

Online Appendix

Behavioral Hazard in Health Insurance

Katherine Baicker
Harvard University

Sendhil Mullainathan
Harvard University

Joshua Schwartzstein
Harvard Business School

A Further Results

A.1 Comparing the Neo-classical Optimal Copay to the Optimal Copay

Proposition A.1. *Suppose the neo-classical analyst believes p^N is a candidate for the optimal copay where $M'(p^N) \neq 0$.*

1. $\tilde{W}'(p^N) > 0$ if $\varepsilon^{avg}(p^N) > 0$. Moreover, $p^B > p^N$ under the additional assumption that $\tilde{W}(p)$ is strictly quasi-concave over (p^{min}, p^{max}) .
2. $\tilde{W}'(p^N) < 0$ if $\varepsilon^{avg}(p^N) < 0$. Moreover, $p^B < p^N$ under the additional assumption that $\tilde{W}(p)$ is strictly quasi-concave over (p^{min}, p^{max}) .

This result says that there is a welfare benefit to raising the copay from the neo-classical optimum whenever behavioral hazard is on average positive for people at the margin given this copay, and we further know that the optimal copay is above the neo-classical optimum whenever \tilde{W} satisfies the classical regularity assumption of being strictly quasi-concave. Similarly, there is a welfare benefit to reducing the copay whenever behavioral hazard is on average negative for people at the margin, and the optimal copay is below the neo-classical optimum whenever \tilde{W} is strictly quasi-concave. For example, the neo-classical analyst may underestimate the optimal copay in the case of antibiotics for childrens' ear infections but overestimate the optimal copay in the case of statins for people who have recently had a heart attack.

A.2 Using Nudges to Identify Behavioral Hazard

The next result describes conditions under which nudges can be used to help estimate the degree of marginal behavioral hazard.

Proposition A.2. *Suppose that $\varepsilon_n(s; \theta)$ is constant in θ and $b(s; \gamma)$ is constant in γ for all (n, s) . Let $\varepsilon_n(p) = \mathbb{E}[\varepsilon_n | b + \varepsilon_n = p]$ equal the degree of marginal behavioral hazard given nudge n and copay p .*

1. *(Negative behavioral hazard). Suppose we know that $\varepsilon_0 \leq 0$ and $\varepsilon_n \leq 0$ for all s . Further, let p_0, p_n be such that $p_0 < p_n$, but $0 < M_0(p_0) \leq M_n(p_n) < q$. Then,*

$$-\varepsilon_0(p_0) \geq p_n - p_0. \quad (\text{A.1})$$

2. *(Positive behavioral hazard). Alternatively, suppose we know that $\varepsilon_0 \geq 0$ and $\varepsilon_n \geq 0$ for all s . Further, let p_0, p_n be such that $p_n < p_0$, but $0 < M_n(p_n) \leq M_0(p_0) < q$. Then,*

$$\varepsilon_0(p_0) \geq p_0 - p_n. \quad (\text{A.2})$$

To illustrate how Proposition A.2 can be used to estimate ε_0 , suppose a researcher is convinced that a treatment is undervalued, and he has access to nudge n which he believes reduces behavioral hazard. Bound (A.1) can be applied whenever demand is interior and $M_0(p_0) \leq M_n(p_n)$. The latter condition can be re-written as

$$\underbrace{M_n(p_0) - M_0(p_0)}_{\text{demand response to nudge}} - \underbrace{[M_n(p_0) - M_n(p_n)]}_{\text{demand response to copay change}} \geq 0, \quad (\text{A.3})$$

so bound (A.1) can be applied whenever the demand response to an increase in copay from p_0 to p_n , fixing the nudge at n , is lower in magnitude than the demand response to the nudge, fixing the copay at p_0 . Thus, the tightest lower bound a researcher can estimate for $-\varepsilon_0(p_0)$ for a given nudge n is $\tilde{p}_n - p_0$, where \tilde{p}_n is the value of p_n that equates the demand response to a copay increase to the demand response to the nudge; i.e., it is the value that makes (A.3) hold with equality.

Absent further assumptions, it is necessary to both have an estimate of the impact of a nudge on demand as well as an estimate of demand sensitivity to copays *under the nudge* to directly apply Equation (A.3). For example, if the aim is to estimate the marginal behavioral error by examining the impact of a peer mentoring program on prescription drug utilization, Equation (A.3) requires knowledge both of how the program affects utilization, fixing the copay, and how utilization responds to greater copays when the program is in place. Under stronger assumptions, for example that demand is linear and demand sensitivity to copays is independent of the nudge, it is possible to use less local estimates of this sensitivity.¹

¹To see this, suppose the conditions of the first part of Proposition A.2 hold and, additionally, demand can be

B Further Definitions and Proofs

Before we get to the proofs, we introduce some useful definitions.

Recall that $m(p)$ equals a person's demand for treatment at price p

$$m(p) = \begin{cases} 1 & \text{if } b(s; \gamma) + \varepsilon(s; \theta) \geq p \\ 0 & \text{if } b(s; \gamma) + \varepsilon(s; \theta) < p \end{cases}$$

and

$$M(p) = \mathbb{E}[m(p)] = q\mathbb{E}[m(p)|\text{sick}]$$

equals (per capita) aggregate demand at price p . We can break aggregate demand down into demand given various values of the parameters (γ, θ) :

$$M(p; \gamma, \theta) = \mathbb{E}[m(p)|\gamma, \theta] = q\mathbb{E}[m(p)|\gamma, \theta, \text{sick}] \Rightarrow M(p) = \mathbb{E}_G[M(p; \gamma, \theta)] = \int M(p; \gamma, \theta) dG(\gamma, \theta).$$

Further letting $s(p; \gamma, \theta)$ equal the marginal disease severity given γ, θ :

$$s(p; \gamma, \theta) = \begin{cases} \underline{s} & \text{if } p < b(\underline{s}; \gamma) + \varepsilon(\underline{s}; \theta) \\ \text{the value } s' \text{ satisfying } b(s'; \gamma) + \varepsilon(s'; \theta) = p & \text{if } b(\underline{s}; \gamma) + \varepsilon(\underline{s}; \theta) \leq p \leq b(\bar{s}; \gamma) + \varepsilon(\bar{s}; \theta) \\ \bar{s} & \text{if } p > b(\bar{s}; \gamma) + \varepsilon(\bar{s}; \theta) \end{cases}$$

demand given (γ, θ) can be re-written as

$$M(p; \gamma, \theta) = q \cdot [1 - F(s(p; \gamma, \theta))].$$

Likewise, let

$$H(p; \gamma, \theta) = q \cdot \mathbb{E}[m(p) \cdot b - s | \gamma, \theta, \text{sick}] \Rightarrow H(p) = \int H(p; \gamma, \theta) dG(\gamma, \theta).$$

Finally, let

$$b(p; \gamma, \theta) \equiv b(s(p; \gamma, \theta); \gamma)$$

written as $M_j(p) = \alpha_j - \beta \cdot p$ for nudges $j = 0, n$. Then bound (A.1) implies that

$$-\varepsilon_0(p_0) \geq (M_n(p_0) - M_0(p_0))/\beta,$$

where the right hand side of the inequality gives the amount that copays need to decrease to get a demand response of $(M_n(p_0) - M_0(p_0))$.

equal the marginal agent's benefit to getting treated given price p and parameters (γ, θ) and

$$\varepsilon(p; \gamma, \theta) \equiv \varepsilon(s(p; \gamma, \theta); \theta)$$

equal the corresponding marginal degree of behavioral hazard.

Given these definitions, we can re-express the benevolent insurer's problem as maximizing

$$\begin{aligned} W(p) &= (1 - q)U(y - P) + q\mathbb{E}[U(y - P - s + m(p)(b - p))|\text{sick}] \\ &= (1 - q)U(y - P) + q\mathbb{E}_G \left[\int_{\underline{s}}^{s(p; \gamma, \theta)} U(y - P - s) dF(s) + \int_{s(p; \gamma, \theta)}^{\bar{s}} U(y - P - s + b(s; \gamma) - p) dF(s) \right] \end{aligned} \quad (\text{B.1})$$

subject to $P = M(p) \cdot (c - p)$.

Lemma B.1. *For any function $r(s, \gamma, \theta)$ that takes on real values and all p satisfying $M'(p) \neq 0$ we have:*

$$\mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot r(s(p; \gamma, \theta), \gamma, \theta) \right] = \mathbb{E}[r(s, \gamma, \theta) | b + \varepsilon = p].$$

Proof. By the law of iterated expectations:

$$\mathbb{E}[r(s, \gamma, \theta) | b + \varepsilon = p] = \mathbb{E}[\mathbb{E}[r(s, \gamma, \theta) | b + \varepsilon = p, \gamma, \theta] | b + \varepsilon = p] = \mathbb{E}[r(s(p; \gamma, \theta), \gamma, \theta) | b + \varepsilon = p], \quad (\text{B.2})$$

where the final expectation is taken with respect to the distribution over (γ, θ) given $b + \varepsilon = p$. The probability density function of this distribution equals $\tilde{f}(p; \gamma, \theta) \cdot g(\gamma, \theta) / \tilde{f}(p)$ by Bayes' rule, where $\tilde{f}(\cdot; \gamma, \theta)$ is the probability density function over $b + \varepsilon$ given (γ, θ) . The latter probability density function is derived from the probability distribution function over s , $f(s)$, via a change of variables where $p = b(s; \gamma) + \varepsilon(s; \theta) \equiv \phi(s; \gamma, \theta)$. By standard arguments, $\tilde{f}(p; \gamma, \theta) = f(\phi^{-1}(p)) \cdot |d\phi^{-1}/dp|$, where here $\phi^{-1}(p) = s(p; \gamma, \theta)$ and $d\phi^{-1}/dp = \frac{1}{\partial b / \partial s + \partial \varepsilon / \partial s} = \frac{\partial s(p; \gamma, \theta)}{\partial p}$, so $\tilde{f}(p; \gamma, \theta) = f(s(p; \gamma, \theta)) \cdot \frac{\partial s(p; \gamma, \theta)}{\partial p}$. Using (B.2), we then have

$$\mathbb{E}[r(s, \gamma, \theta) | b + \varepsilon = p] = \frac{\int r(s(p; \gamma, \theta), \gamma, \theta) \cdot f(s(p; \gamma, \theta)) \cdot \frac{\partial s(p; \gamma, \theta)}{\partial p} dG(\gamma, \theta)}{\int f(s(p; \gamma, \theta)) \cdot \frac{\partial s(p; \gamma, \theta)}{\partial p} dG(\gamma, \theta)}. \quad (\text{B.3})$$

Substituting

$$\frac{f(s(p; \gamma, \theta)) \frac{\partial s(p; \gamma, \theta)}{\partial p}}{\int f(s(p; \gamma, \theta)) \frac{\partial s(p; \gamma, \theta)}{\partial p} dG(\gamma, \theta)} = \frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)}$$

into (B.3) yields the desired equality. ■

Proof of Proposition 1. Differentiating (B.1) yields

$$W'(p) = -\mathbb{E}[U'(C)] \cdot \frac{\partial P}{\partial p} - \mathbb{E}[\mathbb{E}[U'(C)|m = 1, \gamma, \theta]M(p; \gamma, \theta)] \\ + q\mathbb{E}_G \left[f(s(p; \gamma, \theta)) \frac{\partial s(p; \gamma, \theta)}{\partial p} (U(y - P - s(p; \gamma, \theta)) - U(y - P - s(p; \gamma, \theta) + b(p; \gamma, \theta) - p)) \right].$$

Now substituting in

$$\begin{aligned} \frac{\partial P}{\partial p} &= M'(p) \cdot (c - p) - M(p) \\ \varepsilon(p; \gamma, \theta) &= p - b(p; \gamma, \theta) \\ \varepsilon'(p; \gamma, \theta) &= \frac{U(y - P - s(p; \gamma, \theta)) - U(y - P - s(p; \gamma, \theta) - \varepsilon(p; \gamma, \theta))}{\mathbb{E}[U'(C)]} \\ \frac{\partial M(p; \gamma, \theta)}{\partial p} &= -qf(s(p; \gamma, \theta)) \frac{\partial s(p; \gamma, \theta)}{\partial p} \\ I &= \frac{\mathbb{E}[U'(C)|m = 1] - \mathbb{E}[U'(C)]}{\mathbb{E}[U'(C)]} \\ \mathbb{E}[\mathbb{E}[U'(C)|m = 1, \gamma, \theta]M(p; \gamma, \theta)] &= \mathbb{E}[U'(C)|m = 1] \cdot M(p), \end{aligned}$$

re-arranging, and converting into a money-metric, we have

$$\frac{\partial W}{\partial p} / \frac{\partial W}{\partial y} = -M'(p) \cdot (c - p) - \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta)}{\partial p} \varepsilon'(p; \gamma, \theta) \right] - I \cdot M(p).$$

Further letting

$$\varepsilon^{\text{avg}}(p) \equiv \mathbb{E}[\varepsilon' | b + \varepsilon = p] = \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot \varepsilon'(p; \gamma, \theta) \right]$$

equal the average normalized marginal behavioral error at price p where the equality follows from Lemma B.1 (we let $-M'(p) \cdot \varepsilon^{\text{avg}}(p) = 0$ whenever $M'(p) = 0$), we can re-express the welfare impact of a copay change as

$$\frac{\partial W}{\partial p} / \frac{\partial W}{\partial y} = -M'(p) \cdot (c - p + \varepsilon^{\text{avg}}(p)) - I \cdot M(p). \quad \blacksquare$$

Proof of Proposition 2. Given linear U , the welfare impact of a marginal copay change is $\tilde{W}'(p) = -M'(p) \cdot (c - p + \varepsilon^{\text{avg}}(p))$ by Proposition 1. It thus suffices to show that

$$\varepsilon^{\text{avg}}(p) = p - \frac{H'(p)}{M'(p)}. \quad (\text{B.4})$$

To show (B.4), first expand

$$H(p; \gamma, \theta) = q \cdot \left(\int_{\underline{s}}^{s(p; \gamma, \theta)} -s dF(s) + \int_{s(p; \gamma, \theta)}^{\bar{s}} (b(s; \gamma) - s) dF(s) \right).$$

After some substitution and simplification, Leibniz's rule then gives us that

$$\frac{\partial H(p; \gamma, \theta)}{\partial p} = \frac{\partial M(p; \gamma, \theta)}{\partial p} \cdot s(p; \gamma, \theta) + \frac{\partial M(p; \gamma, \theta)}{\partial p} \cdot [b(p; \gamma, \theta) - s(p; \gamma, \theta)] = \frac{\partial M(p; \gamma, \theta)}{\partial p} \cdot b(p; \gamma, \theta).$$

As a result, $\frac{\partial H(p; \gamma, \theta)}{\partial p} / \frac{\partial M(p; \gamma, \theta)}{\partial p} = b(p; \gamma, \theta)$, which, using the equality $b(p; \gamma, \theta) + \varepsilon(p; \gamma, \theta) = p$, yields

$$\varepsilon(p; \gamma, \theta) = p - \frac{\partial H(p; \gamma, \theta)}{\partial p} / \frac{\partial M(p; \gamma, \theta)}{\partial p}. \quad (\text{B.5})$$

From the proof of Proposition 1, $\varepsilon^{\text{avg}}(p) = \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot \varepsilon'(p; \gamma, \theta) \right]$, which with the assumption of linear utility implies that

$$\varepsilon^{\text{avg}}(p) = \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot \varepsilon(p; \gamma, \theta) \right]. \quad (\text{B.6})$$

Plugging (B.5) into (B.6) then gives us

$$\varepsilon^{\text{avg}}(p) = \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot \left(p - \frac{\partial H(p; \gamma, \theta)}{\partial p} / \frac{\partial M(p; \gamma, \theta)}{\partial p} \right) \right] = p - \frac{H'(p)}{M'(p)},$$

thus establishing (B.4). ■

Proof of Proposition 3. Trivially comes from setting (5) equal to zero and re-arranging. ■

Proof of Proposition 4. First note that

$$\mathbb{E}[b|\text{sick}] = \frac{H(p^{\min}) - H(p^{\max})}{M(p^{\min}) - M(p^{\max})}$$

so we can substitute $\mathbb{E}[b|\text{sick}]$ for $(H(p^{\min}) - H(p^{\max})) / (M(p^{\min}) - M(p^{\max}))$ in the rest of the proof.

Since U is linear,

$$\tilde{W}'(p) = -M'(p) \cdot (c - p + \varepsilon^{\text{avg}}(p)) = -M'(p) \cdot (c - b^{\text{avg}}(p)),$$

where $b^{\text{avg}}(p) \equiv \mathbb{E}_G \left[\frac{\partial M(p; \gamma, \theta) / \partial p}{M'(p)} \cdot b(p; \gamma, \theta) \right] = \mathbb{E}[b|b + \varepsilon = p]$ by Lemma B.1. As a result,

$$\tilde{W}'(p) = -M'(p) \cdot (c - \mathbb{E}[b|b + \varepsilon = p]).$$

By Proposition 3 in Chambers and Healy (2012), when $\mathbb{E}[\varepsilon] = 0$ for almost every p there exists an $\alpha \in [0, 1]$ such that $\mathbb{E}[b|b + \varepsilon = p] = \alpha \cdot p + (1 - \alpha) \cdot \mathbb{E}[b|\text{sick}]$. Since the distribution of $\varepsilon - \mathbb{E}[\varepsilon]$ is symmetric and quasi-concave whenever the distribution of ε is symmetric and quasi-concave, Chambers and Healy's result further implies that when $\mathbb{E}[\varepsilon] < 0$ then for almost every p there exists an $\alpha \in [0, 1]$ such that $\mathbb{E}[b|b + \varepsilon = p] > \alpha \cdot p + (1 - \alpha) \cdot \mathbb{E}[b|\text{sick}]$ and when $\mathbb{E}[\varepsilon] > 0$ then for almost every p there exists an $\alpha \in [0, 1]$ such that $\mathbb{E}[b|b + \varepsilon = p] < \alpha \cdot p + (1 - \alpha) \cdot \mathbb{E}[b|\text{sick}]$. Armed with these facts, we can establish the three parts of the proposition:

1. If $\mathbb{E}[b|\text{sick}] < c$ and $\mathbb{E}[\varepsilon] \geq 0$, then $\mathbb{E}[b|b + \varepsilon = p] < c$ for all $p \leq c$. As a result, $\tilde{W}'(p) \geq 0$ for such p with strict inequality when $M'(p) \neq 0$, in particular at $p = c$ given the assumption that $M'(c) \neq 0$, implying that $p^B > c$.
2. If $\mathbb{E}[b|\text{sick}] = c$ and $\mathbb{E}[\varepsilon] = 0$, then $\mathbb{E}[b|b + \varepsilon = c] = c$, while $\mathbb{E}[b|b + \varepsilon = p] < c$ for $p < c$ and $\mathbb{E}[b|b + \varepsilon = p] > c$ for $p > c$. This implies that $\tilde{W}'(p) \geq 0$ for $p \leq c$, $\tilde{W}'(p) = 0$ for $p = c$, and $\tilde{W}'(p) \leq 0$ for $p > c$, so $p^B = c$.
3. If $\mathbb{E}[b|\text{sick}] > c$ and $\mathbb{E}[\varepsilon] \leq 0$, then $\mathbb{E}[b|b + \varepsilon = p] > c$ for all $p \geq c$. As a result, $\tilde{W}'(p) \leq 0$ for such p with strict inequality when $M'(p) \neq 0$, in particular at $p = c$ given the assumption that $M'(c) \neq 0$, implying that $p^B < c$.

■

Lemma B.2. Suppose U is strictly concave, $\varepsilon(s; \theta) = \tilde{\varepsilon} \in \mathbb{R}$ and $b(s; \gamma) = s$ for all (s, γ, θ) .

1. If $\tilde{\varepsilon} > 0$ then $I(p) \leq 0$ for all $p \leq 0$ with equality at $p = 0$ and $I(p) > 0$ for all $p > 0$ satisfying $M(p) > 0$.
2. If $\tilde{\varepsilon} < 0$ then $I(p) < 0$ for all $p < 0$ satisfying $M(p) > 0$.

Proof. Recall

$$I(p) = \frac{\mathbb{E}[U'(C)|m = 1] - \mathbb{E}[U'(C)]}{\mathbb{E}[U'(C)]},$$

where $C = y - P - s + m \cdot (b - p)$, which under the assumption that $b = s$ reduces to

$$C = \begin{cases} y - P - p & \text{when } m = 1 \\ y - P - s & \text{when } m = 0. \end{cases}$$

Since $s \geq 0$, whenever $p < 0$ we have $y - P - p > y - P - s$, which implies that $I(p) < 0$ for all $p < 0$ satisfying $M(p) > 0$, establishing part 2 of the lemma.

To establish part 1 now specialize to the case where $\tilde{\varepsilon} > 0$. In this case, for all $p \leq 0$ we have $M(p) > 0$, so $I(p) < 0$ for all $p < 0$. Moreover, for $p = 0$, C equals $y - P$ for everybody so $I(p = 0) = 0$. For $p > 0$, $I(p) > 0$ for all $p > 0$ satisfying $M(p) > 0$ since $y - P - s > y - P - p$ for all $s < s(p)$ as a result of the fact that $s(p) < p$ when $\tilde{\varepsilon} > 0$. ■

Proof of Proposition 5. First consider the case where $\tilde{\varepsilon}$ is large. Specifically, suppose $\tilde{\varepsilon} > c$, so everybody gets treated when $p = c$. In this case, $M'(p) = 0$ for $p < c$, so $d\tilde{W}^N(p)/dp = -M'(p) \cdot (c - p) - I(p) \cdot M(p) \leq 0$ for all $p \geq 0$, with strict inequality for $p \in (0, c]$. This implies that $p^N \leq 0$. Since, additionally, $I(p) \leq 0$ for $p \leq 0$ with equality at $p = 0$ (by the assumption that $b(s; \gamma) = s$) and strict inequality when p is smaller than but sufficiently close to 0, we have that $d\tilde{W}^N(p)/dp \geq 0$ for $p < 0$ with strict inequality for p sufficiently close to 0, so $p^N = 0$. On the other hand, since demand must be price sensitive at the optimal copay (by Assumption 1), we must have that $p^B > c$ when $\tilde{\varepsilon} > c$. For example, if $-U''/U' \approx 0$, then $p^B \approx c + \tilde{\varepsilon} > c$, since this copay implements first best utilization.

If $\tilde{\varepsilon}$ is sufficiently low, for example $\tilde{\varepsilon} < -\bar{s}$, then $M(p) = 0$ for all $p \geq 0$, so $d\tilde{W}^N(p)/dp = 0$ for all $p \geq 0$. Since, in addition, $I(p) < 0$ for all $p < 0$ satisfying $M(p) > 0$, we have $d\tilde{W}^N(p)/dp \geq 0 \forall p \leq 0$ with strict inequality whenever $M(p) \neq 0$ or $M'(p) \neq 0$. The neo-classical analyst thus believes that $p^N = c$ is a candidate for the optimal copay. On the other hand, since nobody gets treated at positive values of p , we must have $p^B < 0$ by the assumption that $M'(p^B) \neq 0$ (Assumption 1). To illustrate, if $-U''/U' \approx 0$, then $p^B \approx c + \tilde{\varepsilon} < c - \bar{s} < 0$. ■

Proof of Corollary 1. Follows immediately from the proof of Proposition 5. ■

Proof of Proposition A.1. By definition,

$$\frac{d\tilde{W}^N}{dp}(p^N) = -M'(p^N) \cdot (c - p^N) - I(p^N) \cdot M(p^N) = 0.$$

As a result,

$$-M'(p^N) \cdot (c - p^N + \varepsilon^{\text{avg}}(p^N)) - I(p^N) \cdot M(p^N) = -M'(p^N) \cdot \varepsilon^{\text{avg}}(p^N),$$

which takes the sign of $\varepsilon^{\text{avg}}(p^N)$ given the assumption that $M'(p^N) \neq 0$.

Under the assumption that $\tilde{W}(p)$ is strictly quasi-concave over (p^{\min}, p^{\max}) then $\tilde{W}(p)$ must be nondecreasing for all $p < p^B$ and nonincreasing for all $p > p^B$. Given the result that $\tilde{W}'(p^N)$ takes

the sign of $\varepsilon^{\text{avg}}(p^N)$ this means that $p^B > p^N$ when $\varepsilon^{\text{avg}}(p^N) > 0$ and $p^B < p^N$ when $\varepsilon^{\text{avg}}(p^N) < 0$. ■

Proof of Proposition A.2. (Part 1) Let s_0 denote the severity of the marginal agent given copay p and nudge $n = 0$, so

$$b(s_0) + \varepsilon_0(s_0) = p_0. \tag{B.7}$$

(This is uniquely defined by the assumption that b and ε are constant in (γ, θ) .) Since $M_n(p_n) \geq M_0(p_0)$, we also have that

$$b(s_0) + \varepsilon_n(s_0) \geq p_n. \tag{B.8}$$

Inserting the first equality into the second expression yields

$$p_n - p_0 \leq \varepsilon_n(s_0) - \varepsilon_0(s_0) \leq -\varepsilon_0(s_0), \tag{B.9}$$

where the final inequality follows from the assumption that $\varepsilon_n(s_0) \leq 0$.

The proof of the second part is similar, and hence omitted. ■

C Case Study on Hypertension

High blood pressure is a prevalent and potentially deadly condition: 68 million adults in the U.S. have high blood pressure (CDC Vital Signs 2011), which is associated with adverse events such as heart attacks and stroke that carry with them serious health consequences including risk of death. The cost of treating hypertension and its consequences is high: Hodgson and Cai (2001) estimate the expenditures associated with hypertension and its effects to be about 11% of health expenditures, or over \$5,000 annually per hypertensive patient (\$3,800 in 1998, inflated using CPI). We use this important disease as a stylized example to illustrate implications of a model that incorporates behavioral hazard, examining: (1) the existence of effective treatments to avoid adverse consequences; (2) adherence and responsiveness to nudges; (3) effects of adherence on blood pressure and health outcomes.

The Efficacy of Drug Treatments and Consequences of Uncontrolled Hypertension: There are several classes of drugs (such as beta blockers and ACE inhibitors) that aim to reduce patients' blood pressure and thereby reduce the chance of serious downstream health events. The medical literature suggests that policies that increase compliance with anti-hypertensives would have

substantial health effects through lowering blood pressure. Use of beta-blockers post-heart attack can reduce subsequent mortality by more than 40% (Soumerai 1997). Hsu et al. (2006) found a 30% drop in anti-hypertensive compliance was associated with a 3% increase in hypertension and subsequent hospital and emergency department use. Anderson et al. (1991) present a model of how risk factors such as hypertension are associated with adverse events including heart attack and stroke in a non-elderly population, and calculate an overall risk of mortality from cardiovascular disease. For a 50 year old non-smoking, non-diabetic man with somewhat elevated cholesterol, a decrease in systolic blood pressure from 160 mmHg to 140 mmHg would reduce the risk of 10-year cardiovascular disease mortality by 2.5 percentage points; a decrease in diastolic blood pressure from 100 to 90 would reduce it by 5 percentage points. Long et al. (2006) find that the advent of anti-hypertensive drugs reduced blood pressure in the population over age 40 by 10 percent or more, and averted 86,000 deaths from cardiovascular disease in 2001 and 833,000 hospitalizations for strokes and heart attacks. They also note that in addition to these health improvements observed under existing use, under “guideline” use these numbers might have been twice as high – suggesting that improved patient adherence (as well as physician prescribing practices) might generate substantial health gains.

Adherence and Responsiveness to Nudges and Copays: Patient adherence to anti-hypertensives is not only far from perfect, but is sensitive to both finances and nudges. Schroeder et al. (2008) review the evidence on adherence to anti-hypertensives and efforts to improve it based on non-financial strategies, including studies that use reminder systems and innovative packaging. Overall adherence to hypertensive therapies is around 50%-70%, but such interventions were able to increase it by around 10-20 percentage points. Several of the studies they review find not only improvements in adherence, but also reductions in blood pressure. McKenney (1992), for example, finds that an intervention including electronic medicine caps and reminders increased adherence by 20 percentage points and reduced systolic and diastolic blood pressure by 7-15 mmHg. Several of the studies examining the price-sensitivity of demand for pharmaceuticals look at results for anti-hypertensives in particular. Many of these estimates cluster around -0.1 to -0.2 (including Chandra, Gruber and McKnight (2010); Landsman et al. (2005); and Chernew et al. (2008)).² The drop in use found by Hsu et al. (2006) was in response to the imposition of a cap on drug benefits

²Chandra et al. (2010) find an elasticity of -0.09 for anti-hypertensives among chronically ill HMO patients, based on an increase in copayments of around \$5 (unpublished detail). Chernew et al. (2008) estimate elasticities of -.12 for ACE inhibitors/ARBs and -.11 for beta blockers, based on copay reductions from \$5 to \$0 for generics and \$25 to \$12.50 for branded drugs. Landsman et al. (2005) find elasticities of -.16 for ARBs and CCBs and -.14 for ACE inhibitors, based on the introduction of tiering that raised copays by \$20 or less. Lohr et al. (1986) find a reduction in the use of beta blockers of 40% among those exposed to copayments in the RAND HIE versus those who were not, but the finding was not statistically significant. Similarly, Hsu et al. (2006) find that the imposition of a cap on Medicare beneficiaries’ drug benefits results in an increase in anti-hypertensive non-adherence of 30%.

(with the imposition of caps in general resulting in a decrease of 30% in pharmaceutical use but an offsetting increase in non-elective hospital use of 13% and emergency department use of 9%).

Effects on Health Outcomes: Unlike the Choudhry et al. (2011) study examined in the main text, most of these studies do not individually include the full set of outcomes needed to perform welfare calculations under models of moral hazard and behavioral hazard (and indeed, many do not even report the change in all-payer drug expenditures), but they can be used in combination to illustrate the point. For example, the drop in total drug utilization in one of the policy experiments studied in Chandra et al. (2010) is around \$23 a month when copays go up to about \$7.50 per drug among members who use about 1.4 drugs per month, or to a coinsurance rate of about 22% of the \$48 per month in drug spending. Following the logic from the Choudhry example in the main text, the standard moral hazard model would thus suggest that this copay increase generated less than about \$5 per month in health cost (with the remaining \$18 reduction in utilization attributable to reduced moral hazard)—which is clearly at odds with the observed changes in health outcomes.³ The imposition of benefit caps studied by Hsu et al. (2006) produced a similar magnitude decline in utilization, and was associated with an increase in death rates of 0.7 percentage points, along with increased blood pressure, cholesterol, and blood sugar—implying a cost from increased mortality alone of \$7,000 using conventional valuations.⁴

Another way of synthesizing this stylized evidence is to calculate the likely mortality reduction from changes in copayments or nudges that promote adherence and compare it to the cost of the intervention. Estimates suggest that interventions like a \$5 reduction in copayments or a nudge with comparable demand response applied to the 40% of people who are not adherent could increase compliance with anti-hypertensive therapy by something like 10 percentage points, resulting in a decrease in blood pressure of 15 mmHg and subsequent 3 percentage point reduction in deaths from cardiovascular disease (and even greater gains for readily-identifiable subpopulations like those with previous heart attacks, who may see a 40 percent reduction in subsequent mortality). This reduction in mortality would be valued at \$30,000 (Beaulieu et al. 2003). This might be compared to the cost of an adherence program. If such a program worked on ¼ of the people to whom it was applied and came at a cost of less than \$7,500, then it would be welfare improving based on this outcome alone. Given the estimates of the total annual cost of treating hypertensive patients

³Chandra et al. (2010) do not measure health directly, but the increased hospitalization rate is indicative of substantially worse outcomes. These stylized examples ignore the fact that the price of drugs is not likely an adequate proxy for their actual marginal cost.

⁴How we value reductions in mortality and improvements in health is of course a subject of major debate. Some estimates of the monetary value of life-years are derived from revealed preference arguments that are inherently grounded in a rational agent model, but others are based on labor market earnings, social welfare arguments, etc. Commonly used estimates cluster around \$100,000 per “quality-adjusted life year” and \$1 million per death averted (although this clearly varies based on the age at which death is averted and the life expectancy gained—for example, averting the death of a young healthy worker might be valued at \$5 million).

(around \$5,000), and that these interventions largely operate on the low-marginal-cost margin of increased adherence to prescriptions that have already been obtained through an office visit, this seems likely to be the case—and is consistent with meta-analysis suggesting that interventions to manage use of hypertension medications were highly cost-effective (Wang 2011).

As the Cutler et al. (2007) estimates suggest, there could be around 90,000 total deaths averted through greater compliance with optimal antihypertensive therapy, suggesting the scope of such gains could be vast. Furthermore, this can be viewed as a lower bound, insofar as there are many other health benefits of reduced hypertension beyond just the deaths from cardiovascular disease—including improved quality of life, lower incidence of expensive hospitalizations, etc. This example clearly over-simplifies (to the point of inaccuracy) complex medical pathways, but is meant to be illustrative both about the steps involved in such a calculation and the rough order of magnitude of the potential effects.

D Appendix Tables

Online Appendix Table 1: Examples of Underuse and Overuse

Panel A: Underuse of High-Value Care			
	Estimates of return to care	Possible unobserved private costs (side-effects often rare)	Usage rates of clinically relevant population
Statins	Reduce all cause mortality (Relative Risk= .88), cardiovascular disease mortality (RR .81), myocardial infarction or coronary death (RR .77) (1)	Muscle pain, digestive problems	Adherence < 70% (2)
Beta-blockers	Reduce mortality by 25% post heart attack (3)	Fatigue, cold hands	Adherence < 50% (4)
Anti-asthmatics	Reduce hospital admissions (Odds Ratio= .58). Improve airflow obstruction (OR .43) (5)	Stomach upset, headache, bruising	Adherence < 50% (6)
Anti-diabetics	Decrease cardiovascular mortality (OR .74) (7)	Headache, stomach upset	Adherence < 65% (8)
Immunosuppressants for kidney transplant	Reduce risk of organ rejection seven-fold (9)	Infections	Adherence < 70% (9)(10)
Recommended preventive care	Care of known efficacy including immunizations, disease management, follow-up care post surgery	Time costs; discomfort of screening; acknowledgment of disease	< 40% of diabetics receive semi-annual blood tests (11) Recommended immunization rates 60% for children, 24% for adolescents (12)
Pre-natal care	Reduces infant mortality and incidence of low birthweight and premature births (RR .47 to .57) (13) (14)	Time costs	< 50 % receive adequate or better care (13) (15)
Panel B: Overuse of Low-Value Care			
	Estimates of return to care to patient	Possible unobserved private benefits	Usage rates in populations with low benefits
MRIs for low back pain	Increase the number of surgeries with no resultant improvement in outcomes (16) (17)	Anxiety reduction	20% of patients with occupational low back pain received MRI within 6 weeks; 34% within a year (18)
PSA testing	No significant change in overall mortality (19)	Uncertainty reduction	49% of 50- to 79-year old men have had PSA test in past 2 years (20)
Prostate cancer surgery	No difference in overall survival (21)	Anxiety reduction	16% of patients with localized prostate cancer undergo prostatectomy within 9 months of diagnosis (22)
Antibiotics for children's ear aches	At best modest improvement, but with common side-effects (rashes, diarrhea) (23)	Positive action	98% of visits result in antibiotic Rx (24)

Sources: Authors' summary of literature:

- | | | |
|---|-------------------------------|-----------------------------|
| (1) Cholesterol Trtmt Trialists Collab (2005) | (10) Dobbels et al. (2010) | (18) Graves et al. (2012) |
| (2) Pittmen et al. (2011) | (11) Sloan et al. (2004) | (19) Schroder et al. (2012) |
| (3) Yusuf et al. (2010) | (12) McInerny et al. (2005) | (20) Ross et al. (2008) |
| (4) Kramer et al. (2006) | (13) Gortmaker (1979) | (21) Holmberg et al. (2002) |
| (5) Krishnan et al. (2009) | (14) Patridge et al. (2012) | (22) Snyder et al. (2010) |
| (6) Krishnan et al. (2004) | (15) Collins and David (1992) | (23) Sanders et al. (2004) |
| (7) Selvin et al. (2008) | (16) Jarvik et al. (2003) | (24) Froom et al. (1990) |
| (8) Bailey and Kodack (2011) | (17) Chou et al. (2009) | |
| (9) Butler et al. (2004) | | |

Online Appendix Table 2: Typical Health Insurance Plan Features

	Notes	Copay Structure
Public Plans		
Federal Employees Health Benefits Plan	Menu of private plans offered to federal employees. Details for most popular plan given	Physician office visit: \$20 Inpatient services: 15% Rx: Mail: \$10 generic, \$65 branded; Retail: 20%
Medicare	A&B (Hospital and physician) D (Drugs). Varied private plans. Basic plan given	Physician: 20% Inpatient: \$1,156 deductible (60 days) + \$289/day (thereafter) Rx: 25% up to initial coverage limit, 100% in "doughnut hole"; 5% above
Tricare Standard Plan	Civilian health benefits for military personnel/additional agencies, families	Physician: 20% Inpatient: max(\$25/admission, \$15.65/day) Rx: Mail: \$0 generic, \$9 preferred branded, \$25 non-preferred; Retail: 5/12/25
14 Medicaid	Varies state to state	Physician: 25 states have copays for physician visits
Private Plans		
Employer-sponsored	Varies. Averages given	Physician: \$22 generalist; \$32 specialist Rx: \$10 generic; \$29 preferred branded; \$49 non-preferred branded

Sources:

FEHBP: Blue Cross Blue Shield Standard plan: <http://www.fepblue.org/benefitplans/compare/index.jsp>.

Medicare : <http://www.medicare.gov/cost/>.

Tricare : <http://www.military.com/benefits/tricare/tricare-cost-co-pay-schedule.html> and <http://www.tricare.mil/mybenefit/home/Prescriptions/Costs?>.

Medicaid : Kaiser Family Foundation Medicaid Benefits database, located at <http://medicaidbenefits.kff.org/service.jsp?gr=off&nt=on&so=0&tg=0&yr=5&cat=6&sv=30>.

Private plan : Kaiser Family Foundation Health Research & Education Trust (2011)

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