Online Appendix for "Variety and Experience: Learning and Forgetting in the Use of Surgical Devices"

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OA.1: Test for Serial Correlation of Error Term

In section 4.1 of our paper, the baseline specification is

$$y_{st} = \beta X_{st} + \gamma e_{st} + \alpha w_{st1} + \theta \log\left[w_{st2}\right] + \varepsilon_{st}. \tag{1}$$

Here, y_{st} is the log value of duration of the surgery performed by surgeon s at time t, e_{st} is the total experience of surgeon s at time t, X_{st} is a vector of control variables, w_{st1} and w_{st2} are vectors of (observed) device-specific experience variables related to learning and forgetting for surgeon s at time t, as explained below, and ε_{st} is the error term.

Since we have an unbalanced panel with varying time gaps between observations for each surgeon (for example, a surgeon may do three surgeries one day, none the next, and two the day after that), we construct a nonparametric estimator of the correlation between errors from two surgeries done by the same surgeon following Stern et al. (2010). In particular, we can write

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the error ε_{st} in any of the models we have discussed above as

$$\varepsilon_{st} = \rho\left(d_{t,t-1}\right)\varepsilon_{st-1} + \eta_{st}; \eta_{st} \sim iid\left(0, \sigma_\eta^2\right). \tag{2}$$

In this appendix, we show how to estimate a correlation function $\rho\left(d_{t,v}\right)$ for two surgeries t and v by the same surgeon as a function of the time gap $d_{t,v} = |t - v|$ (measured in days) between them.

Define $\widetilde{\epsilon}_{st}$ as the residual from the pooled OLS presented by specification (1), $\widetilde{\epsilon}_{s\cdot}$ as the sample mean of $\widetilde{\epsilon}_{st}$ for each individual, and $\widehat{\widetilde{\epsilon}}_{st}$ as the standardized residual which is

$$\widehat{\widetilde{\epsilon}}_{st} = \frac{\widetilde{\epsilon}_{st} - \widetilde{\epsilon}_{s\cdot}}{\sigma_{\widetilde{\epsilon}}}.$$

where $\sigma_{\widetilde{\epsilon}}$ is the standard deviation of $\widetilde{\epsilon}_{st}$. A kernel-based estimate of the correlation function $\rho\left(d\right)$ is

$$\widehat{\rho}\left(d\right) = \frac{\sum_s \sum_{t,v} K\left(d_{t,v} - d\right)\widehat{\widetilde{\epsilon}}_{st}\widehat{\widetilde{\epsilon}}_{sv}}{\sum_s \sum_{t,v} K\left(d_{t,v} - d\right)} \tag{3}$$

where $K\left(\cdot\right)$ is a kernel function. We use

$$K\left(z\right) = \begin{cases} \frac{b^{-1}}{\sqrt{2\pi}} \exp\left\{-.5\frac{z^2}{b^2}\right\} & \text{if } |z| \leq 4 \\ 0 & \text{if } |z| > 4 \end{cases}$$

and set $b = \sigma_d$, the sample standard deviation of distances. Note that the model which can be described by both equations (1) and (2) assumes a balanced panel, but the estimator for $\rho\left(d\right)$ in equation (3) does not require a balanced panel.

Figure A1 displays the estimated correlation function $\rho\left(d_{t,v}\right)$. We see that $\widehat{\rho}\left(0\right) \approx 0.25$, implying that, even for surgeries performed by a surgeon on the same day, the estimated correlation coefficient is relatively small. Also, the estimated correlation function dies out pretty quickly. Therefore, serial correlation in ε_{st} is not a concern even though we observe surgeons over a long time period.

OA.2: Possible Biases Caused by Left-Censored Experience Variables

We use two examples to discuss the possible biases of our estimates if we don't consider the data censoring issue in our estimation. First, consider the simple case which has only a left-censored explanatory variable:

$$y_i = \beta z_i + u_i \tag{4}$$

with $\beta > 0$. Instead of observing z_i, we observe $w_i = \min\left(w_i^c, z_i\right)$ which means we can only observe a threshold value w_i^c whenever $z_i > w_i^c$. If we run the regression,

$$y_i = bw_i + e_i,$$

then

$$\begin{aligned}
\widehat{b} &= \frac{n^{-1}\sum_i w_i y_i}{n^{-1}\sum_i w_i^2} \\
&= \frac{n^{-1}\sum_i w_i\left(\beta z_i + u_i\right)}{n^{-1}\sum_i w_i^2} \\
&= \beta\frac{n^{-1}\sum_i w_i z_i}{n^{-1}\sum_i w_i^2} + \frac{n^{-1}\sum_i w_i u_i}{n^{-1}\sum_i w_i^2} \\
&= \beta\frac{n^{-1}\sum_i w_i\left(z_i + w_i - w_i\right)}{n^{-1}\sum_i w_i^2} + \frac{n^{-1}\sum_i w_i u_i}{n^{-1}\sum_i w_i^2} \\
&= \beta\left[\frac{n^{-1}\sum_i w_i\left(z_i - w_i\right)}{n^{-1}\sum_i w_i^2} + \frac{n^{-1}\sum_i w_i^2}{n^{-1}\sum_i w_i^2}\right] + \frac{n^{-1}\sum_i w_i u_i}{n^{-1}\sum_i w_i^2} \\
&= \beta\left[\frac{n^{-1}\sum_{i:z_i>w_i^c} w_i\left(z_i - w_i^c\right)}{n^{-1}\sum_i w_i^2} + 1\right] + \frac{n^{-1}\sum_i w_i u_i}{n^{-1}\sum_i w_i^2};
\end{aligned}$$

$$\begin{aligned} plim\widehat{b} &= \beta+\beta\frac{plim\left(n^{-1}\sum_{i:x_i>w_i^c} w_i\left(z_i-w_i^c\right)\right)}{plim\left(n^{-1}\sum_i w_i^2\right)}+\frac{plim\left(n^{-1}\sum_i w_i u_i\right)}{plim\left(n^{-1}\sum_i w_i^2\right)} \\ &= \beta+\beta\frac{plim\left(n^{-1}\sum_{i:x_i>w_i^c} w_i\left(z_i-w_i^c\right)\right)}{plim\left(n^{-1}\sum_i w_i^2\right)}>\beta. \end{aligned}$$

For this simple case, we know that, if we do not take the data left-censoring issue into account, then the estimate of the parameter has bias in the same direction as the true sign of the coefficient. However, if we have other covariates which have no censoring issues, we may not be able to sign the bias. Now, we rewrite the equation (4) as

$$y_i = X_i\alpha+\beta z_i+u_i$$

where X_i includes variables which are not left-censored and z_i is the left-censored variable with threshold value w_i^c. Like the first example, we can observe only $w_i=\min\left(w_i^c,z_i\right)$, and we run the regression,

$$y_i = X_i a+bw_i+e_i.$$

By the same logic and after some algebra, we have

$$\begin{aligned} \begin{pmatrix} \widehat{a} \\ \widehat{b} \end{pmatrix} &= \begin{pmatrix} n^{-1}\sum_i X_i'X_i & n^{-1}\sum_i X_i'w_i \\ n^{-1}\sum_i w_i'X_i & n^{-1}\sum_i w_i^2 \end{pmatrix}^{-1} \begin{pmatrix} n^{-1}\sum_i X_i'y_i \\ n^{-1}\sum_i w_i'y_i \end{pmatrix} \\ &= \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + \begin{pmatrix} n^{-1}\sum_i X_i'X_i & n^{-1}\sum_i X_i'w_i \\ n^{-1}\sum_i w_i'X_i & n^{-1}\sum_i w_i^2 \end{pmatrix}^{-1} \\ & \quad \begin{pmatrix} \beta n^{-1}\sum_i X_i'\left(z_i-w_i\right)+n^{-1}\sum_i X_i'u_i \\ \beta n^{-1}\sum_i w_i'\left(z_i-w_i\right)+n^{-1}\sum_i w_i'u_i \end{pmatrix}; \end{aligned}$$

$$plim \begin{pmatrix} \widehat{a} \\ \widehat{b} \end{pmatrix} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + plim \begin{pmatrix} n^{-1}\sum_i X_i'X_i & n^{-1}\sum_i X_i'w_i \\ n^{-1}\sum_i w_i'X_i & n^{-1}\sum_i w_i^2 \end{pmatrix}^{-1}$$

$$plim \begin{pmatrix} \beta n^{-1}\sum_i X_i'(z_i - w_i) + n^{-1}\sum_i X_i'u_i \\ \beta n^{-1}\sum_i w_i'(z_i - w_i) + n^{-1}\sum_i w_i'u_i \end{pmatrix}$$

$$= \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + \beta plim \begin{pmatrix} n^{-1}\sum_i X_i'X_i & n^{-1}\sum_i X_i'w_i \\ n^{-1}\sum_i w_i'X_i & n^{-1}\sum_i w_i^2 \end{pmatrix}^{-1}$$

$$plim \begin{pmatrix} n^{-1}\sum_{i:z_i>w_i^c} X_i'(z_i - w_i^c) \\ n^{-1}\sum_{i:z_i>w_i^c} w_i'(z_i - w_i^c) \end{pmatrix}.$$

In general, all we can say is that

$$plim \left(n^{-1} \sum_{i:z_i>w_i^c} w_i'(z_i - w_i^c) \right) > 0.$$

But this is not enough to sign any of the biases. However, if we can assume that

$$plim \left[n^{-1} \sum_{i:z_i>w_i^c} X_i'(z_i - w_i^c) \right] = 0$$

or is small and

$$plim \left[n^{-1} \sum_i X_i'w_i \right] = 0$$

or is small, then,

$$AsyBias \begin{pmatrix} \widehat{a} \\ \widehat{b} \end{pmatrix} \approx \beta plim \begin{pmatrix} n^{-1}\sum_i X_i'X_i & 0 \\ 0' & n^{-1}\sum_i w_i^2 \end{pmatrix}^{-1}$$

$$plim \begin{pmatrix} 0 \\ n^{-1}\sum_{i:z_i>w_i^c} w_i'(z_i - w_i^c) \end{pmatrix}$$

$$= \beta plim \frac{n^{-1}\sum_{i:z_i>w_i^c} w_i'(z_i - w_i^c)}{n^{-1}\sum_i w_i^2}$$

which has the same sign as β.

OA.3 Endogeneity Test

To determine whether our models havepotential endogeneity issues, we model a surgeon's decision to use a new device version using a probit specification and test whether there are common unobserved factors driving both duration of surgery and the decision to use a new device version. A surgeon's decision to use a new device version for a surgery for each of the four key device types can be represented as

$$\begin{aligned} m^*_{sjt1} &= \gamma_j X_{st} + \nu_{sjt}, \\ \nu_{sjt} &\sim iidN\left(0,1\right), \\ m_{sjt1} &= 1\left(m^*_{sjt1} > 0\right) \end{aligned} \tag{5}$$

where X_{st} is the vector of observed exogenous control variables, and ν_{sjt} is the error term representing unobserved factors impacting new device choice decision. The issue of interest is whether the error term of the duration equation (1), ε_{st}, is correlated with any of the errors $\nu_{st} = (\upsilon_{s1t}, \upsilon_{s2t}, \upsilon_{s3t}, \upsilon_{s4t})$, from the "new-device-choice" probit model presented in equation (5) for each device. More formally, we assume that, for surgeon s during surgery t,

$$\begin{pmatrix} \varepsilon_{st} \\ \nu_{s1t} \\ \vdots \\ \nu_{sJt} \end{pmatrix} \sim iidN \left[0, \begin{pmatrix} \sigma^2_\varepsilon & \rho_{\varepsilon 1 \nu} & \cdots & \rho_{\varepsilon J \nu} \\ \rho_{\varepsilon 1 \nu} & 1 & \cdots & \rho_\nu \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{\varepsilon J \nu} & \rho_\nu & \cdots & 1 \end{pmatrix} \right]$$

where $\rho_{\varepsilon j \nu}$ is the covariance between ε_{st} and ν_{sjt}. $c_{\varepsilon j \nu} = \frac{\rho_{\varepsilon j \nu}}{\sigma_\varepsilon}$ is the corresponding correlation coefficient, and we construct the hypothesis of interest as $H_0 : c_{\varepsilon j \nu} = 0$ against $H_A : c_{\varepsilon j \nu} \neq 0$.

The intuition for this test is straightforward. If there are common unobserved factors driving both duration of surgery and the choice to use a new device version, then ε_{st} and ν_{sjt} should be correlated and $c_{\varepsilon j\nu}$ should be greater than zero. Therefore, we first construct generalized residuals of duration equation and device choice equation, ε_{st} and ν_{sjt}. Then we calculate the correlation coefficient, $c_{\varepsilon j\nu}$, of those two random variables, use it as the test statistic, and determine whether it is statistically significantly greater than zero. Particularly, for baseline specification with OLS estimation, we define $\widehat{\varepsilon}_{st}$ as the generalized residual for equation (1) and

$$\begin{aligned}\widehat{\nu}_{sjt} &= E\left[\nu_{sjt} \mid w_{sjt1}, X_{st}\right] \\ &= \begin{cases} \frac{\phi\left(\widehat{\gamma}_j X_{st}\right)}{\Phi\left(\widehat{\gamma}_j X_{st}\right)} & \text{if } w_{sjt1} = 1 \\ \frac{-\phi\left(\widehat{\gamma}_j X_{st}\right)}{1-\Phi\left(\widehat{\gamma}_j X_{st}\right)} & \text{if } w_{sjt1} = 0 \end{cases}\end{aligned}$$

as the generalized residual for equation (5) (e.g., Gourieroux et al., 1987; Dean et al., 2015)

For MSLE, the probit model in (5) can be written as

$$\begin{aligned} m^*_{sjt1} &= \gamma_j X_{st} + \nu_{sjt}, \qquad (6) \\ \nu_{sjt} &\sim iidN\left(0,1\right), \\ m_{sjt1} &= 1 \; \Rightarrow \; \left(m^*_{sjt1} > 0 \text{ and } d_{sjt} = 1\right), \text{or } \left(m^*_{sjt1} < 0 \text{ and } d_{sjt} = 0\right), \\ m_{sjt1} &= 0 \Rightarrow m^*_{sjt1} < 0. \end{aligned}$$

where $d_{sjt} \sim Bernoulli\left(p_{sjt}\right)$ is the event that the observed first usage is the true first usage (i.e., $w_{sjt1} = z_{sjt1} = 1$) and p_{sjt} the probability of the observed first usage being the true first usage. p_{sjt} is calculated as the proportion of simulated $z^r_{sjt1} = 1$ when $w_{sjt1} = 1$.[1] Note that

[1] As in the description of simulation details in Section A.2, for surgeries using observed new devices, we compare the simulated experience gap with the observed time gap between the sample start day and the surgery day. If the simulated value is smaller than the observed value, the simulated first usage dummy, $z^r_{sjt1} = 1$. Otherwise, $z^r_{sjt1} = 0$.

above, if $w_{sjt1} = 0$, then it cannot be the case that $z_{sjt1} = 1$, as a prior usage has been observed. On the other hand, if $w_{sjt1} = 1$, then either $z_{sjt1} = 1$ and therefore $d_{sjt} = 1$ (this happens if the utility surgeon s gets from using a new device version for device-type j exceeds zero on his t^{th} surgery), or his utility is less than zero and $d_{sjt} = 0$.

The MSLE probit estimator of γ_j, $\widehat{\gamma}_j$, maximizes

$$L_j = \sum_{s,t} \left\{ w_{sjt1} \log \left[p_{sjt} \Phi\left(\gamma_j X_{st}\right) + \left(1 - p_{sjt}\right)\left(1 - \Phi\left(\gamma_j X_{st}\right)\right) \right] + \left(1 - w_{sjt1}\right) \log \left[1 - \Phi\left(\gamma_j X_{st}\right) \right] \right\}.$$

Next, the generalized residual $\widehat{\nu}_{sjt}$ when $w_{sjt1} = 1$ is

$$\begin{aligned}
\widehat{\nu}_{sjt} &= E\left[\nu_{sjt} \mid w_{sjt1} = 1, X_{st}\right] \\
&= \frac{p_{sjt} E\left(\nu_{sjt} \mid m^*_{sjt1} > 0\right) \Phi\left(\widehat{\gamma}_j X_{st}\right) + \left(1 - p_{sjt}\right) E\left(\nu_{sjt} \mid m^*_{sjt1} < 0\right) \left[1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)\right]}{\Pr\left[w_{sjt1} = 1 \mid X_{st}\right]} \\
&= \frac{p_{sjt} \frac{\phi\left(\widehat{\gamma}_j X_{st}\right)}{\Phi\left(\widehat{\gamma}_j X_{st}\right)} \Phi\left(\widehat{\gamma}_j X_{st}\right) - \left(1 - p_{sjt}\right) \frac{\phi\left(\widehat{\gamma}_j X_{st}\right)}{1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)} \left[1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)\right]}{p_{sjt} \Phi\left(\widehat{\gamma}_j X_{st}\right) + \left(1 - p_{sjt}\right)\left[1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)\right]} \\
&= \frac{p_{sjt} \phi\left(\widehat{\gamma}_j X_{st}\right) - \left(1 - p_{sjt}\right) \phi\left(\widehat{\gamma}_j X_{st}\right)}{p_{sjt} \Phi\left(\widehat{\gamma}_j X_{st}\right) + \left(1 - p_{sjt}\right)\left[1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)\right]} \\
&= \frac{\left(2 p_{sjt} - 1\right) \phi\left(\widehat{\gamma}_j X_{st}\right)}{p_{sjt} \Phi\left(\widehat{\gamma}_j X_{st}\right) + \left(1 - p_{sjt}\right)\left[1 - \Phi\left(\widehat{\gamma}_j X_{st}\right)\right]}.
\end{aligned}$$

Note that, if an observed first usage of a device version occurs towards the end of the sample period, then it is more likely that this observed first usage represents a true first usage. In this case, $p_{sjt} \to 1$, and the generalized residual converges to

$$\widehat{\nu}_{sjt} \to \frac{\phi\left(\widehat{\gamma}_j X_{st}\right)}{\Phi\left(\widehat{\gamma}_j X_{st}\right)}.$$

On the other hand, if an observed first usage of a device version by a surgeon occurs towards the beginning of the sample period, then it is less likely that the observed first usage is a true first usage. In this case, $p_{sjt} \to 0$, and the generalized residual converges to

$$\widehat{\nu}_{sjt} \to \frac{-\phi\left(\widehat{\gamma}_j X_{st}\right)}{\left[1-\Phi\left(\widehat{\gamma}_j X_{st}\right)\right]}.$$

When $w_{sjt1} = 0$, then $\widehat{\nu}_{sjt}$ is

$$\begin{aligned}\widehat{\nu}_{sjt} &= E\left[\nu_{sjt} \mid w_{sjt1} = 0, X_{st}\right] \\ &= E\left(\nu_{sjt} \mid m^*_{sjt1} < 0\right) = -\frac{\phi\left(\widehat{\gamma}_j X_{st}\right)}{1-\Phi\left(\widehat{\gamma}_j X_{st}\right)}.\end{aligned}$$

Next we can construct a correlation term either for each device j or for all devices together. The device-specific correlation term is

$$\widehat{c}_j = \frac{n_j^{-1}\sum_{st}\widehat{\varepsilon}_{st}\widehat{\nu}_{sjt}}{\sqrt{\left(n_j^{-1}\sum_{st}\widehat{\varepsilon}^2_{st}\right)\left(n_j^{-1}\sum_{st}\widehat{\nu}^2_{sjt}\right)}}$$

where n_j is the total number of surgeries using device j, and the correlation term for all devices together is

$$\widehat{c} = \frac{n^{-1}\sum_{st}\widehat{\varepsilon}_{st}\overline{\nu}_{st}}{\sqrt{\left(n^{-1}\sum_{st}\widehat{\varepsilon}^2_{st}\right)\left(n^{-1}\sum_{st}\overline{\nu}^2_{st}\right)}}$$

where n is the total number of surgeries in the sample and $\overline{\nu}_{st} = J^{-1}\sum_j \widehat{\nu}_{sjt}$. Under the null hypothesis,

$$plim\widehat{c}_j \propto plim\left(n_j^{-1}\sum_{st}\widehat{\varepsilon}_{st}\widehat{\nu}_{sjt}\right) = 0 \tag{7}$$

where the proportionality factor is the plim of the denominator.

In order to actually use the test statistic, one must know something about the sample distribution of the test statistic. Instead of deriving the asymptotic distribution for our test statistic officially, we simulate the small sample distribution of the test statistic and then use simulated critical values to perform the test. In particular, define $\widetilde{\varepsilon}$ as the sample vector of $\widehat{\varepsilon}_{st}$

and $\widetilde{\nu}_j$ analogously for device j. Define $\widetilde{\nu}_j^r$ as the rth random reordering of $\widetilde{\nu}_j$.[2] If $\widetilde{\varepsilon}_{st} \sim iidF_{\varepsilon}$, $\widetilde{\nu}_{sjt} \sim iidF_{\nu j}$, and $\widetilde{\varepsilon} \perp \widetilde{\nu}_j$, then $\widetilde{\nu}_j^r \sim iidF_{\nu j}$ and $\widetilde{\varepsilon} \perp \widetilde{\nu}_j^r$ as well. Define

$$\widehat{c}_j^r = \frac{n_j^{-1} \sum_{st} \widetilde{\varepsilon}_{st} \widetilde{\nu}_{sjt}^r}{\sqrt{\left(n_j^{-1} \sum_{st} \widetilde{\varepsilon}_{st}^2\right) \left(n_j^{-1} \sum_{st} \left(\widetilde{\nu}_{sjt}^r\right)^2\right)}}$$

as a single draw of $\widehat{c}_j$ and repeat R independent times. Then find the 2.5% and 97.5% percentiles of $\left\{\widehat{c}_j^r\right\}_{r=1}^R$. These are the 5% critical values for the test statistic; reject H_0 iff $\widehat{c}_j$ falls outside the two critical values.

Table A1-1 and Table A1-2 list the test results which show no significant correlation between these error terms. We therefore believe that our main results are robust to this type of potential endogeneity.

[2] Consider a vector of variables $\nu = (\nu_1, \nu_2, .., \nu_n)'$. Simulate $\xi^r = (\xi_1^r, \xi_2^r, .., \xi_n^r)'$ as a vector of random numbers where $\xi_k^r \sim iidU(0,1)$, and construct ν^r as ν reordered in the same way as ξ^r if sorted from smallest to largest; i.e., $\nu_m^r = \nu_k$ iff ξ_k^r is the m'th smallest element of ξ^r. ν_m^r is a random permutation of ν and independent across $r = 1, 2, .., R$.

OA.4: Tables and Figures

Table A1-1: Endogeneity Test for Fist Use Dummies – OLS

Device		Shell	Stem	Liner	Head	New Device
# of Observations		414	408	349	468	483
Correlation Term		-0.005	0.040	-0.022	0.010	0.044
α=1%	CV-Lower	-0.141	-0.125	-0.131	-0.114	-0.107
	CV-Upper	0.142	0.132	0.136	0.109	0.124
	Rejection	NO	NO	NO	NO	NO
α =5%	CV-Lower	-0.092	-0.097	-0.101	-0.092	-0.089
	CV-Upper	0.096	0.097	0.110	0.084	0.093
	Rejection	NO	NO	NO	NO	NO
α =10%	CV-Lower	-0.084	-0.083	-0.091	-0.075	-0.073
	CV-Upper	0.083	0.078	0.085	0.074	0.077
	Rejection	NO	NO	NO	NO	NO

Note: CV -- Critical Value; Null Hypothesis: Correlation Term =0

Table A1-2: Endogeneity Test for Fist Use Dummies - MSLE

Device		Shell	Stem	Liner	Head	New Device
# of Observations		414	408	349	468	483
Correlation Term		-0.015	0.045	-0.018	0.012	0.049
α =1%	CV-Lower	-0.125	-0.128	-0.141	-0.110	-0.129
	CV-Upper	0.134	0.129	0.136	0.117	0.118
	Rejection	NO	NO	NO	NO	NO
α =5%	CV-Lower	-0.094	-0.093	-0.102	-0.089	-0.091
	CV-Upper	0.094	0.102	0.117	0.094	0.090
	Rejection	NO	NO	NO	NO	NO
α =10%	CV-Lower	-0.077	-0.081	-0.087	-0.073	-0.072
	CV-Upper	0.079	0.084	0.090	0.077	0.077
	Rejection	NO	NO	NO	NO	NO

Note: CV -- Critical Value; Null Hypothesis: Correlation Term =0

Table A2: Estimation Results for the Baseline Specification: Dependent Variable is Ln(Duration)

Explanatory Variable	Column (3) OLS: Add Device Experience		Column (4) OLS: Add Dummies for New Device Combinations and # of New Devices		Column (5) MSLE: Add Device Experience		Column (6) MSLE: Add Dummies for New Device Combinations and # of New Devices	
	Coef.	(Std. Err.)	Coef.	(Std. Err.)	Coef.	(Std. Err.)	Coef.	(Std. Err.)
Total Experience/100	0.027	(0.050)	0.030	(0.050)	0.026	(0.061)	0.030	(0.064)
First Use Dummy								
Shell	0.131	(0.091)	0.262**	(0.111)	0.155*	(0.087)	0.276**	(0.115)
Stem	0.262***	(0.073)	0.296***	(0.078)	0.286***	(0.060)	0.324***	(0.064)
Liner	0.078	(0.076)	0.129	(0.090)	0.089	(0.076)	0.125	(0.087)
Head	-0.029	(0.068)	0.007	(0.075)	-0.031	(0.076)	0.014	(0.084)
Log(Experience Gap)								
Shell	-0.009	(0.015)	-0.009	(0.015)	-0.009	(0.017)	-0.010	(0.016)
Stem	0.030**	(0.013)	0.030**	(0.013)	0.029**	(0.013)	0.029**	(0.013)
Liner	0.031**	(0.015)	0.030**	(0.015)	0.030*	(0.016)	0.030*	(0.016)
Head	0.001	(0.012)	0.002	(0.012)	0.001	(0.014)	0.002	(0.014)
Dummies for New Device Combinations								
Shell and Liner			-0.266	(0.232)			-0.266	(0.859)
Stem and Head			-0.116	(0.191)			-0.182	(0.190)
Dummies for # of New Devices								
2 New Devices			0.016	(0.122)			-0.012	(0.117)
3 New Devices			-0.203	(0.261)			-0.327	(1.013)
4 New Devices			-0.069	(0.456)			0.180	(1.783)
Patient Characteristics								
Male	0.107***	(0.030)	0.105***	(0.030)	0.106***	(0.032)	0.105***	(0.032)
BMI/100	0.381*	(0.214)	0.469**	(0.218)	0.387*	(0.190)	0.466**	(0.220)
Age/100	-0.445***	(0.125)	-0.401***	(0.126)	-0.440***	(0.125)	-0.408***	(0.131)
ASA Average	0.002	(0.033)	-0.003	(0.033)	0.003	(0.035)	0.002	(0.036)
# of Comorbidities	0.030**	(0.012)	0.029**	(0.012)	0.029**	(0.013)	0.028**	(0.013)
Surgery Characteristics								
Both Legs	0.706***	(0.155)	0.719***	(0.155)	0.710	(0.559)	0.719	(0.545)
Reason: Revision	0.286***	(0.077)	0.292***	(0.078)	0.285***	(0.067)	0.293***	(0.069)
Reason: Avascular Necrosis	-0.073	(0.066)	-0.076	(0.066)	-0.072	(0.082)	-0.075	(0.082)
Reason: Displasia	0.068	(0.073)	0.077	(0.073)	0.068	(0.089)	0.081	(0.093)
Reason: Arthritis	-0.044	(0.071)	-0.054	(0.071)	-0.041	(0.081)	-0.043	(0.083)
Reason: Severe Arthritis	0.108	(0.098)	0.085	(0.098)	0.107	(0.118)	0.091	(0.117)
Reason: End Stage Arthritis	0.033	(0.092)	0.019	(0.092)	0.035	(0.117)	0.025	(0.119)
Reason: Fracture	-0.036	(0.077)	-0.040	(0.078)	-0.038	(0.081)	-0.041	(0.081)
Reason: Other	-0.019	(0.105)	-0.055	(0.106)	-0.022	(0.106)	-0.047	(0.106)
Reasons for revision	-0.026	(0.082)	-0.042	(0.082)	-0.026	(0.082)	-0.035	(0.082)
Use: shell	0.023	(0.078)	0.038	(0.078)	0.027	(0.076)	0.036	(0.076)
Use: stem	-0.074	(0.079)	-0.080	(0.080)	-0.077	(0.076)	-0.079	(0.075)
Use: liner	-0.057	(0.061)	-0.062	(0.061)	-0.057	(0.063)	-0.059	(0.062)
Use: head	-0.072	(0.099)	-0.062	(0.099)	-0.069	(0.101)	-0.059	(0.098)
Time Trend	0.072**	(0.029)	0.065**	(0.030)	0.070*	(0.035)	0.066*	(0.035)
Quadratic Time Trend	-0.003	(0.003)	-0.003	(0.003)	-0.003	(0.003)	-0.003	(0.003)
Unihead	-0.064	(0.075)	-0.061	(0.076)	-0.067	(0.078)	-0.056	(0.079)
Cemented	0.008	(0.052)	-0.003	(0.053)	0.010	(0.054)	0.005	(0.055)
Company 2	0.107	(0.076)	0.109	(0.076)	0.104	(0.068)	0.102	(0.069)
Company 3	0.078	(0.092)	0.087	(0.093)	0.076	(0.080)	0.063	(0.083)
Company: 4	0.210**	(0.097)	0.219**	(0.097)	0.210**	(0.083)	0.203**	(0.085)
Multiple Companies Indicator	0.146**	(0.071)	0.140*	(0.072)	0.150**	(0.061)	0.142**	(0.062)
Surgeon: 2	0.142	(0.087)	0.140	(0.089)	0.139	(0.090)	0.153*	(0.093)
Surgeon: 3	0.147*	(0.080)	0.144*	(0.081)	0.143*	(0.085)	0.159*	(0.086)
Surgeon: 4	0.193	(0.119)	0.201*	(0.122)	0.189	(0.133)	0.216	(0.141)
Surgeon FE	Yes		Yes		Yes		Yes	
Quadratic Time Trend	Yes		Yes		Yes		Yes	
# of Observations	483		483		483		483	
Adj. R-squared	0.429		0.432		-		-	

Note: Time Trend is defined as the number of days since start of the sample period divided by 100. Standard errors are in parentheses.
* p<0.10, ** p<0.05, *** p<0.01. All regressions include controls for patient characteristics, surgery characteristics, and device characteristics defined in Section 3.

Table A3: Estimation Results using Alternative Experience Variables: Dependent Variable is Ln(Duration)

Explanatory Variable	Column (1) OLS: Add nth Usage Counts		Column (2) OLS: Add 2nd to 4th Usage Dummies		Column (3) OLS: Add # of Surgeries in-between		Column (4) OLS: Add Switch Dummy		Column (5) OLS: Add Switch Variety	
	Coef.	(Std. Err.)	Coef.	(Std. Err.)	Coef.	(Std. Err.)	Coef.	(Std. Err.)	Coef.	(Std. Err.)
Total Experience/100	0.091	(0.059)	0.031	(0.051)	0.024	(0.050)	0.024	(0.051)	0.031	(0.052)
Shell 1st Use Dummy	0.190*	(0.118)	0.247**	(0.112)	0.242**	(0.113)	0.267**	(0.112)	0.246**	(0.112)
Stem 1st Use Dummy	0.294***	(0.085)	0.308***	(0.080)	0.316***	(0.079)	0.308***	(0.079)	0.302***	(0.079)
Liner 1st Use Dummy	0.112	(0.093)	0.098	(0.091)	0.089	(0.092)	0.135	(0.092)	0.110	(0.091)
Head 1st Use Dummy	-0.018	(0.084)	-0.048	(0.079)	-0.013	(0.078)	-0.033	(0.080)	0.018	(0.078)
Shell 2nd Use Dummy			-0.008	(0.095)						
Stem 2nd Use Dummy			0.147*	(0.080)						
Liner 2nd Use Dummy			0.116	(0.091)						
Head 2nd Use Dummy			-0.026	(0.068)						
Shell 3rd Use Dummy			0.126	(0.090)						
Stem 3rd Use Dummy			0.179**	(0.082)						
Liner 3rd Use Dummy			-0.104	(0.089)						
Head 3rd Use Dummy			-0.024	(0.065)						
Shell 4th Use Dummy			0.103	(0.086)						
Stem 4th Use Dummy			0.130	(0.081)						
Liner 4th Use Dummy			0.033	(0.093)						
Head 4th Use Dummy			-0.001	(0.077)						
Shell nth Usage Counts/100	-0.101	(0.065)								
Stem nth Usage Counts/100	0.000	(0.053)								
Liner nth Usage Counts/100	-0.031	(0.065)								
Head nth Usage Counts/100	-0.046	(0.058)								
Shell Log(Experience Gap)	-0.018	(0.017)	-0.014	(0.016)	-0.022	(0.019)	-0.008	(0.017)	-0.026	(0.020)
Stem Log(Experience Gap)	0.030**	(0.015)	0.012	(0.015)	0.043**	(0.017)	0.024*	(0.014)	0.036*	(0.019)
Liner Log(Experience Gap)	0.033**	(0.015)	0.025*	(0.015)	0.013	(0.018)	0.026*	(0.016)	0.020	(0.020)
Head Log(Experience Gap)	-0.002	(0.014)	0.005	(0.014)	-0.004	(0.016)	0.008	(0.013)	0.004	(0.018)
Shell # of Surgeries in-between/10					0.024*	(0.014)				
Stem # of Surgeries in-between/10					-0.009	(0.010)				
Liner # of Surgeries in-between/10					0.027*	(0.016)				
Head # of Surgeries in-between/10					0.003	(0.008)				
Shell Device Switch Dummies							0.011	(0.039)		
Stem Device Switch Dummies							0.038	(0.039)		
Liner Device Switch Dummies							0.027	(0.044)		
Head Device Switch Dummies							-0.075	(0.046)		
Shell Device Switch Variety									0.018	(0.012)
Stem Device Switch Variety									-0.003	(0.008)
Liner Device Switch Variety									0.010	(0.011)
Head Device Switch Variety									-0.001	(0.005)
Shell and Liner Comb. Dummy	-0.280	(0.232)	-0.273	(0.236)	-0.275	(0.231)	-0.265	(0.232)	-0.279	(0.232)
Stem and Head Comb. Dummy	-0.127	(0.191)	-0.078	(0.194)	-0.130	(0.191)	-0.107	(0.192)	-0.130	(0.192)
2 New Devices Dummy	0.054	(0.123)	0.053	(0.125)	0.030	(0.123)	0.013	(0.122)	0.023	(0.123)
3 New Devices Dummy	-0.133	(0.263)	-0.183	(0.267)	-0.183	(0.262)	-0.205	(0.262)	-0.187	(0.262)
4 New Devices Dummy	0.041	(0.459)	0.000	(0.462)	0.002	(0.458)	-0.083	(0.457)	0.000	(0.459)
Male	0.111***	(0.030)	0.109***	(0.030)	0.103***	(0.030)	0.107***	(0.030)	0.108***	(0.030)
BMI/100	0.456**	(0.219)	0.457**	(0.218)	0.481**	(0.218)	0.461**	(0.219)	0.480**	(0.219)
Age/100	-0.378***	(0.128)	-0.397***	(0.127)	-0.385***	(0.126)	-0.414***	(0.127)	-0.392***	(0.127)
ASA Average	-0.005	(0.033)	-0.005	(0.033)	-0.005	(0.033)	-0.001	(0.033)	-0.005	(0.033)
# of Comorbidities	0.031**	(0.012)	0.030**	(0.012)	0.027**	(0.012)	0.028**	(0.012)	0.028**	(0.012)
Both Legs	0.728***	(0.155)	0.751***	(0.155)	0.716***	(0.154)	0.691***	(0.156)	0.714***	(0.155)
Reason: Revision	0.298***	(0.078)	0.264***	(0.079)	0.299***	(0.078)	0.291***	(0.078)	0.292***	(0.078)
Reason: Avascular Necrosis	-0.064	(0.066)	-0.075	(0.066)	-0.080	(0.066)	-0.082	(0.066)	-0.083	(0.066)
Reason: Displasia	0.068	(0.074)	0.097	(0.073)	0.069	(0.073)	0.080	(0.073)	0.070	(0.073)
Reason: Arthritis	-0.042	(0.072)	-0.054	(0.072)	-0.056	(0.072)	-0.064	(0.072)	-0.060	(0.072)
Reason: Severe Arthritis	0.086	(0.099)	0.083	(0.099)	0.083	(0.098)	0.083	(0.099)	0.080	(0.099)
Reason: End Stage Arthritis	0.028	(0.092)	0.025	(0.092)	0.015	(0.092)	0.009	(0.092)	0.014	(0.092)
Reason: Fracture	-0.052	(0.079)	-0.060	(0.079)	-0.063	(0.079)	-0.047	(0.078)	-0.051	(0.078)
Reason: Other	-0.069	(0.107)	-0.050	(0.107)	-0.083	(0.107)	-0.061	(0.107)	-0.073	(0.107)
Reasons for revision	-0.059	(0.083)	-0.052	(0.083)	-0.066	(0.082)	-0.051	(0.083)	-0.053	(0.082)
Use: shell	0.097	(0.086)	0.038	(0.080)	0.030	(0.079)	0.025	(0.079)	0.032	(0.079)
Use: stem	-0.082	(0.088)	-0.095	(0.080)	-0.090	(0.080)	-0.086	(0.081)	-0.078	(0.080)
Use: liner	-0.049	(0.067)	-0.045	(0.062)	-0.033	(0.063)	-0.059	(0.063)	-0.047	(0.062)
Use: head	-0.021	(0.107)	-0.072	(0.099)	-0.046	(0.099)	-0.020	(0.102)	-0.063	(0.099)
Time Trend	0.057*	(0.030)	0.079**	(0.031)	0.062**	(0.029)	0.063**	(0.030)	0.064**	(0.030)
Quadratic Time Trend	-0.003	(0.003)	-0.004	(0.003)	-0.002	(0.003)	-0.002	(0.003)	-0.003	(0.003)
Unihead	-0.079	(0.076)	-0.065	(0.076)	-0.082	(0.076)	-0.065	(0.076)	-0.074	(0.076)
Cemented	-0.016	(0.053)	0.018	(0.054)	-0.015	(0.053)	-0.001	(0.053)	-0.006	(0.053)
Company 2	0.130*	(0.077)	0.116	(0.077)	0.140*	(0.077)	0.118	(0.077)	0.135*	(0.077)
Company 3	0.086	(0.093)	0.127	(0.094)	0.098	(0.093)	0.091	(0.093)	0.098	(0.093)
Company 4	0.218**	(0.097)	0.282***	(0.101)	0.219**	(0.097)	0.233**	(0.098)	0.232**	(0.098)
Multiple Companies Indicator	0.132*	(0.072)	0.153**	(0.073)	0.134*	(0.073)	0.146**	(0.072)	0.145**	(0.072)
Surgeon: 2	0.174*	(0.091)	0.102	(0.091)	0.175*	(0.091)	0.124	(0.090)	0.171*	(0.092)
Surgeon: 3	0.168**	(0.082)	0.101	(0.084)	0.174**	(0.083)	0.135*	(0.082)	0.179**	(0.083)
Surgeon: 4	0.268**	(0.127)	0.151	(0.124)	0.242**	(0.123)	0.192	(0.123)	0.246*	(0.127)
Surgeon FE	Yes		Yes		Yes		Yes		Yes	
Quadratic Time Trend	Yes		Yes		Yes		Yes		Yes	
# of Observations	483		483		483		483		483	
Adj. R-squared	0.433		0.438		0.436		0.431		0.432	

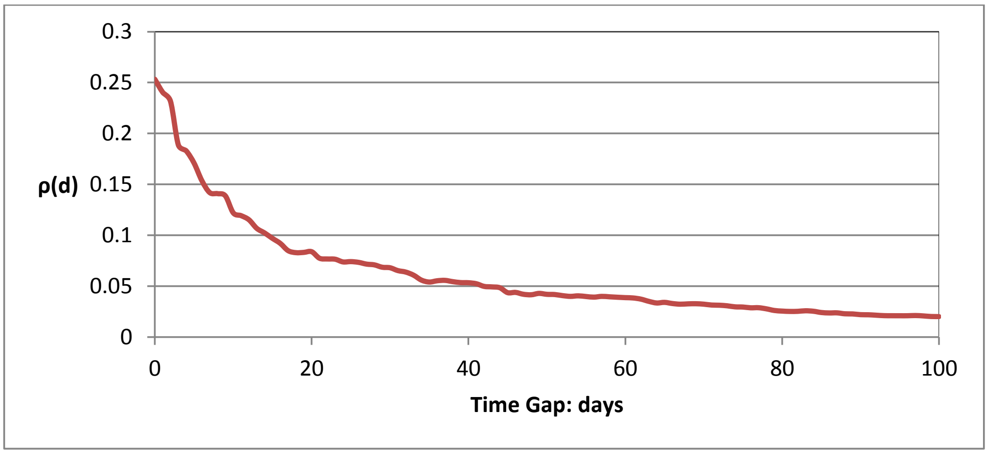
Note: Time Trend is defined as the number of days since start of the sample period divided by 100. Standard errors are in parentheses. * p<0.10, **p<0.05, *** p<0.01. All regressions include controls for patient characteristics, surgery characteristics and device characteristics defined in Section 3.

Table A4: Descriptive Statistics

Variable	# of Obs.	Mean	Std. Dev.
Duration (minutes)	483	164.98	70.47
Total Experience	483	141.97	104.56
Shell			
1st Use Dummy	414	0.05	0.21
2nd Use Dummy	414	0.04	0.19
3rd Use Dummy	414	0.04	0.19
4th Use Dummy	414	0.04	0.20
nth Usage Count	414	41.36	47.37
Stem			
1st Use Dummy	408	0.09	0.29
2nd Use Dummy	408	0.06	0.24
3rd Use Dummy	408	0.05	0.22
4th Use Dummy	408	0.04	0.21
nth Usage Count	408	52.56	60.62
Liner			
1st Use Dummy	349	0.08	0.28
2nd Use Dummy	349	0.04	0.20
3rd Use Dummy	349	0.04	0.20
4th Use Dummy	349	0.04	0.19
nth Usage Count	349	29.22	32.68
Head			
1st Use Dummy	468	0.10	0.30
2nd Use Dummy	468	0.08	0.27
3rd Use Dummy	468	0.07	0.26
4th Use Dummy	468	0.04	0.20
nth Usage Count	468	34.75	47.04
Shell			
Experience Gap	394	24.44	47.87
# of Surgeries inbetween	394	6.27	15.12
Device Switch Dummy	394	0.65	0.48
Device Switch Variety	394	1.61	2.07
Stem			
Experience Gap	371	30.08	64.57
# of Surgeries inbetween	371	8.44	23.03
Device Switch Dummy	371	0.59	0.49
Device Switch Variety	371	1.94	3.34
Liner			
Experience Gap	320	26.02	52.08
# of Surgeries inbetween	320	7.06	14.81
Device Switch Dummy	320	0.72	0.45
Device Switch Variety	320	1.93	2.33
Head			
Experience Gap	423	42.46	85.45
# of Surgeries inbetween	423	11.25	26.20
Device Switch Dummy	423	0.83	0.38
Device Switch Variety	423	3.86	5.41
Shell and Liner	483	0.01	0.11
Stem and Head	483	0.02	0.14
2 New Devices	483	0.04	0.19
3 New Devices	483	0.01	0.11
4 New Devices	483	0.00	0.06
Male	483	0.49	0.50
BMI	483	29.90	7.02
Age	483	60.34	13.65
ASA Average	483	2.43	0.51
# of Comorbidities	483	1.99	1.45
Both Legs	483	0.01	0.09
Reason: Revision	483	0.24	0.43
Reason: Avascular Necrosis	483	0.11	0.31
Reason: Displasia	483	0.04	0.20
Reason: Arthritis	483	0.58	0.49
Reason: Severe Arthritis	483	0.04	0.19
Reason: End Stage Arthritis	483	0.05	0.23
Reason: Fracture	483	0.07	0.26
Reason: Other	483	0.05	0.21
Reasons for Revision	483	0.17	0.40
Use: Shell	483	0.86	0.35
Use: Stem	483	0.84	0.36
Use: Liner	483	0.72	0.45
Use: Head	483	0.97	0.17
Unihead	483	0.07	0.25
Cemented	483	0.16	0.37
Company 2	483	0.52	0.50
Company 3	483	0.19	0.39
Company 4	483	0.24	0.43
Multiple Companies Indicator	483	0.05	0.22
Surgeon 1	483	0.55	0.50
Surgeon 2	483	0.17	0.37
Surgeon 3	483	0.19	0.40
Surgeon 4	483	0.08	0.28

Notes: # of surgeons = 4; # of observations = 483.

Figure A1: Serial Correlation Function $\rho(d)$



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