APPENDIX

We extend the model of Brekke et al. (2011) to include changes in insurer and consumer payments due to the introduction of endogenous or exogenous reference pricing (RP).

A. Endogenous Reference Pricing

For endogenous RP, the expected changes in insurer and consumer payments to both non-VBPD and VBPD hospitals due to the introduction of RP are as follows:

\[ \frac{\partial ip^p_b}{\partial \beta} < 0, \quad \frac{\partial ip^p_g}{\partial \beta} < 0, \]

\[ \frac{\partial ip^p_b}{\partial \beta} > \frac{\partial ip^p_g}{\partial \beta} \]

and \( \frac{\partial cs^p_b}{\partial \beta} < 0, \) where \( ip^p_b \) and \( ip^p_g \) refer to insurer payments to non-VBPD and VBPD hospitals under RP, respectively; \( cs^p_b \) and \( cs^p_g \) refer to consumer cost sharing payments to non-VBPD and VBPD hospitals under RP, respectively; and \( \beta \) refers to the weights determining the weighted average of market prices that the reference price is assumed to be based on following Brekke et al. (2011):

\[ R = \beta p_g + (1-\beta) p_b \]

(A.1)

where \( 0 < \beta < 1 \). A change in \( \beta \) is equivalent to the introduction of RP (\( \beta \) moving from zero to positive).

From equation (22) in Brekke et al. (2011), we form the following equation:

\[ ip^p_b = p^p_b - [f + \alpha p^p_b + \beta(p^p_b - p^p_g)(1-\alpha)], \]

(A.2)
where \( f \) is a deductible and \( \alpha \) is the coinsurance rate. The insurer payment to VBPD hospitals, also based on equation (22), is given by

\[
i p_{g}^{p} = p_{g}^{p} - (f + \alpha p_{g}^{p}) = p_{g}^{p}(1 - \alpha) - f \tag{A.3}
\]

From equation (A.2) it follows that

\[
i p_{b}^{p} = (1 - \alpha) p_{b}^{p} - f - \beta(p_{g}^{p} - p_{b}^{p})(1 - \alpha) \tag{A.4}
\]

The first derivative with respect to \( \beta \) (equivalent to the initial implementation of RP) is

\[
\frac{\partial i p_{b}^{p}}{\partial \beta} = (1 - \alpha) \frac{\partial p_{b}^{p}}{\partial \beta} + (p_{g}^{p} - p_{b}^{p})(1 - \alpha) + (\alpha - 1) \beta \frac{\partial p_{b}^{p}}{\partial \beta} + (1 - \alpha) \beta \frac{\partial p_{g}^{p}}{\partial \beta}. \tag{A.5}
\]

Based on equations (19) and (20) in Brekke et al. (2011), which state \( \partial p_{g}^{p} / \partial \beta < 0 \) and

\[
\partial p_{b}^{p} / \partial \beta < 0, \text{ and the fact that } 0 < \alpha < 1 \text{ in the CalPERS system, it follows that } (1 - \alpha) \beta \frac{\partial p_{g}^{p}}{\partial \beta} < 0 \text{ and } (\alpha - 1) \beta \frac{\partial p_{b}^{p}}{\partial \beta} > 0. \]

In addition, \( (p_{g}^{p} - p_{b}^{p})(1 - \alpha) < 0 \) since \( p_{g}^{p} < p_{b}^{p} \). Also, from equation (21) in Brekke et al. (2011), it is implied that \( \frac{\partial p_{b}^{p}}{\partial \beta} > \frac{\partial p_{g}^{p}}{\partial \beta} \). This, along with \( 0 < \beta < 1 \), necessarily implies that \( (1 - \alpha) \frac{\partial p_{b}^{p}}{\partial \beta} > (\alpha - 1) \beta \frac{\partial p_{g}^{p}}{\partial \beta} \). Since \( (1 - \alpha) \frac{\partial p_{b}^{p}}{\partial \beta} < 0 \) and \( (\alpha - 1) \beta \frac{\partial p_{g}^{p}}{\partial \beta} > 0 \), this implies that \( (1 - \alpha) \frac{\partial p_{b}^{p}}{\partial \beta} - (\alpha - 1)(\beta \frac{\partial p_{g}^{p}}{\partial \beta}) < 0 \). Therefore \( \frac{\partial i p_{b}^{p}}{\partial \beta} < 0 \).

Similarly, for equation (A.3), the first derivative with respect to \( \beta \) is

\[
\frac{\partial i p_{g}^{p}}{\partial \beta} = \frac{\partial p_{g}^{p}}{\partial \beta}(1 - \alpha) < 0. \tag{A.6}
\]
The reduction in insurer expenditures can also be shown to be larger for the non-VBPD hospital. Start with A.5 and A.6 above. From equation (21) in Brekke et al. (2011), it is implied that \( \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} < \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \). Thus \( (1 - \alpha) \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} < (1 - \alpha) \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \). Since

\[
\left[ (p_{g}^{\text{rp}} - p_{b}^{\text{rp}})(1 - \alpha) + (\alpha - 1)\beta \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} + (1 - \alpha)\beta \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \right] < 0 ,
\]

it follows that

\[
\frac{\partial ip_{b}^{\text{rp}}}{\partial \beta} < \frac{\partial ip_{g}^{\text{rp}}}{\partial \beta} \quad \text{or} \quad \left| \frac{\partial ip_{b}^{\text{rp}}}{\partial \beta} \right| > \left| \frac{\partial ip_{g}^{\text{rp}}}{\partial \beta} \right| \quad \text{(A.7)}
\]

Consumer cost sharing, from (A.2) and (A.3), is expressed for each non-VBPD and VBPD hospital, respectively, as follows:

\[
cs_{b}^{\text{rp}} = f + ap_{b}^{\text{rp}} + \beta(p_{b}^{\text{rp}} - p_{g}^{\text{rp}})(1 - \alpha) , \quad \text{(A.8)}
\]

\[
cs_{g}^{\text{rp}} = ap_{g}^{\text{rp}} + f . \quad \text{(A.9)}
\]

We now show that \( \frac{\partial cs_{b}^{\text{rp}}}{\partial \beta} < 0 \) (under certain conditions) and \( \frac{\partial cs_{g}^{\text{rp}}}{\partial \beta} < 0 \). From (A.2), it follows that: \( cs_{b}^{\text{rp}} = f + ap_{b}^{\text{rp}} + \beta(p_{b}^{\text{rp}} - p_{g}^{\text{rp}})(1 - \alpha) \)

\[
\text{(A.10)}
\]

The first derivative with respect to \( \beta \) is

\[
\frac{\partial cs_{b}^{\text{rp}}}{\partial \beta} = \alpha \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} + \left( p_{b}^{\text{rp}} - p_{g}^{\text{rp}} \right) + \beta \left( \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} - \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \right) \left(1 - \alpha\right) . \quad \text{(A.11)}
\]

We know that \( \alpha \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} < 0 \) and that, based on equation (21), that \( \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} < \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \), so

\[
\beta \left( \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} - \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \right) < 0 . \quad \text{Thus, if } \left| p_{b}^{\text{rp}} - p_{g}^{\text{rp}} \right| < \beta \left( \frac{\partial p_{b}^{\text{rp}}}{\partial \beta} - \frac{\partial p_{g}^{\text{rp}}}{\partial \beta} \right) \left( \text{if the difference between the absolute prices of the hospitals in RP equilibrium is less than the relative reduction in prices due} \right)
\]
to the introduction of RP), then 
\[ \left( p_{r}^{p} - p_{g}^{p} \right) + \beta \left( \frac{\partial p_{r}^{p}}{\partial \beta} - \frac{\partial p_{g}^{p}}{\partial \beta} \right) \] < 0 and \( \frac{\partial cs_{r}^{p}}{\partial \beta} < 0 \). However, this assumption is ad-hoc, thus the sign of \( \frac{\partial cs_{r}^{p}}{\partial \beta} \) may be considered ambiguous.

It is simple to show that \( \frac{\partial cs_{g}^{p}}{\partial \beta} < 0 \):

\[
cs_{g}^{p} = \alpha p_{g}^{p} + f
\]

\[
\frac{\partial cs_{g}^{p}}{\partial \beta} = \alpha \frac{\partial p_{g}^{p}}{\partial \beta} < 0.
\]

(B. Exogenous Reference Pricing)

Exogenous reference pricing is a fixed level, \( r \). Thus, the insurer payment to non-VBPD hospitals from can be simplified from A.2 based on equation (13) from Brekke et al. (2011)

\[
i p_{b}^{p} = p_{b}^{p} - [f + \alpha r + (p_{b}^{p} - r)]
\]

The first derivative with respect to \( r \), reflecting an increase in \( r \), is positive: \( \frac{\partial i p_{b}^{p}}{\partial r} = (1 - \alpha) > 0 \).

However, we normally think of a reduction in \( r \) (the reference price becomes smaller than the market price) when the reference price is introduced, so this implies with the introduction of the reference price, the insurer payment to non-VBPD hospitals decreases.

For VBPD hospitals, the insurer payment would be A.3. The first derivative with respect to an increase in \( r \) would be \( \frac{\partial i p_{g}^{p}}{\partial r} = \frac{\partial p_{g}^{p}}{\partial r}(1 - \alpha) \). We know from equation (14) in Brekke et al,
(2011) that the first derivative of price with respect to an increase in $r$ is $\frac{\partial p_g^p}{\partial r} < 0$, so

$$\frac{\partial ip_p^p}{\partial r} = \frac{\partial p_g^p}{\partial r} (1 - \alpha) < 0$$

However, as above, we normally think of a reduction in $r$, so this implies that with the introduction of reference pricing, the insurer payment to VBPD hospitals increases.

Consumer cost sharing, from (A.14) and (A.3), is expressed for each non-VBPD and VBPD hospital, respectively, as follows:

$$cs_b^p = f + \alpha r + (r - p_b^p), \quad (A.15)$$

$$cs_g^p = \alpha p_g^p + f. \quad (A.12)$$

The first derivative with respect to $r$ (equivalent to increasing $r$) for A.15 is as follows:

$$\frac{\partial cs_b^p}{\partial r} = [(1 + \alpha) - \frac{\partial p_b^p}{\partial r}] \quad (A.16)$$

which has an ambiguous sign, unless additional assumptions are added. In contrast, the first derivative with respect to $r$ (equivalent to introducing RP) for A.12 is as follows since $\frac{\partial p_g^p}{\partial r} < 0$ from equation (14) in Brekke et al, (2011): $\frac{\partial cs_g^p}{\partial r} = \alpha \frac{\partial p_g^p}{\partial r} < 0$. Once again, considering the introduction of reference pricing as a decrease in $r$, we find that the introduction of reference pricing results in an increase in the consumer payments from coinsurance to VBPD hospitals.