Appendix A: Empirical Model for Measuring the Changes in Economic Surpluses

The empirical economic surplus model proposed by Alston et al. is based on the assumption that the U.S. and ROW supply and demand functions can be modeled with the following equations:

U.S. supply: $Q_{US} = \alpha_{US} + \beta_{US} (P + k_{US}) = (\alpha_{US} + \beta_{US} k_{US}) + \beta_{US} P$,

U.S. demand: $C_{US} = \gamma_{US} - \delta_{US} P$,

ROW supply: $Q_{ROW} = \alpha_{ROW} + \beta_{ROW} (P + k_{ROW}) = (\alpha_{ROW} + \beta_{ROW} k_{ROW}) + \beta_{ROW} P$,

and

ROW demand: $C_{ROW} = \gamma_{ROW} - \delta_{ROW} P$,

where Q_{US} and C_{US} are the quantities produced and consumed of the commodity (which may include biotech and/or conventional varieties) in the United States. Similarly, Q_{ROW} and C_{ROW} are the quantities produced and consumed in the ROW.[1] The terms k_{US} and k_{ROW} are the vertical shift in the U.S. and ROW supply curves due to the introduction of biotechnology. Last, P is the equilibrium world price of the commodity. A graphical representation of this model is presented in figure 5.

The first step in deriving the formulas that determine changes in producer and consumer surpluses is to use the identity $Q_{US} + Q_{ROW} = C_{US} + C_{ROW}$, which allows for the estimation of P. The existence of a single equilibrium world price follows from the Law of One Price assumption, which states that regional prices only differ from the world price by transportation costs (Falck-Zepeda et al., 2000a).

The equilibrium price observed after the introduction of biotechnology is referred to as P_1, while the counterfactual price—the price that would have prevailed had the technology not been introduced and identical supply and demand conditions existed—is denoted by P_0. Because the welfare changes associated with the adoption of biotechnology are measured relative to the absence of the innovation, P_0 must be estimated. The formula for estimating the world price is

$$P = (\gamma_{US} + \gamma_{ROW} - \alpha_{US} - \alpha_{ROW} - \beta_{US} k_{WORLD}) / (\beta_{US} + \delta_{US} + \beta_{ROW} + \delta_{ROW}),$$

where k_{WORLD} is the sum of k_{US} and k_{ROW}. If there is no supply shift, k_{US}, k_{ROW}, and thus k_{WORLD}, equal 0 and

$$P = P_0 = (\gamma_{US} + \gamma_{ROW} - \alpha_{US} - \alpha_{ROW}) / (\beta_{US} + \delta_{US} + \beta_{ROW} + \delta_{ROW}).$$

[1] As in the Moschini and Lapan model, this study does not consider consumer heterogeneity in valuing biotech innovations. Different consumer preferences toward biotech products and government regulations among export markets could lead to divergent values of biotech and nonbiotech products for U.S. and ROW consumers. Considering consumer heterogeneity could affect the resulting surplus changes, including the benefits for consumers as a whole as well as those with divergent preferences toward biotech products, in this study.

On the other hand, if there is a shift in supply due to the introduction of biotechnology and k_{WORLD} equals KP_0, where $K = k_{WORLD}/P_0$, then $P = P_1 = (\gamma_{US} + \gamma_{ROW} - \alpha_{US} - \alpha_{ROW} - \beta_{US} K P_0) / (\beta_{US} + \delta_{US} + \beta_{ROW} + \delta_{ROW})$ and the change in price, $P_1 - P_0 = - \beta_{US} KP_0 / (\beta_{US} + \delta_{US} + \beta_{ROW} + \delta_{ROW})$. The absolute value of the relative price change (Z) is $Z = -(P_1 - P_0) / P_0 = \beta_{US} K / (\beta_{US} + \delta_{US} + \beta_{ROW} + \delta_{ROW})$, which is assumed to be the same for all U.S. production regions due to the Law of One Price. By using the trade equilibrium assumption $QT_0 = C_{ROW,0} - Q_{ROW,0} = Q_{US,0} - C_{US,0}$ (the zero subscripts indicate counterfactual values), Z can be defined in elasticity form as

$$Z = \varepsilon_{US} K / [\varepsilon_{US} + S_{US} \eta_{US} + (1 - S_{US}) \eta_{EROW}].$$

The term ε_{US} is the U.S. supply elasticity for the biotech crop, η_{US} is the absolute value of the U.S. demand elasticity for the commodity, η_{EROW} is the absolute value of the net export demand elasticity, and S_{US} is the share of U.S. production that is consumed domestically.

As adapted from Alston et al., the formulas for changes in producer and consumer surpluses in the United States and the ROW are:

$$\Delta PS_{US} = P_0 Q_{US,0} (K_{US} - Z) (1 + 0.5 Z\varepsilon_{US}),$$

$$\Delta CS_{US} = P_0 C_{US,0} Z (1 + 0.5 Z \eta_{US}),$$

$$\Delta PS_{ROW} = -P_0 Q_{ROW,0} (K_{ROW} - Z) (1 + 0.5 Z\varepsilon_{ROW}),$$

$$\Delta CS_{ROW} = P_0 C_{ROW,0} Z (1 + 0.5 Z \eta_{ROW}),$$

$$\Delta USAS_{US} = \Delta CS_{US} + \Delta PS_{US},$$

and

$$\Delta ROWS_{ROW} = \Delta CS_{ROW} + \Delta PS_{ROW},$$

where ΔPS_{US} is the change in U.S. producer surplus, ΔCS_{US} is the change in U.S. consumer surplus, ΔPS_{ROW} is the change in ROW producer surplus, ΔCS_{ROW} is the change in ROW consumer surplus, ε_{ROW} is the ROW supply elasticity, and η_{ROW} is the absolute value of the ROW demand elasticity. The terms $\Delta USAS_{US}$ and $\Delta ROWS_{ROW}$ represent the change in total surplus in the United States and ROW. These formulas assume that the pre-adoption world and U.S. regional prices, quantities, and relevant elasticities are known. While the counterfactual commodity prices and quantities are not known, they can be estimated from the equations above. Following Alston et al. and Pinstrup-Andersen et al., the equations are:

$$P_0 = P_1 / \{1 - [\varepsilon_{US} K / [\varepsilon_{US} + S_{US} \eta_{US} + (1 - S_{US})\eta_{EROW}] \}$$

and

$$Q_0 = Q_1 / \{1 + [\varepsilon_{US} K ((S_{US} \eta_{US}) + (1 - S_{US})\eta_{EROW})] / [\varepsilon_{US} + S_{US} \eta_{US} + (1 - S_{US}) \eta_{EROW}]\}.$$

After estimating the shift in supply due to the adoption of biotechnology as well as the counterfactual world price, the surplus changes accruing to U.S. farmers, U.S. consumers, and ROW consumers and producers are calculated. The gains realized by the technology innovators are estimated separately using data on adoption rates, technology fees, and seed premiums.