period:[a] $(t_2 - t_1) = 4/12$ years

Number of producers:[b] $n_G = 7.4$ million, $n_{\mathcal{G}} = 15.4$ million

Coefficient of absolute risk aversion:[c] $\lambda_g = 3.1/E_0(\pi_{g,2}^{A \times C})$

Production cost elasticity: $\eta_g = 2.5$

Processing cost elasticity: $\eta_{MD} = 4$

Import cost elasticity: $\eta_{MW} = 1.1$

Consumer demand elasticity: $\eta_D = 0.7$

Futures price at planting:[d] $F_0 = 178$ dollars/tn

Exchange rate at planting:[e] $X_0 = 12$ pesos/dollar

Intermediaries' market power:[f] $\mu_{MD} = 0.1$, $\mu_{Mg} = 0.2$

Option cost recovery share:[g] $\omega_G = \omega_M = 0.6$

Output shock coefficient of variation:[h] $CV_g = 0.2$

Output shock skewness:[h] $Skew_g = -0.2$

Output shock correlation:[h] $Correlation_{G\mathcal{G}} = 0.1$

Annual volatility of world price shocks:[i] $\sigma_F = 0.34$

Annual volatility of exchange rate shocks:[j] $\sigma_X = 0.13$

Annual volatility of consumption shocks:[k] $\sigma_D = 0.06$

Annual risk-free interest rate: $r = 0.02$

A×C Administration Cost:[l] 10% of Direct Subsidies

Marginal Deadweight Loss of Raising Tax Revenues:[m] 25%

[a]Based on SIAP (2007), ASERCA (2010a, 2010b), and Servicio de Información Agroalimentaria y Pesquera (SIAP).

[b]Set equal to $n_g = \bar{Q}_{g,2}$ in Table 3.2 to facilitate computations (see main text).

[c]Coefficient of relative risk aversion set equal to 3.1 following Zant (2001, p. 700).

[d]Based on 2007-2010 average of daily settlement prices for the July 2007, July 2008, July 2009, July 2010, and July 2011 corn contracts at CME (Note: According to personal communications from ASERCA employees, July futures are used as reference for contracting purposes).

[e]Based on 2007-2010 average of the daily "Tipo de Cambio FIX" from Banco de México (*http://www.banxico.org.mx/portal-mercado-cambiario/index.html*).

[f]Calculated by employing the approximations $\mu_{MD} \cong 1/[\eta_D \times (\text{Number of Intermediaries})]$ and $\mu_{Mg} \cong 1/[(g \text{ Supply Elasticity}) \times (\text{Number of Intermediaries})] \times (F_0 + Basis)/Basis$, with Basis = 55 dollars/tn (implied by $\bar{P}_{M\mathcal{G},2}$ in Table 2) and Number of Intermediaries = 14.

[g]ASERCA (2011, p. 33).

[h]Estimated from annual changes in the logarithms of detrended corn yields over 1980-2010. The coefficient of variation, skewness, and correlation correspond to the period planting/post-harvest. The variance of the output shocks is assumed to increase linearly with time.

[i]Annualized historical standard deviation of the natural logarithm of the daily settlement prices for the July 2007, July 2008, July 2009, July 2010, and July 2011 corn contracts at CME.

[j]Annualized historical standard deviation of the natural logarithm of the daily "Tipo de Cambio FIX" from Banco de México (*http://www.banxico.org.mx/portal-mercado-cambiario/index.html*) over 2007-2010.

[k]$2^{0.5}$ times the estimated standard deviation of the annual changes in log-consumption over the period 2002-2010 (SIAP, (*http://www.siap.gob.mx/index.php?option=com_content&view=article&id=12&Itemid=17*). This implies that one-half of the variance of the year-to-year changes in log-consumption is attributed to demand shocks.

[l]Budget figures in SAGARPA (2010a) imply that administering farm programs costs 23.4 pesos per 100 pesos in subsidies.

[m]Behrman (2010). Estimates vary widely (Diewert, Lawrence, and Thompson 1998), but Harberger (1997) has proposed 20% to 25% as a lower-bound estimate of the marginal cost of public funds for almost all countries. For the United States, it is often assumed that one extra dollar in tax revenues costs 1.30 dollars to the economy (e.g., Poterba 1996), which is the cost adopted by Barofsky (2011) to assess the welfare impact of Mexico's "Seguro Popular."

Table 2. Values of Endogenous Variables Used to Calibrate Scaling Parameters

Calibrating Endogenous Variable	Value
Mean participants' output:[a]	$\overline{Q}_{G,2} = 7.4$ million tn
Mean non-participants' output:[b]	$\overline{Q}_{\mathcal{G},2} = 15.4$ million tn
Mean imports:[c]	$\overline{Q}_{W,2} = 8.0$ million tn
Mean price paid by consumers:[d]	$\overline{P}_{D,2} = 4,000$ pesos/tn
Mean price paid to non-participants:[e]	$\overline{P}_{M\mathcal{G},2} = 2,800$ pesos/tn

[a]2007-2010 annual average production for "agricultura por contrato" (Grupo Consultor de Mercados Agrícolas (GCMA) 2011, pp. 24-25).

[b]Calculated by subtracting the mean participants' output from the 2007-2010 annual average production (SIAP, *http://www.siap.gob.mx/*).

[c]2007-2010 annual averages of imports (SIAP).

[d]130% of the 2007-2010 averages of monthly market prices in the main consumption areas (GCMA).

[e]2007-2010 averages of monthly market prices paid to producers (GCMA).

Table 3. Percentage Changes (Relative to the Scenario without A×C) in Equilibrium Prices, Quantities, Profits, and Consumer Expenditures Caused by A×C Program for Corn

Variable	Risk-Neutral Producers	Risk-Averse Producers
	Mean (St. Dev.) [0.1, 0.5, 0.9] Quantiles	**Mean** (St. Dev.) [0.1, 0.5, 0.9] Quantiles
Net Prices:		
Received by Participants	**5.3** (−18.5) [11.1, 2.4, −1.2]	**4.8** (−14.5) [11.1, 2.4, −1.4]
Received by Non-Participants	**−0.5** (−6.4) [−0.1, −1.5, −1.3]	**−1.0** (−1.7) [−0.1, −1.5, −1.5]
Paid to Participants	**−5.6** (−32.2) [0.3, −2.6, −11.4]	**−6.0** (−28.8) [0.3, −2.6, −11.6]
Paid to Non-Participants	**−0.5** (−6.4) [−0.1, −1.5, −1.3]	**−1.0** (−1.7) [−0.1, −1.5, −1.5]
Paid by Consumers	**−0.1** (−0.4) [0.0, 0.0, −0.1]	**−0.1** (−0.4) [0.0, −0.1, −0.2]
Quantities:		
Participants' Output	**3.6** (3.6) [3.6, 3.6, 3.6]	**3.9** (3.9) [3.9, 3.9, 3.9]
Non-Participants' Output	**−0.3** (−0.3) [−0.3, −0.3, −0.3]	**−0.3** (−0.3) [−0.3, −0.3, −0.3]
Imports	**−2.4** (0.0) [−6.2, −2.8, −1.4]	**−2.6** (0.0) [−6.7, −3.0, −1.5]
Consumption	**0.1** (−0.3) [0.1, 0.0, 0.0]	**0.1** (−0.3) [0.1, 0.0, 0.0]
Profits:		
Participants	**9.2** (−0.6) [16.2, 10.8, 6.0]	**8.5** (1.4) [14.0, 10.5, 5.9]
Non-Participants	**−0.7** (−3.2) [0.3, −0.2, −1.3]	**−1.5** (−1.8) [0.0, −0.4, −1.6]
Intermediaries	**4.0** (−42.9) [9.3, 5.1, 1.6]	**5.3** (−15.6) [9.5, 5.2, 1.9]
Consumer Expenditures:	**0.0** (0.0) [0.0, 0.0, 0.0]	**0.0** (0.0) [0.0, 0.0, 0.0]

Table 4. Average Changes (Relative to the Scenario without A×C) in Equilibrium Surpluses Caused by A×C Program for Corn, for Different Levels of Intermediaries' Market Power (Measured in Million Dollars)[a]

Sector	Low Market Power ($\mu_{MD} = 0.05$, $\mu_{Mg} = 0.1$)		High Market Power ($\mu_{MD} = 0.1$, $\mu_{Mg} = 0.2$)	
	Risk-Neutral Producers	Risk-Averse Producers	Risk-Neutral Producers	Risk-Averse Producers
Participants (p)	95	92	92	89
Non-participants (n)	−3	−12	−15	−23
Intermediaries (i)	84	110	106	136
Consumers (c)	8	8	8	9
Taxpayers (t = d + a)	−202	−202	−210	−210
Direct Subsidies (d)	−184	−184	−191	−191
Administration (a = 0.1 d)	−18	−18	−19	−19
Society (s = 0.25 t)	−50	−50	−53	−53
Total (= p + n + i + c + t + s)	−70	−56	−71	−52

[a]Original figures are computed in Mexican pesos, but to facilitate interpretation they are converted into U.S. dollars at the fixed exchange rate of 12 pesos per dollar.

Table 5. Average Changes (Relative to the Scenario without A×C) in Equilibrium Surpluses Caused by A×C Program for Corn, Assuming that Intermediaries' Market Power in the Crop Market Equals $\hat{\mu}_{Mg}^{A\times C}(\cdot)$ under the no-A×C Scenario (Measured in Million Dollars)[a]

A. Intermediaries' market power levels of $\mu_{MD} = 0.05$ and $\hat{\mu}_{Mg}^{A\times C}(0.1)$.

Sector	Risk-Neutral Producers $\hat{\mu}_{Mg}^{A\times C}(0.1) = 0.184$		Risk-Averse Producers $\hat{\mu}_{Mg}^{A\times C}(0.1) = 0.207$	
	$\mu_{Mg}^{A\times C} = 0.1$	$[\mu_{Mg}^{A\times C} = 0.184]$	$\mu_{Mg}^{A\times C} = 0.1$	$[\mu_{Mg}^{A\times C} = 0.207]$
Participants (p)	120	[88]	122	[85]
Non-participants (n)	51	[−15]	53	[−21]
Intermediaries (i)	0	[103]	0	[130]
Consumers (c)	15	[6]	16	[7]
Taxpayers (t)	−202	[−200]	−202	[−200]
Society (s = 0.25 t)	−50	[−50]	−50	[−50]
Total (= p + n + i + c + t + s)	−67	[−68]	−62	[−50]

B. Intermediaries' market power levels of $\mu_{MD} = 0.1$ and $\hat{\mu}_{Mg}^{A\times C}(0.2)$.

Sector	Risk-Neutral Producers $\hat{\mu}_{Mg}^{A\times C}(0.2) = 0.321$		Risk-Averse Producers $\hat{\mu}_{Mg}^{A\times C}(0.2) = 0.346$	
	$\mu_{Mg}^{A\times C} = 0.2$	$[\mu_{Mg}^{A\times C} = 0.321]$	$\mu_{Mg}^{A\times C} = 0.2$	$[\mu_{Mg}^{A\times C} = 0.346]$
Participants (p)	125	[82]	126	[81]
Non-participants (n)	53	[−30]	59	[−34]
Intermediaries (i)	0	[130]	0	[153]
Consumers (c)	19	[5]	21	[6]
Taxpayers (t)	−210	[−205]	−210	[−205]
Society (s = 0.25 t)	−53	[−51]	−53	[−51]
Total (= p + n + i + c + t + s)	−66	[−70]	−57	[−50]

[a]Original figures are computed in Mexican pesos, but to facilitate interpretation they are converted into U.S. dollars at the fixed exchange rate of 12 pesos per dollar.
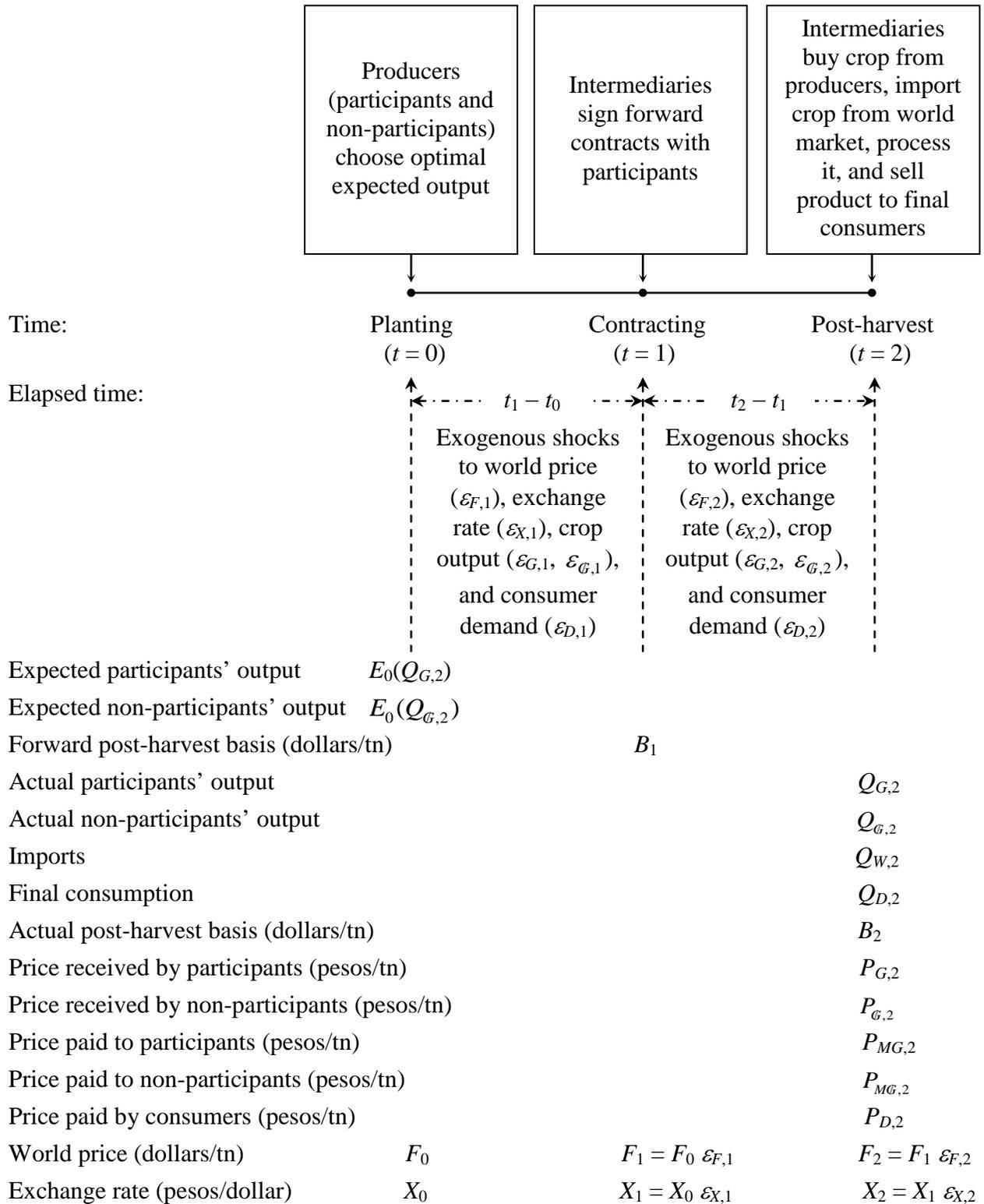
Figure boxes (left to right):

- Producers (participants and non-participants) choose optimal expected output
- Intermediaries sign forward contracts with participants
- Intermediaries buy crop from producers, import crop from world market, process it, and sell product to final consumers

	Planting ($t = 0$)	Contracting ($t = 1$)	Post-harvest ($t = 2$)
Time:	Planting ($t = 0$)	Contracting ($t = 1$)	Post-harvest ($t = 2$)
Elapsed time:	$t_1 - t_0$	$t_2 - t_1$	

Exogenous shocks to world price ($\varepsilon_{F,1}$), exchange rate ($\varepsilon_{X,1}$), crop output ($\varepsilon_{G,1}$, $\varepsilon_{\mathcal{G},1}$), and consumer demand ($\varepsilon_{D,1}$)

Exogenous shocks to world price ($\varepsilon_{F,2}$), exchange rate ($\varepsilon_{X,2}$), crop output ($\varepsilon_{G,2}$, $\varepsilon_{\mathcal{G},2}$), and consumer demand ($\varepsilon_{D,2}$)

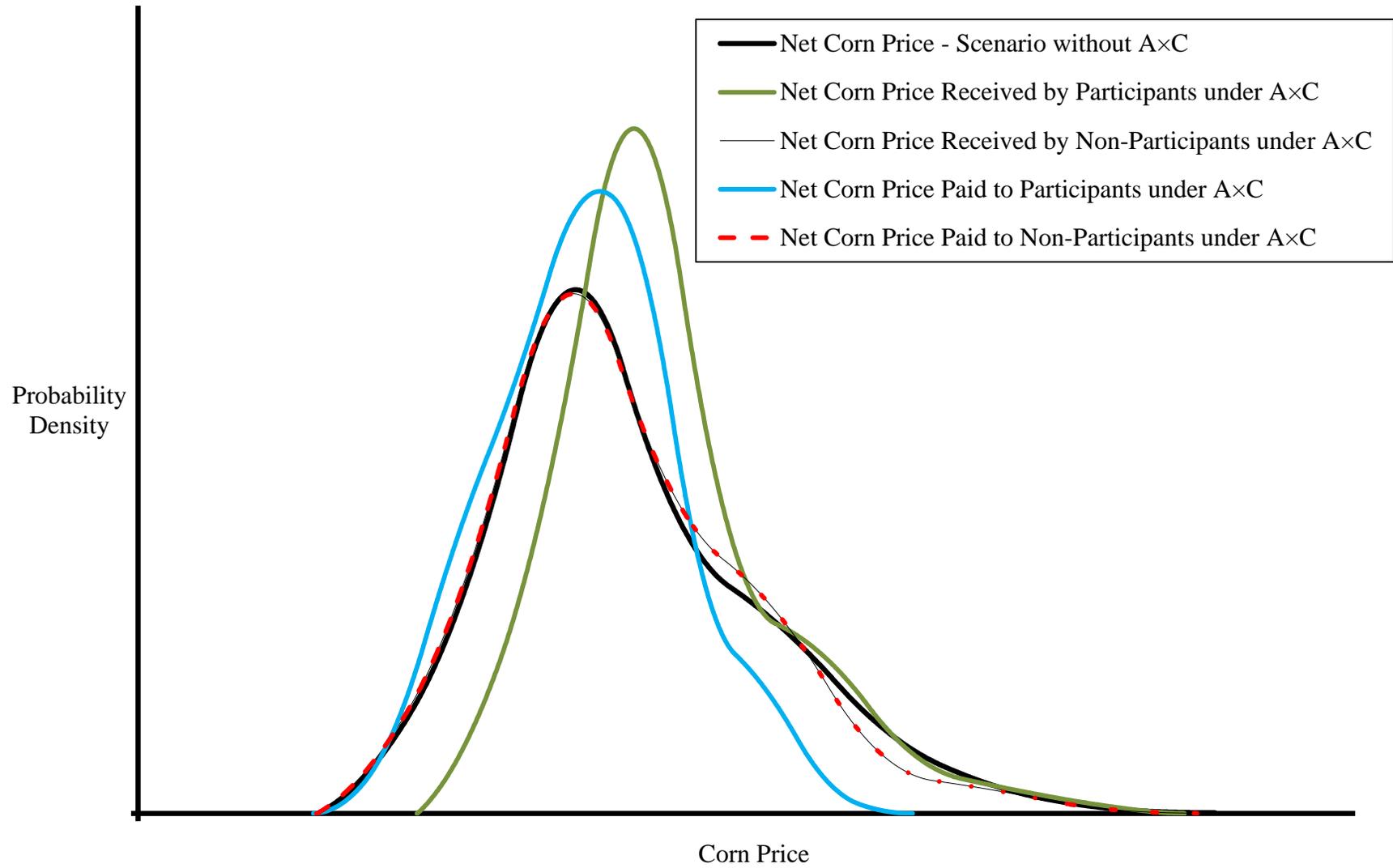|	Planting ($t=0$)	Contracting ($t=1$)	Post-harvest ($t=2$)
Expected participants' output	$E_0(Q_{G,2})$		
Expected non-participants' output	$E_0(Q_{\mathcal{G},2})$		
Forward post-harvest basis (dollars/tn)		B_1	
Actual participants' output			$Q_{G,2}$
Actual non-participants' output			$Q_{\mathcal{G},2}$
Imports			$Q_{W,2}$
Final consumption			$Q_{D,2}$
Actual post-harvest basis (dollars/tn)			B_2
Price received by participants (pesos/tn)			$P_{G,2}$
Price received by non-participants (pesos/tn)			$P_{\mathcal{G},2}$
Price paid to participants (pesos/tn)			$P_{MG,2}$
Price paid to non-participants (pesos/tn)			$P_{M\mathcal{G},2}$
Price paid by consumers (pesos/tn)			$P_{D,2}$
World price (dollars/tn)	F_0	$F_1 = F_0\,\varepsilon_{F,1}$	$F_2 = F_1\,\varepsilon_{F,2}$
Exchange rate (pesos/dollar)	X_0	$X_1 = X_0\,\varepsilon_{X,1}$	$X_2 = X_1\,\varepsilon_{X,2}$

Figure 1. Timing framework for the analysis

Figure 2. Probability density functions of corn prices with and without A×C, assuming risk-averse producers