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# **Understanding Transient Technology Use among Smallholder Farmers in Africa**

*Maolong Chen and Robert J. Myers<sup>1</sup>*

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<sup>1</sup> Maolong Chen (contact author: [chenmaol@msu.edu](mailto:chenmaol@msu.edu)) is a graduate student in the Department of Agricultural, Food & Resource Economics at Michigan State University; Robert J. Myers is a university distinguished professor in the Department of Agricultural, Food & Resource Economics at Michigan State University.

## **Abstract**

Development and adoption of new crop varieties and other technological improvements have led to massive increases in agricultural productivity in many parts of the world. However, the progress of technology development and adoption in Africa remains slow, due partly to the high rate of disadoption and switching back and forth between modern and traditional technologies. This paper studies this transient technology use in a dynamic context. A dynamic conceptual model is developed to explain transient use, and the model is calibrated and solved using a dynamic programming algorithm. Numerical results show that relative profitability, yield uncertainty, and switching costs are important influences on the pattern of adoption and disadoption. Switching costs play a role in preventing households from both entering and exiting modern technology use, and the profitability of modern technologies determines if the switching cost will encourage or discourage long-run adoption.

*Key words:* technology adoption, transient technology use, switching cost, dynamic programming.

## **Introduction**

Development and adoption of new crop varieties and other technological improvements have led to massive increases in agricultural productivity in many parts of the world. However, productivity gains in Africa have been disappointing (Mwangi 1996; Duflo, Kremer, and Robinson 2008). Given apparent land scarcity and low land fertility in Africa, many view intensive agriculture based on modern technologies as crucial for Africa to reach its development potential (De Groote et al. 2002; Lee 2005; Pannell and Vanclay 2011).

A number of important policies have been implemented to encourage the adoption of new technologies and modern inputs throughout Africa, including direct input subsidies (primarily fertilizer), government-facilitated provision of input credit, and centralized control of input procurement and distribution (Ouma et al. 2002). Even with these initiatives, however, the progress of technology development and adoption in Africa remains slow (Spencer 1996).

Given the importance of this issue, there is considerable existing research on technology adoption (e.g. Byerlee 1994; Mwangi 1996; Zeller, Diagne, and Mataya 1998; Sunding and

Zilberman 2001; Doss 2006). This research has focused on explaining technology adoption based on farmer characteristics, farmer information, expected profitability, risk, the existence of marketing and transportation infrastructure, and the availability of credit and liquidity for seed and fertilizer purchases. For example, Mwangi (1996) identified liquidity constraints as one of the key factors affecting the adoption decision, especially when farmers with little cash are planting under high risk. Byerlee et al. (1994) comment “the profitability of using technologies is highly site-specific, depending on land pressure, agro-climatic variables, fertilizer costs, and farm-gate crop prices”.

Most of the existing research on technology adoption assumes that adoption is a one-time decision so that, once adopted, a new technology will continue to be used at least until a better one becomes available. There has been some work on technology adoption in a dynamic context which makes allowance for learning effects and the option to delay adoption (e.g. Foster and Rosenzweig 1995; Conley and Udry 2010). However, the decision to adopt is still typically viewed a one-time decision.<sup>2</sup> This is at odds with what we observe in some technology adoption environments where farmers switch back and forth between two or more technologies. This is particularly true for hybrid seed use in Africa where panel data sets reveal individual farmers commonly switching back and forth between modern varieties and traditional local varieties (Ouma et al. 2002; Tura et al. 2010). We provide some descriptive data below that support these observations for maize production in Kenya and Zambia. We term this technology switching behavior “transient technology use” and it has been little studied to date.<sup>3</sup>

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<sup>2</sup> There is also a small literature on technology disadoption as well but again disadoption is viewed as a one-time decision (Moser and Barrett 2003).

<sup>3</sup> Suri (2011) noted this transient use and attributed it to heterogeneous returns to adoption in a cross-sectional setting.

The objective of this paper is to provide a better understanding of transient technology use. Because transient technology use is clearly a dynamic process, investigating it will require a dynamic modelling framework. In this paper, we develop a dynamic theoretical model of transient technology choice. In our model, transient technology use is driven by the relative profitability of different technologies, the costs of switching between them, and a learning process that reduces switching costs as experience with new technologies grows. The switching costs introduce a certain degree of irreversibility in technology adoption choices, but does not make them fully irreversible as is implicitly assumed in much of the existing literature. The conceptual model is then calibrated and solved numerically using a dynamic programming algorithm. Simulations of the model illustrate how changes in switching costs and relative profitability can lead to different patterns and duration of transient technology use.

## **Background**

The model in this paper is motivated by, and calibrated to, farmer data from the Tegemeo Agricultural Monitoring and Policy Analysis Project between Tegemeo Institute at Egerton University, Kenya and Michigan State University. It is a four-wave household level panel survey (2000, 2004, 2007, 2010), representative of rural maize-growing areas in Kenya.

The sample has 1207 observations tracked in all four waves. Table 1 lists all the possible four period transitions of hybrid seed use, and the corresponding number of the 1207 households that fall into each transition category. Table 2 then classifies the households according to their adoption history (never adopted, always adopted, adopted and continued, adopted and disadopted, and transient use). Two observations are worth noting. First, while over 90% of households adopted hybrids at least once, almost 23% of the sample subsequently disadopted

them. Second, 15% of the sample displayed transient use (switching back and forth between hybrids and traditional varieties). These data show that transient use of hybrid seeds is an important phenomenon in Kenya and suggests that transient technology use may be important in other technology adoption contexts as well.

**Table 1. Possible Transitions across Hybrid/Non-Hybrid Use**

Hybrid Use Transitions (2000 2004 2007 2010)	No.	Fraction of Sample (%) (N=1207 Households)
N N N N	99	8.20
N N N H	70	5.80
N N H H	67	5.55
N N H N	21	1.74
N H H H	53	4.39
N H H N	9	0.75
N H N H	14	1.16
N H N N	10	0.83
H H H H	643	53.27
H H H N	13	1.08
H H N N	9	0.75
H N N N	34	2.82
H H N H	27	2.24
H N H H	79	6.55
H N H N	18	1.49
H N N H	41	3.40

*Note: "H" denotes the use of hybrid seed and "N" denotes the use of non- hybrid seed.*

**Table 2. Proportion of Households by Adoption History Category**

	No. of Households	Proportion of the Sample (%)
Total	1207	100
1. Never Adopted	99	8.2
2. Adopted at least once	1108	91.8
2.1 Always Adopted	643	53.3
2.2 Adopted and continued	190	15.7
2.3 Adopted and then Disadopted	96	7.9
2.4. Transient use (back and forth)	179	14.8

Of course, transient technology use may occur simply because the relative returns from using the alternative technologies fluctuates over time, and the costs of switching between them are minimal. In most technology environments, however, it is not costless to switch technologies. As well as the financial investment required, production processes and practices may have to be adjusted and an investment has to be made in learning how to use the new technology, at least until some experience has been gained with it. This suggests that transient technology use is a dynamic process and we need a dynamic conceptual model to characterize it.

### Conceptual Model

We consider a farmer with two available maize seed technologies—hybrid and traditional seeds. If the hybrid variety is used realized production profits per acre are given by  $\pi_t^H = p_t y_t^H - c_t^H$  where  $p$  is maize price,  $y$  is maize yield,  $c$  is cost of production per acre, and superscript  $H$  indicates hybrid. Similarly, if the traditional variety is used realized production profits per acre are given by  $\pi_t^T = p_t y_t^T - c_t^T$  where the superscript  $T$  indicates traditional variety seed. We assume maize output price is the same irrespective of whether maize is produced from hybrid or

traditional seed, and that price and yield are unknown at planting time when the seed technology choice has to be made. We keep other resource allocation decisions in the background by assuming that, once a seed choice has been made, production practices and other input use are set to recommended levels for that seed technology (seed is the only explicit choice variable).

In addition to production costs there are costs from switching from one seed type to the other. The cost of switching from traditional to hybrid seeds includes costs of searching for and establishing a relationship with vendors, screening to ensure seed quality, and investing in learning about differences in recommended production practices. The cost of switching from hybrid to traditional seeds include the cost of adjusting back to traditional production practices, re-acquainting with traditional farming practices, learning about changes to soil quality brought on by hybrid production practices, etc. We might expect the cost of switching from traditional to hybrid seeds to be higher than the cost of switching from hybrid to traditional seeds, and switching costs to be decreasing in the number of times hybrids have been used in the past (a learning effect). Per acre switching costs are denoted by  $s_t^{T \rightarrow H}(n_t)$  for switching from traditional to hybrids and  $s_t^{H \rightarrow T}(n_t)$  for switching from hybrids to traditional varieties, where  $n_t$  is the number of times hybrids have been used in the past.

We assume the farmer is risk-neutral (or can insure risks) and chooses traditional or hybrid seed to maximize the discounted sum of expected lifetime profits over an infinite horizon:<sup>4</sup>

$$(1) \quad \max_{\{d_t\}} E_{-1} \sum_{t=0}^{\infty} \beta^t \{ d_t [\pi_t^H - s_t^{T \rightarrow H}(n_t)(d_t - d_{t-1})] + \\ (1 - d_t) [\pi_t^T - s_t^{H \rightarrow T}(n_t)(d_{t-1} - d_t)] \}$$

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<sup>4</sup> Most households in the Kenya data chose to plant only one type of seed in each season so profit is normalized to a per acre basis and the seed decision is assumed to be binary.



subject to  $n_{t+1} = n_t + d_t$  where  $d_t$  is a binary decision variable with  $d_t = 1$  indicating hybrid seed is chosen and  $d_t = 0$  indicating traditional seed is chosen. Switching cost is incurred only when  $d_t \neq d_{t-1}$  (i.e. the technology is switched).

We solve the problem using dynamic programming. The relevant value function is:

$$(2) \quad v_t(d_{t-1}) = \max \{v_t^H(d_{t-1}), v_t^T(d_{t-1})\}$$

where  $v_t^H(d_{t-1})$  and  $v_t^T(d_{t-1})$  are the conditional value functions for hybrid and traditional seed use given by:

$$(3a) \quad v_t^H(d_{t-1}) = E_{t-1}(\pi_t^H) - s_t^{T \rightarrow H}(n_t)(1 - d_{t-1}) + \beta E_{t-1}v_{t+1}(1); \text{ and}$$

$$(3b) \quad v_t^T(d_{t-1}) = E_{t-1}(\pi_t^T) - s_t^{H \rightarrow T}(n_t)d_{t-1} + \beta E_{t-1}v_{t+1}(0)$$

where  $v_{t+1}(d_t)$  is the discounted value of future profits from choosing hybrid ( $d_t = 1$ ) or traditional ( $d_t = 0$ ) seed today, assuming optimal seed choices are made in the future.

There are two cases to consider. First, suppose the traditional variety was used last planting period ( $d_{t-1} = 0$ ). Then the switch to hybrids will occur if:

$$(4) \quad E_{t-1}(\pi_t^H) - E_{t-1}(\pi_t^T) > s_t^{T \rightarrow H}(n_t) + \beta[E_{t-1}v_{t+1}(0) - E_{t-1}v_{t+1}(1)]$$

otherwise, traditional seeds will continue to be used. Without switching costs the right hand side of (4) is zero and the decision rule reduces to the simple static condition that to switch to hybrids the expected current production profits under hybrids must exceed expected production profits from using traditional seeds. With switching costs, however, the difference in expected production profit must exceed a premium composed of two parts. The first part is the (always positive) switching costs. The second part is the discounted expected future profit premium from sticking with the traditional seeds today. The second part may be positive or negative, depending on the expected future profitability of hybrids compared to traditional varieties, and on the expected magnitude and frequency of future switching costs. If the premium is positive we may observe the

farmer continuing to use traditional varieties, even when the current expected return from switching to hybrids is positive. The model is therefore capable of explaining non-adoption even when adoption is expected to increase current profits. The reason is essentially that non-adoption now reduces the costs of switching back to traditional varieties at some point in the future.

Second, suppose the hybrid variety was used last planting period ( $d_{t-1} = 1$ ). Then the switch to traditional varieties will occur if:

$$(5) \quad E_{t-1}(\pi_t^T) - E_{t-1}(\pi_t^H) > s_t^{H \rightarrow T}(n_t) + \beta[E_{t-1}v_{t+1}(1) - E_{t-1}v_{t+1}(0)]$$

otherwise, hybrids will continue to be used. With no switching costs the rule again collapses to the simple static result that whichever seed type is expected to provide the most current production profit is used. With switching costs, however, the difference in expected production profit from switching to traditional varieties must exceed a premium composed of (positive) switching costs and a (positive or negative) discounted expected future profit premium from sticking with the hybrids today. If the premium is negative we may observe the farmer switching to traditional varieties, even when the current expected profits from using traditional seeds is lower than the current expected profits from using hybrids. The model is therefore capable of explaining disadoption, even when continuing to use hybrids would be expected to generate increased current profits. The reason is essentially that disadopting now reduces the costs of switching back to traditional varieties at a later date.

A number of results emerge from this conceptual model. First, because of switching costs the history of adoption decisions has an important influence on current adoption choice (current seed choice is conditioned on past practice). However, if switching costs decline as more experience is gained with hybrids (learning effect), then dependence on the history of past seed use will also decline. Second, the relative yields and costs from using hybrid versus traditional

seeds will continue to play a major role in hybrid adoption and disadoption, because these will have a major impact on current and future profitability from adoption. Hence, the stochastic processes driving prices, yields, and costs, as well as the magnitude and dynamics of switching costs, will have a major impact on the prevalence of transient technology use. Third, there will be a band of inaction (waiting) in the optimal seed use rule. If traditional varieties (hybrids) are being used and the returns from adoption (disadoption) get high enough adoption (disadoption) will occur. However there will also be a band of inaction where returns that are not too far apart will lead to maintaining the status quo (continuing to use the current technology).

### Numerical Model

The conceptual model is parameterized and solved numerically to highlight a number of important implications of switching costs for transient technology use. For the numerical model stochastic processes for price, yields and costs need to be defined. Maize price was assumed to follow a mean reverting process:

$$(6) \quad p_t = \bar{p} + \gamma_1(p_{t-1} - \bar{p}) + \varepsilon_{pt}$$

where  $\bar{p}$  is the long-run price mean,  $\gamma_1$  characterizes the speed of price mean reversion, and  $\varepsilon_{pt} \sim N(0, \sigma_p^2)$  is a random price shock. We then normalized the production profit from using traditional varieties to zero and assume the yield and production cost *differentials* between hybrid and traditional seed technologies follow:

$$(7) \quad y_t = \bar{y} + \gamma_2(y_{t-1} - \bar{y}) + \varepsilon_{yt}$$

$$(8) \quad c_t = \bar{c}$$

where  $\bar{y}$  is the long-run mean of the yield differential,  $\gamma_2$  characterizes the speed of mean reversion in the yield differential, and  $\varepsilon_{yt} \sim N(0, \sigma_y^2)$  is a random shock to the yield differential.

The production cost differential is assumed to be a constant  $\bar{c}$  and the price and yield differential shocks are allowed to be correlated with correlation coefficient  $\rho$ . The farmer is assumed to form price and yield differential expectations using the price and yield processes (6) and (7).

Switching costs are defined as:

$$(9) \quad s_t^{T \rightarrow H}(n_t) = \alpha^{T \rightarrow H} + \begin{cases} a_0 & \text{if } n_t = 0 \\ a_1 & \text{if } n_t = 1 \\ \vdots & \\ 0 & \text{if } n_t \geq 6 \end{cases} \quad \text{and}$$

$$(9b) \quad s_t^{H \rightarrow T}(n_t) = \alpha^{H \rightarrow T} + \begin{cases} a_0 & \text{if } n_t = 0 \\ a_1 & \text{if } n_t = 1 \\ \vdots & \\ 0 & \text{if } n_t \geq 6 \end{cases}$$

where  $a_0 > a_1 > \dots > 0$ . This allows for a switching costs to start out high and decline with experience using hybrids, up to 5 instances of hybrid use, after which time switching costs remain fixed at a lower level. The fixed lower levels after learning ( $\alpha^{T \rightarrow N}$  and  $\alpha^{N \rightarrow T}$ ) are allowed to be different depending on the direction of the switch.

The base model was parameterized according to the values in Table 3. The base parameterizations were then changed in various ways (as discussed below) and the model re-solved to illustrate various effects. Switching costs were specified to be relatively high to make results clearer and accentuate effects to aid interpretation. The numerical model was solved using DPSOLVE in the Compecon Toolbox programmed in Matlab (Miranda and Fackler 2002). The family basis function we use is a Chebychev polynomial basis.

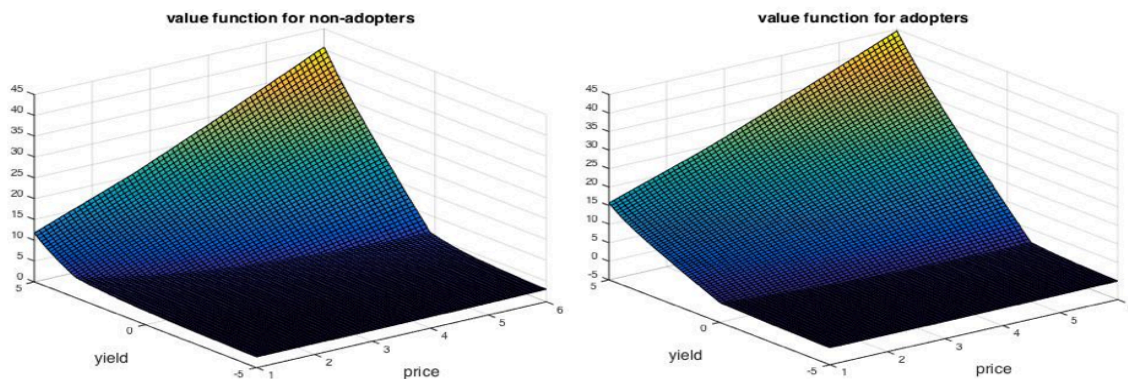
**Table 3: Parameterization for baseline scenario**

Parameter	Description	Base Value
$\bar{p}$	Long-run mean of price	2
$\gamma_p$	Price mean reversion parameter	0.7
$\sigma_p^2$	Price shock variance	1
$\bar{y}$	Long-run mean of yield differential	1.5
$\gamma_y$	Yield differential mean reversion parameter	0.7
$\sigma_y^2$	Yield differential shock variance	1
$\rho$	Price-Yield differential correlation	0
$\bar{c}$	Constant production cost differential	3
$\alpha^{T \rightarrow H}$	Long-run cost of switching to hybrid seed	2
$\alpha^{H \rightarrow T}$	Long-run cost of switching to traditional seed	1
$a_0$	Additional cost for first switch	5
$a_1$	Additional cost for second switch	4
$a_2$	Additional cost for third switch	3
$a_3$	Additional cost for fourth switch	2
$a_4$	Additional cost for fifth switch	1
$a_5$	Additional cost for sixth and more switches	0

## Numerical Results

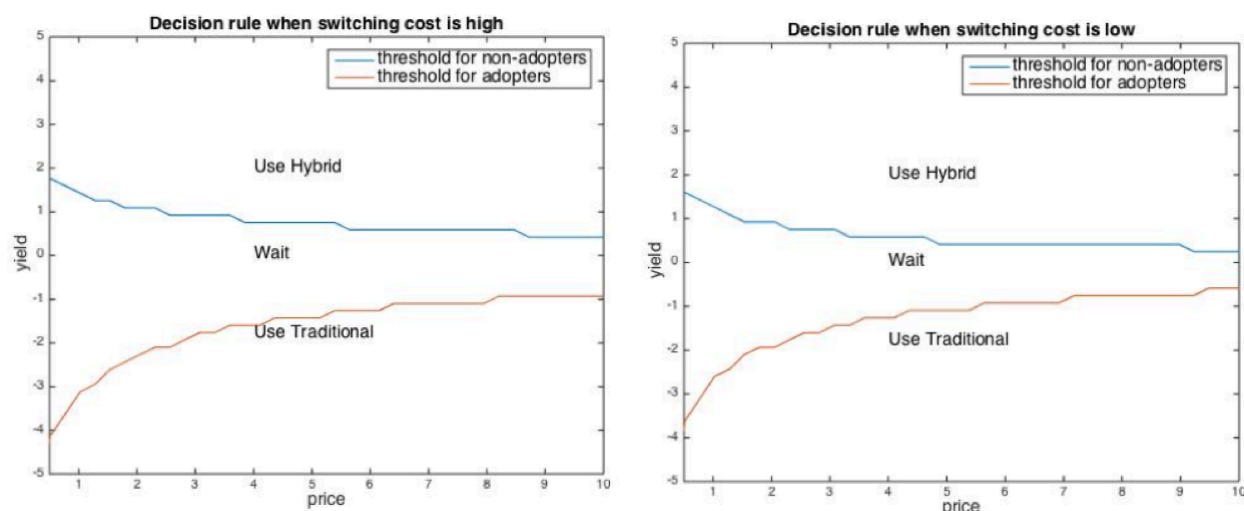
Figure 1 graphs the conditional value functions for current adopters and non-adopters as a function of current prices and yield differentials under the baseline parametrization. Two findings are worth noting. First, both conditional value functions are increasing in current price and yield differential, holding other state variables constant. This indicates that higher prices and yield differentials increase the discounted profit stream for both current adopters and non-adopters alike (since current non-adopters still benefit from the option to adopt in the future). Second, the value function differential between adopters and disadopters is increasing in the

current yield differential, showing the higher the current yield differential the more likely current adoption is the dominant strategy.



**Figure 1. Conditional Value Functions for Adopters and Non-Adopters**

Figure 2 shows optimal seed use rules under higher and lower switching costs as a function of current price and yield differentials. The optimal adoption rule takes the form of pair of threshold lines indicating the boundary between using hybrids and using traditional varieties. If the current price and yield differential are high enough hybrids will always be used. Similarly, if the current price and yield differential are low enough traditional seeds will always be used. At intermediate levels of current price and yield differentials the decision is to wait and continue using the existing technology (whatever it is). The waiting area is due to switching costs that slow down adjustment to changing relative profitability of hybrids versus traditional seeds. As the switching cost is lowered, the waiting area shrinks and it is optimal for households to switch more often in response to changing relative profitability.



**Figure 2. Optimal Adoption Rule Under Alternative Switching Costs**

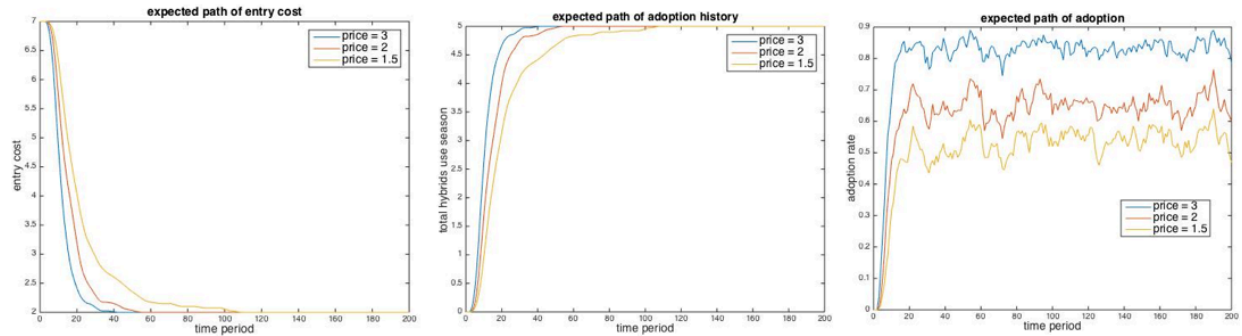
## Scenario Analysis

Monte Carlo simulations were run under different scenarios to evaluate how different factors influence the adoption process. For each scenario, the simulation is run for 200 periods with 200 replications.

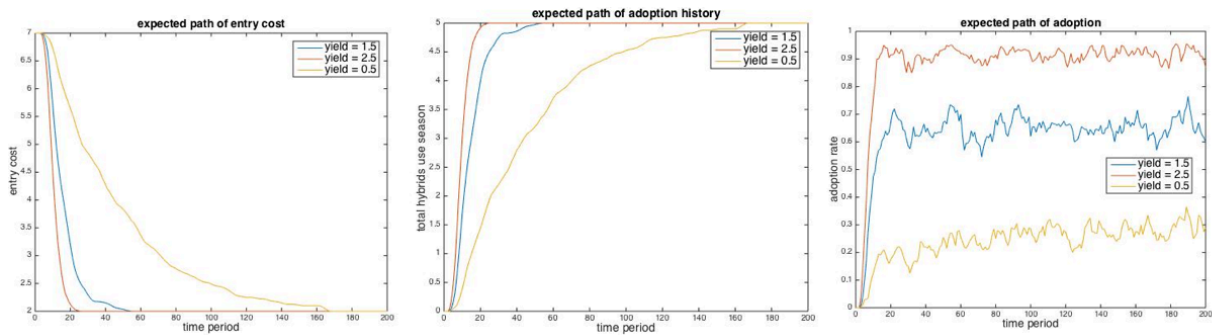
### *Alternative Price and Yield Differential Scenarios*

Figures 3 and 4 illustrate the path of the adoption process under different price and yield differential scenarios. The effects of changes in current price and yield differential on adoption are very similar since increasing either one will increase the incentive to adopt. Holding the other variable constant, a higher level of price or yield differential will encourage households to adopt hybrid seeds at earlier stage. Consequently, the profitability effect triggers the adoption process to converge faster and achieve a higher adoption rate. The first panel of Table 4 shows that a higher current price or yield differential also increases the number of re-adoptions and disadoptions, shortening the duration of adoption and disadoption and increasing transient use.

This occurs because, while profitability and switching costs are the two main determinants of adoption, higher profits decrease the role of switching costs. Hence, with a higher price, the household switches technologies more frequently based on fluctuations in the yield differential.



**Figure 3. Results Under Alternative Price scenario**



**Figure 4: Results Under Alternative Yield Scenarios**

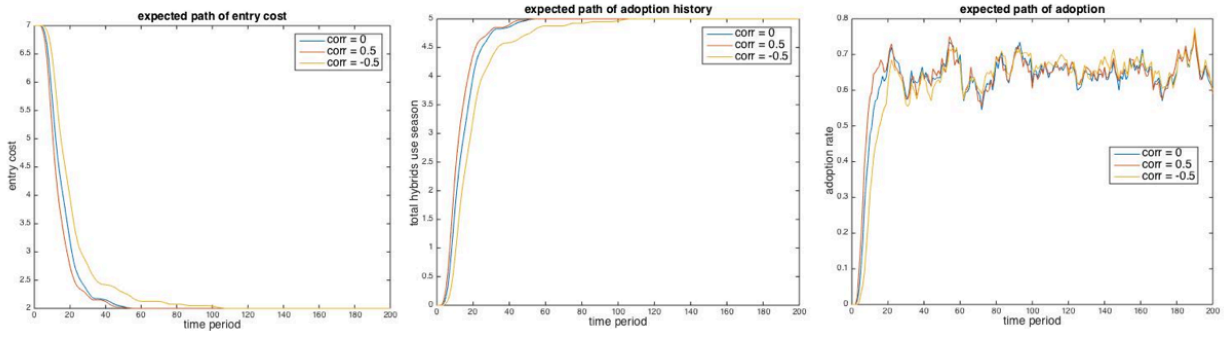


**Table 4. Number of Re-adoptions and Disadoptions, and Adoption Duration Over 200 Periods**

Scenario: price	price			yield		
	low	mid	high	low	mid	high
# of re-adoptions	3.66	4.79	7.26	3.66	2.04	1.34
# of disadoptions	2.85	3.93	6.46	2.85	1.10	0.35
Adoption duration	89.77	83.54	58.60	89.77	144.70	180.58
Disadoption duration	27.90	17.91	13.83	27.90	13.59	8.62
Scenario: Variability	price/yield correlation			yield differential variance		
	zero	positive	negative	low	mid	high
# of re-adoption	4.79	3.81	6.17	4.79	8.95	19.14
# of disadoption	3.93	2.90	5.37	3.93	8.32	18.73
Adoption duration	83.54	105.76	59.63	83.54	41.37	16.93
Disadoption duration	17.91	12.30	21.16	17.91	22.14	22.23
Scenario: switching cost	switching cost (fixed cost)			switching cost(decreasing rate)		
	low	mid	high	low	mid	high
# of re-adoptions	4.79	3.39	2.35	36.70	30.54	30.67
# of disadoptions	3.93	2.55	1.46	35.29	29.43	29.53
Adoption duration	83.54	92.78	110.73	35.35	35.45	35.33
Disadoption duration	17.91	25.06	30.95	17.06	15.61	15.63

*Alternative Price and Yield Differential Correlation Scenarios*

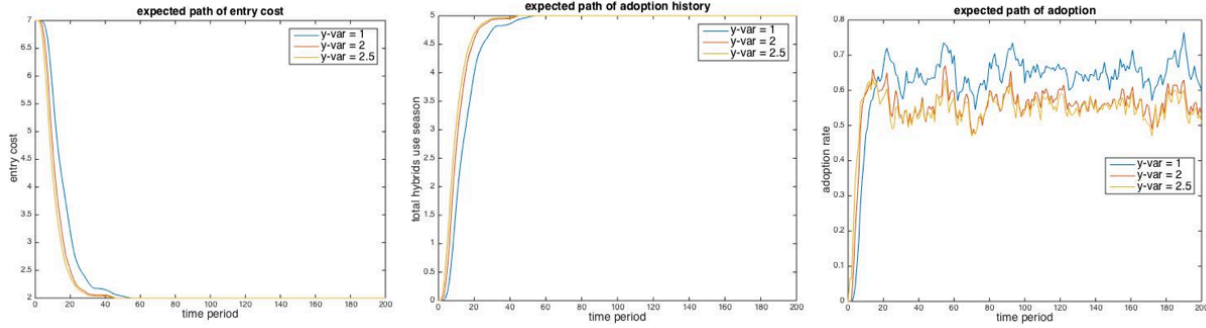
In this scenario, we set the correlation between price and yield differentials to be zero, positive, and negative, and hold all other state variables constant. Results are shown in Figure 5. Positive correlation between price and yield differentials implies higher revenue variability. The additional revenue variability causes more frequent breakthroughs of the threshold boundaries of the optimal decision rule, encouraging adoption at an earlier stage. Thus, the switching cost declines faster (learning effect) as households adopt hybrids earlier and the dynamic process converges to its steady state adoption rate faster. However, a faster convergence does not mean a higher level of adoption, as the price/yield correlation has little effect on long-run profitability. Also, positive correlation gives rise to less re-adoption and disadoption, longer duration of adoption, and shorter duration of disadoption (see the second panel of Table 4).



**Figure 5. Different Price-Yield Differential Correlation Scenarios**

### *Alternative Yield Differential Variance Scenarios*

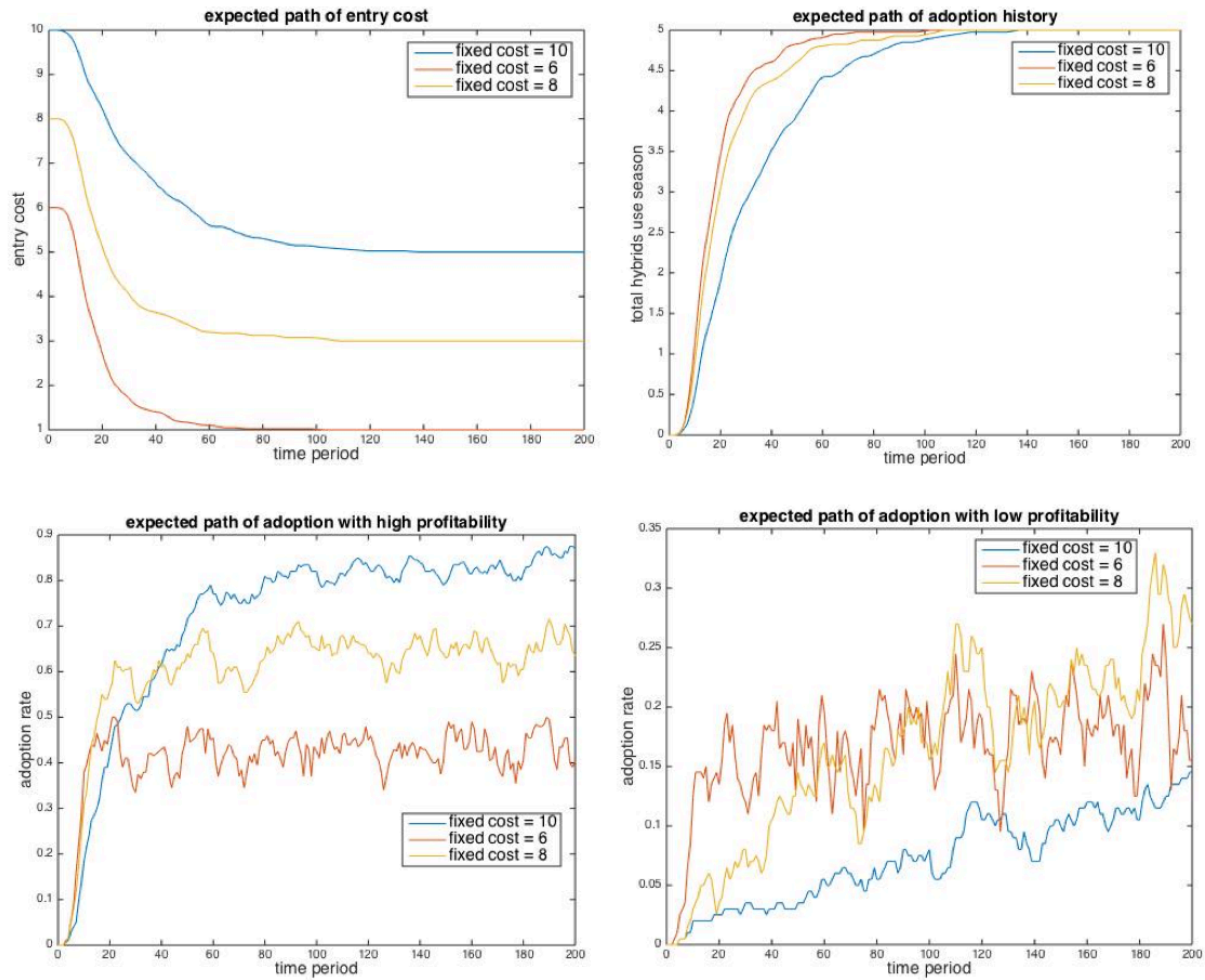
Figure 6 illustrates how the dynamic process evolves given different yield differential variance scenarios. Similar to the case of positive correlation between price and the yield differential, a higher variance will generate more extreme outcomes of production revenue. This increases the frequency of breaking through the threshold values of the optimal decision rule, accelerates the decline of the switching cost, and encourages earlier adoption of hybrids. This, in turn, causes the adoption process to converge faster to the steady state. This can be seen from the second panel of Table 3 where higher uncertainty gives rise to a lower adoption rate, more re-adoption and disadoption, shorter duration of adoption, and longer duration of disadoption. However, once in the steady state higher yield differential uncertainty means a higher likelihood of an extremely unfavorable yield differential realization leading to reversion to traditional varieties. Therefore, the adoption rate under higher yield differential variance is lower.



**Figure 6. Different Yield Differential Variance Scenarios**

### *Alternative Switching Cost Scenarios*

In this scenario, we adjust the size of the switching costs. Figure 7 illustrates how the adoption process evolves and how the switching costs affect the adoption rate given two levels of profitability (high and low). Lower switching costs encourages earlier use of hybrids and switching is more frequent. This can be seen from third panel of Table 3 where lower fixed cost gives rise to more re-adoption and disadoption, and shorter durations of adoption and disadoption. This is because switching costs play a role in preventing entry into the hybrid seed market. While the switching cost influences the speed of adoption, it does not solely determine the level of adoption. The last two graphs in Figure 7 show that the switching cost effect on adoption rate varies for different levels of profitability. A higher switching cost gives rise to a higher adoption rate with high profitability, but a lower adoption rate with low profitability. This implies a complex relationship between switching costs, and profitability, and the adoption process.



**Figure 7. Different Switching Cost Scenarios**

**Decreasing Rate of Switching.** As the switching cost is defined as a sum of a fixed cost and a variable cost, we assume that the variable cost will decrease to zero after a certain number of total seasons of adoption. In this scenario, we adjust the level of decreasing rate (i.e. the number of seasons of adoption for the variable cost to decrease to zero) given the level of fixed cost. While a lower decreasing rate means more seasons of adoption to diminish the variable cost, it is not surprising that households need to adopt hybrids more periods to get a lower switching cost.

However, this does not give rise to a slower convergence or a lower adoption rate, which can be seen from figure 8 and table 3.

## **Conclusions**

This study shines a light on the phenomenon of transient technology use and provides a potential explanation for complex dynamic patterns of adoption and disadoption of new technologies.

Focusing on the role of switching costs, we have studied the effects of various factors on adoption, disadoption, and transient technology use. In particular, the profitability of adoption, the variance of yield differential shocks, and the size of switching costs are all found to be significant factors influencing the pattern of adoption. High yield differential uncertainty encourages adoption when high yield differentials are realized. However, in long-run equilibrium high yield differential variance encourages higher switching costs, and thus lowers the long-run adoption rate. Profitability and switching costs jointly determine the level of adoption in the long run. Switching costs play a role in preventing households from both entering and exiting the hybrid seed market, and the profitability of hybrid seeds determines if the switching cost will maintain or exclude households from using the new technology. Therefore, to expand adoption of modern inputs, especially at the early stage when productivity increases have not been demonstrated, policy could pay more attention to reducing and overcoming these switching costs.

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