*Online Appendix*

*Biological Innovation without Intellectual Property Rights:*

*Cottonseed Markets in the Antebellum American South*

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MODEL EXTENSION

*Quality Ladder and the Introduction of Rival Varieties*

We can investigate more fully a model of a quality ladder where two improved varieties compete. Suppose variety 0 improves quality by v0 and is available in stock S0 at t0 and variety 1 improves quality by v1 and is available in stock S1 at t1. We will normalize the name by letting t0 < t1 but leave the values of v0 and v1. At t0, variety 0 will be sufficient to plant all acreage at T0; variety 1 will be sufficient at T1, and they will jointly be sufficient at T01, To make the competition interesting, let t1 < T0, so that variety 1 is available before variety 0 is in surplus and T01 < t1. If v0 > v1, variety 0 will generate a production advantage of v0 from t0 to T01 and of (v0 – v1) from T01 to T0. Variety 1 will generate a production advantage of v1 from t1 to T01 and then be is surplus. If v1 > v0, variety 0 will generate a production advantage of v0 from t0 to T01and then be in surplus as it is being displaced. Variety 1 will generate a production advantage of v1 from t1 to T01 and then a production advantage of (v1 – v0) to T1. The price paths can be calculated accordingly.

*Quality Deterioration*

We can investigate more fully a model of a quality deterioration. Suppose r is the per period probability that the improved seed reverts to becoming regular seed (with v = 0 thereafter) given this event has not previously occurred, then the seed’s price will be

PN,T–τ = PS + (1 + dm(1– r)+…+(dm(1 – r))τ–1) (d(1 – r)vyPL/b).

*Specialization*

Selecting suitable seed and maintaining quality required extra care and attention—such costs generated the advantages of a division of labor between specialized seed production and more general crop cultivation. Through trial-and-error and careful observation, breeders came to understand the need to separate experimental fields and take special care in ginning. The USDA advocated producers of seed for one-variety community be isolated by one mile from the production of inferior varieties (see Hite, 1933, p. 7).

A planter would face difficulties if he sought, either for the sake of experimentation or to build up supplies internally, to grow both the old and new seeds near one another. Cross-pollination and seed mixing threatened the “purity” of the new variety unless the planter devoted extra care. We can add this to the model by incorporating a per-period per-unit cost, k, to keep the new and old seed separate.

Such costs can be modeled as increasing proportionally the amount of seed handled but independently of the division between old and new seed if positive amounts of each are handled. Records show that large plantations typically had many fields separated from one another. At any one time planters experimented with several varieties in different test plots. So even though one seed variety dominated a constant process of experimentation was underway. In addition, planters sometimes preferred to grow varieties which fruited at different times to spread out the harvest and decrease peak-load picking problems.

The “k” of planters was likely higher than that for breeders, creating advantages of specialization. If a planter with total acreage, ã, bought q units of seed in year t at price PN,t, it would require ť ≥ log(bã/q)/log(m) years before the new seed is in surfeit on the farm. Over this period, the planter incurs the cost, kbãť, to keep the old and new seeds separate. The planter’s decision is to choose the q that minimizes kbãť + qPN,t. Ignoring integer constraints, a necessary condition for optimization is q = kbã/PN,tlog(m) if seeds are purchased in year t. Saving on the costs of isolating the new seed should induce planters to purchase non-infinitesimal quantities. The model in the text leaves indeterminant how much an individual planter purchases.

*Analogous Model for Grain Crops*

The model for cottonseed differs from what would be applicable for a grain crop for which the seed was the final output. The model for such as crop can be sketched as follows. Suppose the old and new varieties differ only in their yields per acre. They do not differ in final use, selling for the same price, P, which will be treated as fixed. The production cost parameters for inputs other than seed—co (per acre costs) and c1 (per quantity or per yield costs)—are also the same. (Treat co as being incurred before planted and c1 during and after harvest.) The amount of seed planted per acre is also identical and can be used to define the unit, such that one unit of seed is used per acre and the input cost of seed is its price. Let yN be the yield per acre of the new seed and yO be the yield of the old seed, where yN > yO. Let PN,t, be the price of new seed in year t.

For simplicity, assume total acreage A is fixed. One can endogenize the acreage A and price P by adding a output demand function Q(P) and a land supply function A(P, y), but this creates complications and little gain to insight. (In a model with fixed acreage, land rents do rise with the increase in yields.)

Let St be the stock of new seed at the start of year t. Again, define year T such that ST > A > ST–1 = ST/yN. For all periods before T, the new seed will be used solely to build up the seed stocks and none will be sold for final use. (One must assume the two varieties can be segregated or distinguished.) From period T forward, a portion of new seed will be sold for final use at price P and thus, PN,t = P for t ≥ T.

Discounted revenues minus costs for production using the old seed are d(P – ci)yO – co – P;

and using the new seed are d(PN,t+1 – ci)yN – co – PN,t.

The returns on the two activities will be equal (in the periods t < T) if

(A1) PN,t = P + d(P – ci )(yN – yO) + dyN(PNt+1 – P).

In year T – 1, Equation (A1) becomes PN,T–1 = P + d(P – ci)(yN – yO).

Applying Equation (A1), one can work backwards to derive:

(A2) PN,T–K= P + (1 + dyN + … + (dyN)K–1)d(P – ci)( yN – yO)

Equation (A2) is analogous in form to Equation (2) in the main text with the new seed’s yield replacing the multiplication ratio, m, and with different measure of additional net returns. The qualitative results in the text are not specific to crops such as cotton where seed is a by-product. Prices fall at a rate faster than the benchmark case (dyN) because there are non-seed inputs, specifically land, in production.