Mathematical Supplement for "An Analysis of Adoption of Digital Health Records under Switching Costs"

This mathematical supplement provides proofs for Propositions 1, 2, and 3. In addition, in developing the proof for Proposition 1, we derive equation (4) in the paper that defines the net anticipated value in period *t+1* for a consumer who purchases from provider *A* in period *t* given switching costs and the potential for being "locked-in" to the prior provider.

Proof of Proposition 1

The proof of Proposition 1 is straightforward, but does involve substantial algebra. To avoid algebraic errors, all results reported below have been checked using Mathematica; a copy of this Mathematica program is available upon request. We start with the determination of prices in the second period: p_{At}, p_{Bt}, p_{At+1}, and p_{Bt+1}..

For provider A, second period profits are given by:

(S1) $$\pi_{At+1} = q_{At+1} L\left(p_{At+1} - \theta\right) - k_A$$

where total sales are defined as follows:

(S2) $$q_{At+1} = \eta_{t+1}\alpha_{t+1} + \mu_{t+1}\left[\alpha_t\, y_{t+1} + \left(1-\alpha_t\right) x_{t+1}\right] + \left(1-\eta_{t+1}-\mu_{t+1}\right)\alpha_t\ .$$

Recall that in our two-period setting,

(S3) $$\alpha_{t+1} = \rho_{t+1} = \left[1 + r_A - p_{At+1} - \left(r_B - p_{Bt+1}\right)\right]/\,2$$

denotes the probability that a new consumer purchases from provider *A* rather than provider *B* in period *t+1*. Further, recall that $y_{t+1} = \rho_{t+1} + s_{AB}/2$ and $x_{t+1} = \rho_{t+1} - s_{BA}/2$. Note that in the following we assume fixed costs for the providers are sufficiently small such that profits are positive at the equilibrium set of prices. We restrict our analysis to the set of parameters such that $0 < y_{t+1} < 1$ and $0 < x_{t+1} < 1$.

At the start of period *t+1*, α_t , the probability an experienced consumer purchased from provider *A* in the period *t*, is taken as given. Substitute (S3) into (S2), and then substitute the result into (S1). Differentiating this expression for profits of provider *A* in period *t+1* with respect to the price p_{At+1}, taking as given the price of the provider B p_{Bt+1}, and rearranging, we obtain the following first-order condition:

$$\text{(S4)} \qquad -p_{At+1} + \frac{1 + p_{Bt+1} + r_A - r_B + \theta}{2} + \frac{-\mu_{t+1}\left[s_{BA}\left(1-\alpha_t\right) + \alpha_t\, s_{AB}\right] + 2\alpha_t\left[1 - \eta_{t+1} - \mu_{t+1}\right]}{2\left(\eta_{t+1} + \mu_{t+1}\right)} = 0$$

A similar analysis for provider *B* results in the following first-order condition for provider *B* with respect to the price p_{Bt+1}:

$$\text{(S5)} \frac{-1 + p_{At+1} - r_A + r_B + \theta}{2} + \frac{2 + \mu_{t+1}\left[s_{BA}\left(1-\alpha_t\right) - \alpha_t\, s_{AB}\right] - 2\alpha_t\left[1 - \eta_{t+1} - \mu_{t+1}\right]}{2\left(\eta_{t+1} + \mu_{t+1}\right)} - p_{Bt+1} = 0 .$$

First-order conditions (S4) and (S5) can define a Nash equilibrium set of prices in the second period under appropriate assumptions regarding key parameters to assure that all consumers in the market purchase from one of the two providers and that there is robust competition across providers for new and experienced consumers in period *t+1*. For such a situation to occur, we assume that the values of providers to consumers $(r_i\ ,\ i = A, B)$ are sufficiently high, that these values are sufficiently similar across providers, that the proportion of customers $\eta_{t+1} + \mu_{t+1}$ who potentially consider a new provider in period *t+1* is less than one but sufficiently large, and that switching costs $(s_{AB},\ s_{BA})$ are sufficiently small.

Under such assumptions, solving (S4) and (S5), we obtain the following Nash equilibrium set of prices in period *t+1*:

(S6) $$p_{At+1}=\theta+\frac{1+r_A-r_B-2\alpha_t}{3}+\frac{2\left(1+\alpha_t\right)+\mu_{t+1}\left[\left(s_{AB}+s_{BA}\right)\alpha_t-s_{BA}\right]}{3\left(\eta_{t+1}+\mu_{t+1}\right)}$$

and

(S7) $$p_{Bt+1}=\theta+\frac{-1-r_A+r_B+2\alpha_t}{3}+\frac{2\left(2-\alpha_t\right)-\mu_{t+1}\left[\left(s_{AB}+s_{BA}\right)\alpha_t-s_{BA}\right]}{3\left(\eta_{t+1}+\mu_{t+1}\right)}$$

In the symmetric case considered in Proposition 1, $s_{AB}=s_{BA}=s$ and $r_A=r_B=r$, such that the above expressions (S6) and (S7) simplify to:

(S8) $$p_{At+1}=\theta+\frac{2\left(1+\alpha_t\right)+\left(\eta_{t+1}+\mu_{t+1}\right)\left(1-2\alpha_t\right)+s\mu_{t+1}\left(2\alpha_t-1\right)}{3\left(\eta_{t+1}+\mu_{t+1}\right)}$$

and

(S9) $$p_{Bt+1}=\theta+\frac{2\left(2-\alpha_t\right)-\left(\eta_{t+1}+\mu_{t+1}\right)\left(1-2\alpha_t\right)-s\mu_{t+1}\left(2\alpha_t-1\right)}{3\left(\eta_{t+1}+\mu_{t+1}\right)}$$

Substituting (S8) and (S9) into (S3), then (S3) into (S2), then (S2), (S8), and (S9) into (S1), and performing a similar analysis for provider *B*, we have the following representation of profits in period *t+1* for providers *A* and *B* given symmetry in consumer values and switching costs:

(S10) $$\begin{aligned}\pi_{At+1}=&-k_A+\frac{4}{18}+\frac{4\left(1-s\mu_{t+1}\right)+\left(\eta_{t+1}+\mu_{t+1}-s\mu_{t+1}\right)^2}{18\left(\eta_{t+1}+\mu_{t+1}\right)}\\&+\frac{4\alpha_t\left[1-\left(\eta_{t+1}+\mu_{t+1}\right)+s\mu_{t+1}\right]\left[\alpha_t+2+\left(1-\alpha_t\right)\left(\eta_{t+1}+\mu_{t+1}-s\mu_{t+1}\right)\right]}{18\left(\eta_{t+1}+\mu_{t+1}\right)}\end{aligned}$$

(S11)
$$\pi_{Bt+1} = -k_B - \frac{8}{18} + \frac{16 + 8s\mu_{t+1} + \left(\eta_{t+1} + \mu_{t+1} - s\mu_{t+1}\right)^2}{18\left(\eta_{t+1} + \mu_{t+1}\right)} + \frac{-4\alpha_t \left[4 - \left(\eta_{t+1} + \mu_{t+1}\right) + s\mu_{t+1}\right]\left[1 - \left(\eta_{t+1} + \mu_{t+1}\right) + s\mu_{t+1}\right]\left(\alpha_t + 1\right)}{18\left(\eta_{t+1} + \mu_{t+1}\right)}$$

Note that in a symmetric equilibrium, $\alpha_t = 1/2$. In such a case, the above profit expressions simplify to $\pi_{At+1} = -k_A + 1/2\left(\eta_{t+1} + \mu_{t+1}\right)$ and $\pi_{Bt+1} = -k_B + 1/2\left(\eta_{t+1} + \mu_{t+1}\right)$.

We now turn to the derivation of the equilibrium set of prices in the first period. In doing so, we seek to retain a key feature of the analysis, namely that equilibrium prices as defined by (S6) and (S7) in period *t+1* and the resulting profits as defined by (S10) and (S11) are increasing in a provider's market share in the prior period (α_t for provider *A*; $(1-\alpha_t)$ for provider *B*) . This feature is assured if we assume that some experienced consumers are "locked-in" $(\eta_{t+1} + \mu_{t+1} < 1)$ and there are positive switching costs. Given these assumptions, the determination of providers' optimal prices in the first period must take into account forward-looking behavior by both consumers and providers who anticipate the effect of the first period's prices on market share, and thus prices and profits in the second period.

For consumers, forward-looking behavior means each consumer anticipates the implications of being a prior customer of a particular provider on her return in the subsequent period given the likelihood that she is either "locked-in" to the prior provider or faces switching costs on choosing the other provider. Recall that V_{At} (V_{Bt}) denotes the expected value associated with period *t+1* purchases of health care services conditional on being a consumer of provider *A* (*B*) in period *t*. Introducing the superscript *e* to denote new consumers' expectations regarding key variables in the next period, we can formally express these expected values as follows:

$$V_{At} = \left[\mu_{t+1}/\left(1-\eta_{t+1}\right)\right]\left\{\int_0^{y_{t+1}^e}\left(r_A - p_{At+1}^e - \varepsilon_A\right)\mathrm{d}\varepsilon_A + \int_{y_{t+1}^e}^1\left[r_B - p_{Bt+1}^e - \left(1-\varepsilon_A\right) - s_{AB}\right]\mathrm{d}\varepsilon_A\right\}$$
$$+\left(1-\mu_{t+1}-\eta_{t+1}\right)\left(r_A - p_{At+1}^e - \alpha_t^e\right)/\left(1-\eta_{t+1}\right) \tag{S12}$$

and

$$V_{Bt} = \left[\mu_{t+1}/\left(1-\eta_{t+1}\right)\right]\left\{\int_0^{x_{t+1}^e}\left(r_A - p_{At+1}^e - \varepsilon_A - s_{BA}\right)\mathrm{d}\varepsilon_0 + \int_{x_{t+1}^e}^1\left[r_B - p_{Bt+1}^e - \left(1-\varepsilon_A\right)\right]\mathrm{d}\varepsilon_A\right\},$$
$$+\left(1-\mu_{t+1}-\eta_{t+1}\right)\left[r_B - p_{Bt+1}^e - \left(1-\alpha_t^e\right)\right]/\left(1-\eta_{t+1}\right) \tag{S13}$$

with the consumers' discount factor $0 < \beta_c \leq 1$. Integrating (S12) and (S13) and combining, we obtain the following expression for the net expected value in period *t+1* to being a customer of provider *A* rather than *B* in period *t*:

$$V_{At} - V_{Bt} = \frac{2\left(1-\mu_{t+1}-\eta_{t+1}\right)}{1-\eta_{t+1}}\left(\rho_{t+1}^e - 1 + \alpha_t^e\right) + \frac{\mu_{t+1}}{1-\eta_{t+1}}\left(s_{AB}+s_{BA}\right)\left[\rho_{t+1}^e - 1 + \left(s_{BA}-s_{AB}\right)/4\right] \tag{S14}$$

Note that while an increase in provider *A*'s period-one price directly reduces the gain to consumer purchases in that period from provider *A*, consumers may anticipate a partially offsetting gain. The source of this gain reflects the fact that a higher price today reduces provider *A*'s market share of experienced consumers in the subsequent period. As discussed in the paper, rational expectations on the part of consumers means that consumers accurately forecast such an effect on a provider's future prices and market shares, such that $\rho_{t+1}^e = \rho_{t+1}$ and $\alpha_t^e = \alpha_t$. The result is that consumers recognize that a higher price today for provider *A* means fewer "locked-in" consumers next period for provider *A*, and thus a lower price for provider *A* next period.

Recall from our discussion in the text that provider *A*'s future market share is given by:

$$\alpha_t = \rho_t + \beta_c\left(V_{At} - V_{Bt}\right)/2 \tag{S15}$$

If we assume rational expectations, we can substitute equation (S14) into equation (S15) and solve for the proportion of new consumers who purchase from provider *A* in period *t*, α_t , under the assumption of rational expectations. Doing so, we obtain:

(S16) $$\alpha_t = \frac{\rho_t T_0 + \beta_c \left(8 + T_1 \eta_{t+1} + T_2 \eta_{t+1}^2 + T_3 \mu_{t+1} + T_4 \eta_{t+1}\mu_{t+1} + T_5 \mu_{t+1}^2\right)}{T_0 + 4\beta_c \left(4 - 2\eta_{t+1} - 2\eta_{t+1}^2 + T_6 \mu_{t+1} + T_7 \eta_{t+1}\mu_{t+1} + T_8 \mu_{t+1}^2\right)}$$

where

$$T_0 = 24\left(1-\eta_{t+1}\right)\left(\eta_{t+1} + \mu_{t+1}\right)$$
$$T_1 = -4\left(1 - r_A + r_B\right)$$
$$T_2 = -4\left(1 + r_A - r_B\right)$$
$$T_3 = -4\left(1 - r_A + r_B - s_{AB} - 3s_{BA}\right)$$
$$T_4 = -\left(4 - s_{AB}\right)\left(2 + 2r_A - 2r_B + 3s_{AB}\right) - 2\left(3 - r_A + r_B\right)s_B - 3s_B^2$$
$$T_5 = -2r_A\left(2 - s_{AB} - s_{BA}\right) - 2r_B\left(2 - s_{AB} - s_{BA}\right) + \left(s_{AB} + s_{BA}\right)\left(3s_{AB} + s_{BA}\right) - 2\left(2 + 5s_{AB} + 3s_{BA}\right)$$
$$T_6 = -2 + 4s_{AB} + 4s_{BA}$$
$$T_7 = -4\left(1 + s_{AB} + s_{BA}\right)$$
$$T_8 = -2 - \left(4 - s_{AB} - s_{BA}\right)\left(s_{AB} + s_{BA}\right)$$

If consumers were myopic (not forward looking, such that $\beta_c = 0$), then from (S16) we have $\alpha_t = \rho_t / 2$. Myopic consumers are more responsive to price changes in period *t*, as they do not anticipate the offsetting effect on a provider's price next period of a price change in the current period. Of course, this discussion reflects our presumption that some experienced consumers are "locked-in" to their prior provider in the following period (i.e., $\eta_{t+1} + \mu_{t+1} < 1$).

For provider A, profits in the first period are given by:

(S17) $$\pi_{At} = q_{At}L\left(p_{At} - \theta\right) - k_A$$

where total sales are given by:

(S18) $$q_{At} = \eta_t \alpha_t + \mu_t \left[\alpha_{t-1} y_t + \left(1-\alpha_{t-1}\right) x_t \right] + \left(1-\eta_t - \mu_t\right) \alpha_{t-1}$$

Recall that α_t denotes the probability that a new consumer purchases from provider *A* rather than provider *B* in period *t*, $y_t = \rho_t + s_{AB}/2$ and $x_t = \rho_t - s_{BA}/2$. Similarly, for provider *B*, we have:

(S19) $$\pi_{Bt} = q_{Bt} L\left(p_{Bt} - \theta\right) - k_A$$

where total sales are given by:

(S20) $$q_{Bt} = \eta_t \left(1-\alpha_t\right) + \mu_t \left[\alpha_{t-1}\left(1-y_t\right) + \left(1-\alpha_{t-1}\right)\left(1-x_t\right) \right] + \left(1-\eta_t - \mu_t\right)\left(1-\alpha_{t-1}\right)$$

Profits over the two periods for providers *A* and *B* are then given by:

(S21) $$\pi_A = q_{At} L\left(p_{At} - \theta\right) + \beta \pi_{At+1} - k_A - \beta k_A$$

(S22) $$\pi_B = q_{Bt} L\left(p_{Bt} - \theta\right) + \beta \pi_{Bt+1} - k_B - \beta k_B$$

At the start of period *t*,the probability an experienced consumer purchased from provider *A* in the prior period, α_{t-1}, is taken as given. Thus, given profits defined by (S21), the first-order condition for provider *A*'s price in the current period is given by:

(S23) $$L\left[\frac{\partial q_{At}}{\partial p_{At}} \left(p_{At} - \theta\right) + q_{At} \right] + \beta \frac{\partial \pi_{At+1}}{\partial \alpha_t} \frac{\partial \alpha_t}{\partial p_{At}} = 0$$

Similarly, given profits defined by (S22) for provider *B*, the first-order condition for the provider *B*'s price in the current period is:

(S24) $$L\left[\frac{\partial q_{Bt}}{\partial p_{Bt}} \left(p_{Bt} - \theta\right) + q_{Bt} \right] + \beta \frac{\partial \pi_{Bt+1}}{\partial \alpha_t} \frac{\partial \alpha_t}{\partial p_{Bt}} = 0$$

Utilizing our previous expressions for equilibrium profits π_{At+1} and π_{Bt+1} in period *t+1* as given by (S10) and (S11), provider *A*'s market share α_t in period *t* as given by (S16), and sales in period *t* as given by (S18) and (S20), we can obtain explicit expressions for (A13) and (A14). Solving these two conditions provides us with expressions for the Nash equilibrium set of prices in period *t*.

These equilibrium expressions are quite lengthy, as they include the effects of changes in current prices on provider's and consumer's anticipated future prices. However, we can simplify the expressions for the equilibrium prices under the assumptions of proposition 1, namely when there are no experienced customers in the current period $(\eta_t = 1, \ \mu_t = 0)$; there is symmetry in the two providers $(s_{AB} = s_{BA} = s, \ r_A = r_B = r$, and $k_A = k_B = k)$ and consumers and providers have a common discount factor $(\beta = \beta_c)$. In such a case, we obtain the following set of prices reported in Proposition 1:

(S25) $$p_{At} = \theta + 1 + \frac{\beta}{3\left(\eta_{t+1} + \mu_{t+1}\right)}\left[3\eta_{t+1} + 2s\mu_{t+1} - \frac{-\mu_{t+1} + 4\eta_{t+1}\mu_{t+1} + \mu_{t+1}^2\left(1 + 4s - 2s^2\right)}{1 - \eta_{t+1}}\right]$$

(S26) $$p_{Bt} = \theta + 1 + \frac{\beta}{3\left(\eta_{t+1} + \mu_{t+1}\right)}\left[3\eta_{t+1} + 2s\mu_{t+1} - \frac{-\mu_{t+1} + 4\eta_{t+1}\mu_{t+1} + \mu_{t+1}^2\left(1 + 4s - 2s^2\right)}{1 - \eta_{t+1}}\right]$$

Note that the symmetric equilibrium has identical prices across providers and equal market shares $(\alpha_t = 1/2)$. Prices in period *t+1* as given by (S8) and (S9) simplify to

(S27) $$p_{At+1} = \theta + \frac{1}{\eta_{t+1} + \mu_{t+1}}$$

and

(S28) $$p_{Bt+1} = \theta + \frac{1}{\eta_{t+1} + \mu_{t+1}}$$

These expressions are identical to those reported in proposition 1. Some special cases for the current price in the symmetric case are:

$$\eta_{t+1}+\mu_{t+1}=1: \quad p_t = \theta+1-\frac{2\beta s\mu_{t+1}(1-s)}{3}$$

$$s=0: \qquad p_t = \theta+1+\frac{\beta}{3\left(\eta_{t+1}+\mu_{t+1}\right)}\left[\frac{(1-n_{t+1}-\mu_{t+1})\left[3\eta_{t+1}+\mu_{t+1}\right]}{\left(1-\eta_{t+1}\right)}\right].$$

Note that the assumption that all consumers perceive a gain to purchasing implies that for new consumers in period *t+1*, $r-p_{t+1}-1>0$. Substituting in the common expression for the equilibrium price in period t+1, such an assumption introduces the following requirement for consumer values relative to marginal cost (θ) and the extent to which consumers in period *t+1* are not locked-in to their prior provider $(\eta_{t+1}+\mu_{t+1})$:

$$r>\theta+1+\frac{1}{\eta_{t+1}+\mu_{t+1}}$$

Note that the assumption that some consumers switch providers in period *t+1* requires that: $0<y_{t+1}=\rho_{t+1}+s/2<1$ and $0<x_{t+1}=\rho_{t+1}-s/2<1$. Given symmetry such that $\rho_{t+1}=1/2$, such an assumption introduces the following bounds for the common switching cost: $1>s>0$.

Substituting the above set of equilibrium prices for periods *t* and *t+1* into the profit expressions prices (S21) and (S22), we obtain the following profit expression reported in Proposition 1:

(S29)

$$\pi=-k\left(1+\beta\right)+\frac{1}{2}+\frac{\beta}{6\left(\eta_{t+1}+\mu_{t+1}\right)}\left[3\left(\eta_{t+1}+1\right)+2s\mu_{t+1}-\frac{-\mu_{t+1}+4\eta_{t+1}\mu_{t+1}+\mu_{t+1}^2\left(1+4s-2s^2\right)}{1-\eta_{t+1}}\right]$$

Proof of Lemma 1

To show Lemma 1, we take the derivative of equilibrium prices and profits for each provider with respect to a change in r_i . We then evaluate these derivatives under parameters that reflect the symmetric base case identified in Proposition 1, which includes the assumption that initially $r_A = r_B = r$. The resulting comparative static results for providers *A*'s and *B*'s prices in periods *t* and t+1 are given by:

(S30)
$$\frac{dp_{At}}{dr_A} = -\frac{dp_{Bt}}{dr_A} = \frac{T_1 - \beta\left(1-\eta_{t+1}\right)T_2 - \beta\left(1-\eta_{t+1}\right)\mu_{t+1}T_3 - \beta^2\left(1-\eta_{t+1}-\mu_{t+1}+s\mu_{t+1}\right)+T_4}{\left(1-\eta_{t+1}\right)\left(T_7 + \beta T_8 + \beta\mu_{t+1}T_9\right)}$$

(S31)
$$\frac{dp_{At+1}}{dr_A} = -\frac{dp_{Bt+1}}{dr_A} = \frac{T_5 + T_6}{T_7 + \beta T_8 + \beta\mu_{t+1}T_9}$$

where

$$T_1 = -9\left(1-\eta_{t+1}\right)^2\left(\eta_{t+1}+\mu_{t+1}\right)$$
$$T_2 = -4\left(1-\eta_{t+1}\right)\left(1+2\eta_{t+1}\right)$$
$$T_3 = -2+14\eta_{t+1}-s\left[8-\eta_{t+1}\left(3+2\eta_{t+1}\right)\right]+\left\{6+s\left[7+2\eta_{t+1}-2s\left(2+\eta_{t+1}\right)\right]\right\}\mu_{t+1}$$
$$T_4 = -\left(1-\mu_{t+1}\right)\mu_{t+1}+\eta_{t+1}^2\left(3+4s\mu_{t+1}\right)+\eta_{t+1}\left(-3-2\mu_{t+1}\left\{-2+s\left[2-\left(2-s\right)\mu_{t+1}\right]\right\}\right)$$
$$T_5 = 3\left(1-\eta_{t+1}\right)\left[1+2\eta_{t+1}+\left(2+s\right)\mu_{t+1}\right]$$
$$T_6 = \beta\left[7-2\eta_{t+1}^2-\eta_{t+1}\left(5+4\mu_{t+1}+14s\mu_{t+1}\right)+\mu_{t+1}\left\{-5-2\mu_{t+1}+7s\left[2-\left(2-s\right)\mu_{t+1}\right]\right\}\right]$$
$$T_7 = 27\left(1-\eta_{t+1}\right)\left(\eta_{t+1}+\mu_{t+1}\right)$$
$$T_8 = 14+\eta_{t+1}\left[3-\eta_{t+1}\left(21-4\eta_{t+1}\right)\right]$$
$$T_9 = -1+28s-2\eta_{t+1}\left[17+10s-4\left(1-s\right)\eta_{t+1}\right]-\mu_{t+1}\left[13-4\eta_{t+1}+2s\left(2-s\right)\left(7+2\eta_{t+1}\right)\right]$$

From the above expressions for the price changes, we can derive the effect of a change in r_A on the change in the likelihood a consumer purchases from each provider each period and the overall effect on two-period profits for each provider. Note that because the price changes for the two providers are mirror images and initially providers are symmetric, it follows that:

(S32) $$\frac{d\pi_A}{dr_A} = -\frac{d\pi_B}{dr_A}$$

A key feature of the above expressions for the effect of the adoption of EHR by provider *A* (and thus an increase in r_A) is that the sign depends on four key variables: η_{t+1} (the proportion of new consumers in period *t+1*), μ_{t+1} (the proportion of consumers who purchased in the prior period and draw a new value for providers in the current period), s (switching costs in period *t+1*), and β (the common discount factor). In addition to initial symmetry across providers, Proposition 1 includes key assumptions regarding these parameters, namely that:

a) $\eta_{t+1} > 0$ and $\mu_{t+1} > 0$, such that there exist both new consumers and experienced consumers who obtain a new value for providers in period *t+1*.

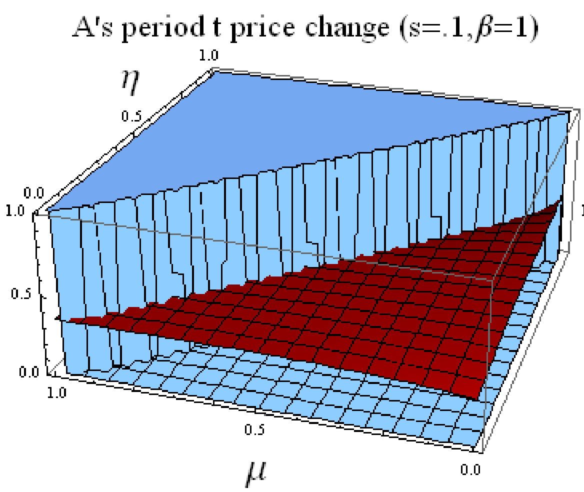
b) $\eta_{t+1} + \mu_{t+1} < 1$, such that there exists a positive proportion of consumers in period *t+1* who are "locked-in;

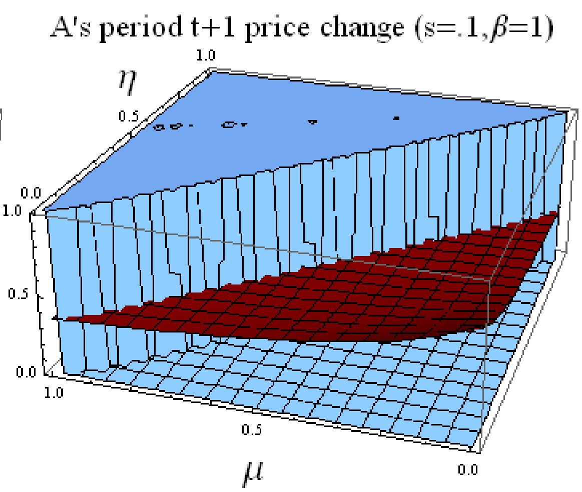
c) $1 - \eta_{t+1} - \mu_{t+1}$ is sufficiently low and consumer values sufficiently high such that consumers' values exceed equilibrium prices in both periods; in particular given our expression for prices in period *t+1*, that $r > \theta + 1 + 1/\left(\eta_{t+1} + \mu_{t+1}\right)$;

d) $1 > s > 0$, such that while switching costs exist, they are sufficiently small that some experienced consumers will switch providers in period *t+1*;

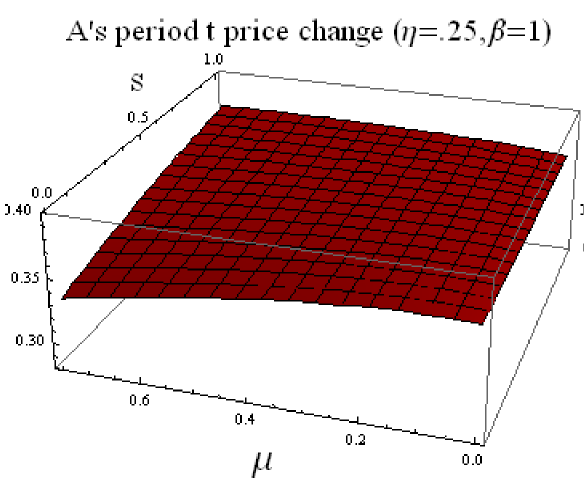
e) $1 \geq \beta > 0$, such that both consumers and providers are forward-looking.

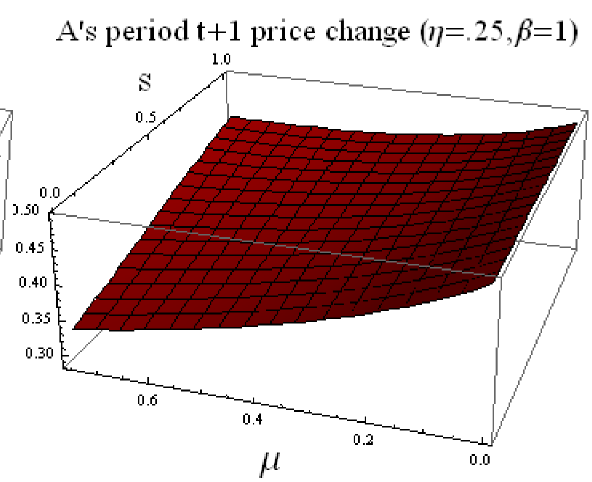
The above parameter constraints provide a method for determining the signs of what are admittedly quite complex comparative static expressions for the effects of a change in r_A on equilibrium prices and profits. This method involves computing the values of dp_{At} / dr_A, dp_{At+1} / dr_A for all feasible values of η_{t+1}, μ_{t+1}, s, and β that satisfy the above conditions a) through e). We rely on Mathematica to perform such computations. Below are examples of these computational results. The first two graphs illustrate price changes in prices p_{At} and p_{At+1} given a one unit increase in r_A for different feasible η_{t+1} and μ_{t+1} over the feasible range $0 < \eta_{t+1} + \mu_{t+1} < 1$ if $\beta = 1$ and $s = .1$:



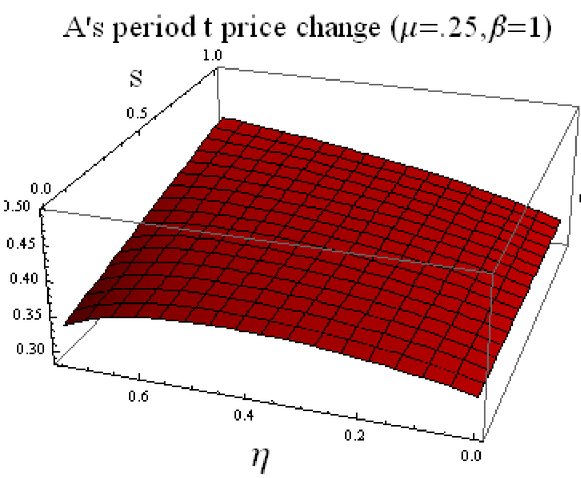


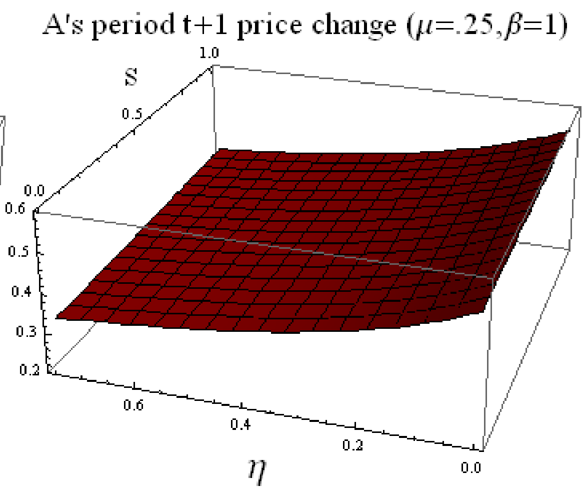
The graphs below illustrate the changes in prices for a one-unit increase in r_A across feasible values for μ_{t+1} and s (recall that $1 > \eta_{t+1} + \mu_{t+1} > 0$ and $1 > s > 0$) if $\eta_{t+1} = .25$ and $\beta = 1$:



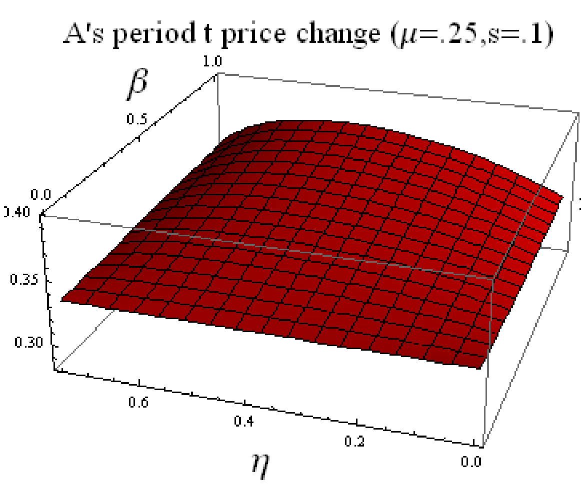


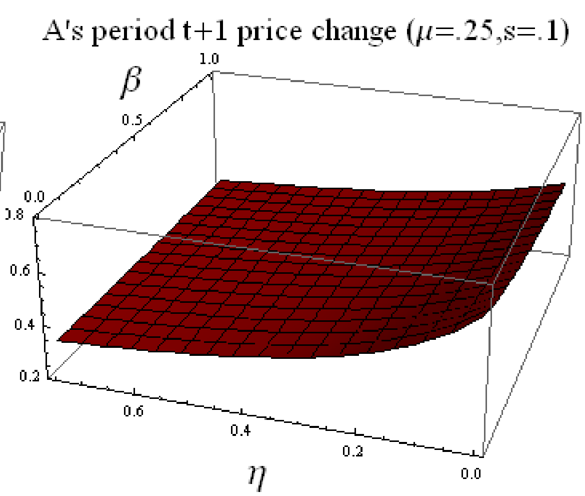
The graphs below illustrate the changes in prices for a one-unit increase in r_A across feasible values of η_{t+1} and s (recall that $1 > \eta_{t+1} + \mu_{t+1} > 0$ and $1 > s > 0$) if $\mu_{t+1} = .25$ and $\beta = 1$:





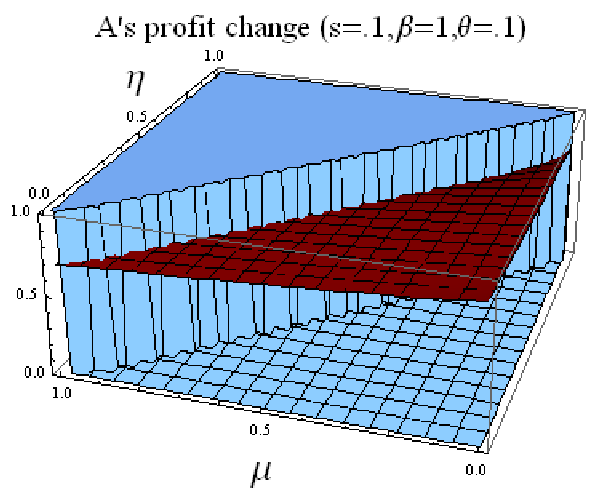
The graphs below illustrate the changes in prices for a one-unit increase in r_A across feasible values for η_{t+1} and β (recall that $1 > \eta_{t+1} + \mu_{t+1} > 0$ and $1 \geq \beta > 0$) if $\mu_{t+1} = .25$ and $s = .1$:





The above graphs, and others not reported, demonstrate the Proposition 2's claim that across parameter values for of η_{t+1}, μ_{t+1}, s, and β that satisfy conditions a) through e) of Proposition 1, the effect of a one unit increase in r_A is an increase in p_{At} and p_{At+1}, with the increase being less than the increase in r_A. Expressions (S30) and (S31) indicate that the changes in prices p_{Bt} and p_{Bt+1} are equal in magnitude, but have the opposite sign.

The above price increases translate into an increase in profits for provider A, and an equal in magnitude but opposite in sign reduction in profits for provider B from (S32). Note that to simulate profit changes, we have to specify the marginal cost, and we set $\theta = .1$. However, the change in profits due to the change in r_A is independent of the marginal cost value as long as consumer values are sufficiently high such that all consumers seek to purchase. The reason for this is that different marginal production cost result in identical changes in prices, and thus no change in profits. Below we provide an example of the change in operating income for different, feasible values of η_{t+1} and μ_{t+1} if one sets $\beta = 1$ and $s = .1$:



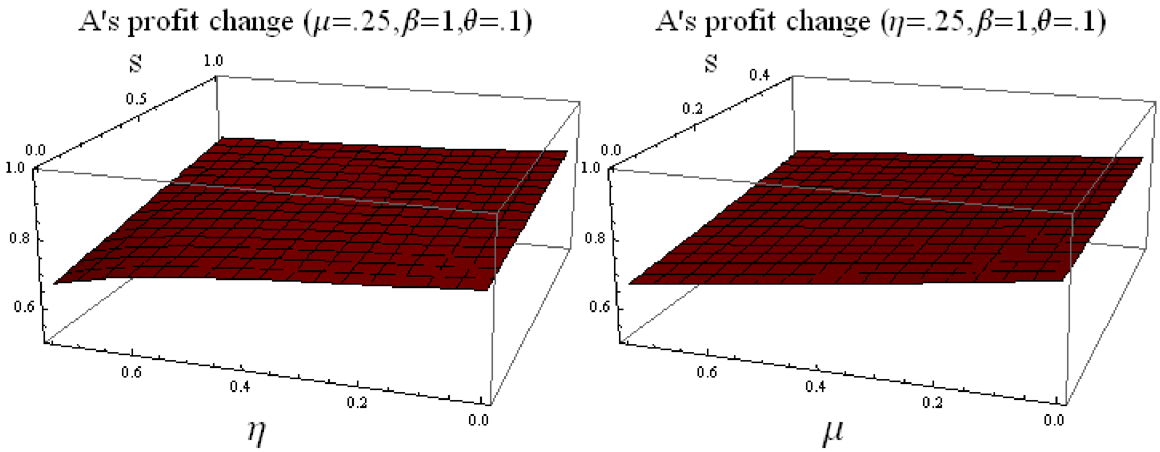
Similar increases in two-period profits can be shown to exist for the entire range of feasible switching costs $(1 > s > 0)$ and for the range of discount factors $1 \geq \beta > 0$.

Proof of Proposition 3

From the results reported above, we can calculate the effect of various factors on the magnitude of increase in the two-period operating profits for Provider *A* given an increase in r_A, First, since net-operating profits increase in r_A, it follows that if consumers place a higher value on EHR, and thus there is a larger increase in r_A due to the unilateral adoption of EHR, then the increase in operating profits is larger. We now establish Proposition 3's claim that higher switching costs (s) or a higher number of locked-in consumers, due either to a lower proportion of new consumers in period t+1 (η_{t+1}) or a lower proportion of experienced consumers with new provider values in period t+1 (μ_{t+1}), increases the magnitude of the increase in a provider's gain to a unilateral adoption of EHR.

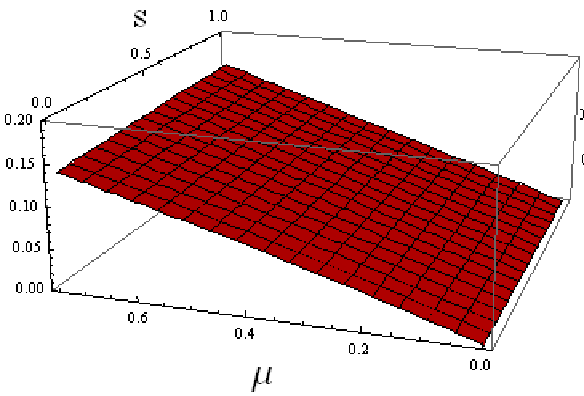
Intuitively, the above results reflect the fact that the gains in operating income to attracting additional consumers in period *t* through the adoption of EHR are enhanced if experienced consumers in period *t+1* have a higher "loyalty" to the prior provider, and this occurs if switching costs are higher or more experienced consumers are locked-in. The result is that $\partial\pi_A / \partial r_A$ increases with a higher *s*, a lower η_{t+1}, or a lower μ_{t+1}. The two graphs below plot on the horizontal axis the increase in the two-period operating income given a one unit increase in r_A $(\partial\pi_A / \partial r_A)$ for various levels of *s*and η_{t+1} and μ_{t+1}.

The two graphs illustrate the claim that the increase in operating income from the adoption of EHR (and resulting higher r_A) is greater at higher switching costs and consumer loyalty measures. Specifically, the graph on the left illustrates that the change in operating income given a one-unit increase in r_A is increasing in switching costs and as the proportion of new customers falls (the proportion of customers locked-in increases). The graph on the right illustrates that the change in operating income given a one-unit increase in r_A is increasing in switching costs and as the proportion of customers who are experienced customers and obtain new values across the two providers falls (the proportion of customers who are locked-in increases).

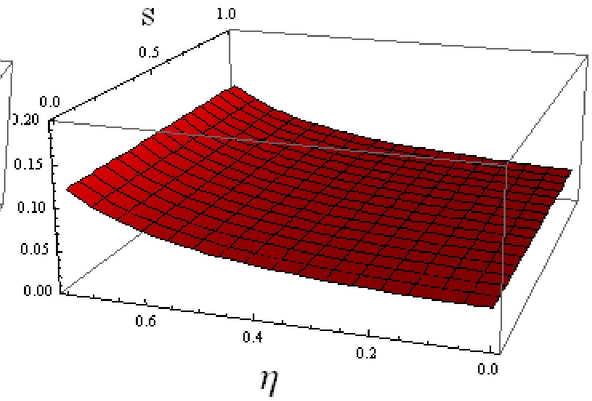


To confirm the above findings, we provide graphs below that indicate the effect of an increase in switching costs (s) or a decrease in the number of locked in consumers (higher η_{t+1} or μ_{t+1}) on $\partial\pi_A / \partial r_A$. In particular, the graphs depict the values of $\partial(\partial\pi_A / \partial r_A) / \partial s$, $\partial(\partial\pi_A / \partial r_A) / \partial\eta$, and $\partial(\partial\pi_A / \partial r_A) / \partial\mu$ across the same set of parameter values. These graphs confirm that $\partial(\partial\pi_A / \partial r_A) / \partial s > 0$ (indicating that the increase in operating income given an increase in r_A is higher if switching costs s are higher), that $\partial(\partial\pi_A / \partial r_A) / \partial\eta < 0$ (indicating that the increase in operating income given an increase in r_A is lower if the proportion of new consumers η_{t+1} is higher, and thus the proportion of locked-in consumers is lower), and that $\partial(\partial\pi_A / \partial r_A) / \partial\mu < 0$ (indicating the increase in operating income given an increase in r_A is lower if the proportion of experienced consumers with new provider values μ_{t+1} is higher, and thus the proportion of locked-in consumers is lower).

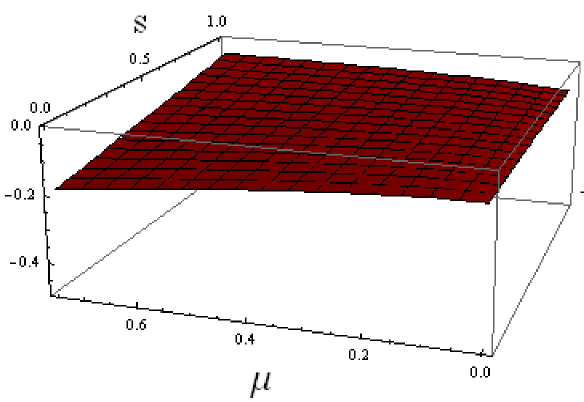
$\partial(\partial\pi_A / \partial r_A)/\partial s \quad (\eta=.25, \beta=1, \theta=.1)$



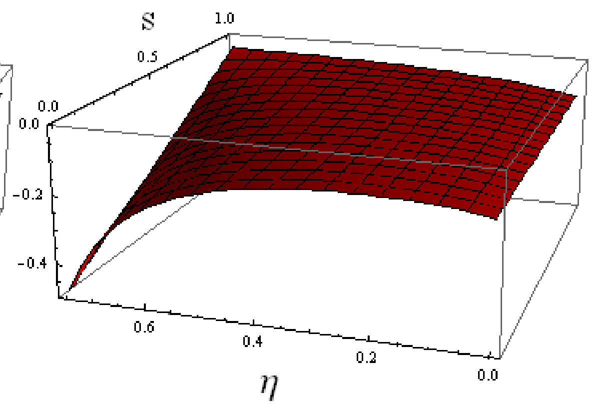
$\partial(\partial\pi_A / \partial r_A)/\partial s \quad (\mu=.25, \beta=1, \theta=.1)$



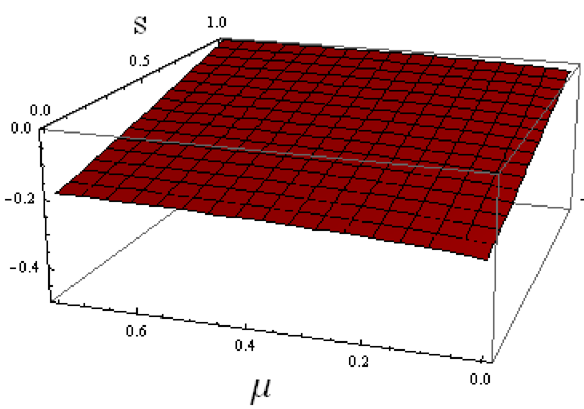
$\partial(\partial\pi_A / \partial r_A)/\partial \eta \quad (\eta=.25, \beta=1, \theta=.1)$



$\partial(\partial\pi_A / \partial r_A)/\partial \eta \quad (\mu=.25, \beta=1, \theta=.1)$



$\partial(\partial\pi_A / \partial r_A)/\partial \mu \quad (\eta=.25, \beta=1, \theta=.1)$



$\partial(\partial\pi_A / \partial r_A)/\partial \mu \quad (\mu=.25, \beta=1, \theta=.1)$