Preliminary ideas

Optimal Health Insurance with Prevention and Multiple Goods

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Classic tradeoff in health economics between risk-spreading and moral hazard

Health care spending is uncertain creating a demand for insurance to reduce the cost of risk.

Spending on health care is subject to moral hazard, where the realized cost with insurance are much higher than without insurance.

Zeckhauser JET (1970) is classic article

Demand responsiveness and degree of risk aversion play key roles.
Different kinds of moral hazard

*Ex ante* moral hazard (prevention effort)
  - Insurance affects consumer effort to avoid illness

*Ex post* moral hazard (utilization when ill)
  - Insurance affects consumer choice of level of spending when ill

Paper ignores *supply side* moral hazard problems

Results from existing literature

Optimal to increase insurance coverage for health care services when
  - Less elastic response to insurance
  - More risk aversion
  - More expensive

Ambiguous results for coverage of preventive care
  - Low variance suggests insurance not needed (Kenkel, 2000)
  - Demand elasticity low relative to curative care (uncertain)
  - Insurance reduces value of prevention (*ex ante* moral hazard)
  - Primary versus secondary prevention
Demand curves for various types of spending, using Rand Health Insurance Experiment data, Newhouse, 1993 and Manning et al 1987.

Questions to be answered in this paper

How should optimal insurance coverage be modified in the presence of
- Multiple health care goods with correlated errors?
- Preventive care services?
- Multiple time periods when out-of-pocket spending is highly correlated over time?
Answers to these questions (hope to show)

1. Health care goods that are highly correlated with total spending should be more generously covered.
   • E.g., cover cancer treatment and all HIV costs generously
   • Cover emergency department care less generously
2. Primary preventive care should be covered generously to offset ex ante moral hazard effects of insurance.
3. Services that are highly serially correlated over time should be covered more generously than those that are less serially correlated
   ♦ Cover pharmaceutical, especially among the elderly

Huge literature potentially related to these questions

Optimal deductibles and copayments
Manning and Marquis, JHE, 1996

Demand responsiveness of specific services
Manning et al, AER 1987

Optimal insurance with multiple goods
Besley, JHE 1988

Dynamic models of health spending
Grossman, JPE, 1972

Prevention
Kenkel, Handbook, 2000

Statistical models of the distribution of health care costs over time
Keeler and Rolph, JASA 1988
French and Jones (J Applied Econometrics, 2004)
Simple model to illustrate main results

One health care good $X$, preventive good $Z$

Two types of states of the world:
- Healthy with probability $\alpha$ where $X^0 = 0$
- Sick with probability $1 - \alpha$ and health shock $\theta$

Linear demand curve $X = \mu_X - B P + \theta$

Marginal cost $= 1$

$P = c =$ cost share of marginal cost

Use CS to calculate welfare loss, ignoring income effects

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Constant welfare loss due to overconsumption of medical service $X_i$

- **Price** ($P_i$)
- **MC $= c = 1$**
- **c=0.2**

- Welfare lost due to overconsumption of medical service

![Diagram showing demand curve and welfare loss](image)
Adding in insurance and cost of risk

Use Arrow-Pratt approximation for welfare loss from financial risk

Cost of risk = (R^2)(variance of out-of-pocket spending)/2

Assume probability of sickness = 1 - \( \alpha(Z) \) [=1/\( \tau \)Z]

Insurance loading factor \( \delta \) implies cost of insuring

\[
= \delta \left( 1-\alpha(Z) \right) (1-c) (\mu_{X} - Bc)
\]

Uncompensated loss from insurance = \( L \)

---

Welfare loss to be minimized is

\[
\Pr(sick) [\text{Moral Hazard Loss} + \text{Loading cost} + \text{Cost of risk} + \text{Health loss}] + \text{cost of prevention}
\]

\[
\left[ 1 - \alpha(Z) \right] (1/2)(1-c)(1-c)B + \delta(1-c)(\mu_{X} - Bc) + R^2 c^2 \sigma_{\mu}^2 / 2 + L \right] + P_2 Z (1+r)
\]

where

- \( Z \) = quantity of preventive care
- \( \alpha(Z) \) = probability of being healthy
- \( c \) = coinsurance rate = share of costs paid by consumer
- \( B \) = slope of demand curves of the form \( X = \mu_{X} - Bc + \theta \)
- \( \delta \) = insurance loading factor
- \( \mu_{X} \) = mean of health care spending
- \( \sigma_{\mu}^2 \) = variance of health care spending
- \( R^2 \) = absolute risk aversion constant = \( -V_{\theta}/V_{\mu} \)
- \( P_2 \) = price of preventive care
- \( r \) = consumer discount rate
- \( \tau \) = effectiveness of prevention
- \( L \) = uncompensated loss from illness
Optimal choices of cost share $c$ and prevention $Z$

$$c^* = \frac{B + B\delta + \mu_c\delta}{B + 2B\delta + 2R^4\sigma_\theta^2}$$

$$Z^* = \sqrt{\frac{-B^2\delta^2 + 2LR^4\sigma_\theta^2 + \delta\mu_c(2R^4\sigma_\theta^2 - \delta\mu_c) + B(L(2 + 4\delta) + R^4\sigma_\theta^2 + 2\delta^2\mu_c)}{B + 2B\delta + 2R^4\sigma_\theta^2}2P_z(1 + r)\tau}$$

Comparative statics on $c^*$ and $Z^*$

<table>
<thead>
<tr>
<th>Effect of:</th>
<th>on: $c^*$</th>
<th>on: $Z^*$</th>
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</thead>
<tbody>
<tr>
<td>Demand slope</td>
<td>$B$</td>
<td>$+$</td>
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<tr>
<td>Risk aversion parameter</td>
<td>$R^4$</td>
<td>$- +$</td>
</tr>
<tr>
<td>Mean health spending</td>
<td>$\mu_c$</td>
<td>$+ ?$</td>
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<tr>
<td>Variance of spending</td>
<td>$\sigma_\theta^2$</td>
<td>$- -$</td>
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<tr>
<td>Price of preventive care</td>
<td>$P_z$</td>
<td>$0 -$</td>
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<tr>
<td>Discount rate</td>
<td>$r$</td>
<td>$0 -$</td>
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<tr>
<td>Effectiveness of prevention</td>
<td>$\tau$</td>
<td>$0 -$</td>
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<tr>
<td>Insurance loading cost</td>
<td>$\delta$</td>
<td>$+ +$</td>
</tr>
<tr>
<td>Uncompensated loss from illness</td>
<td>$L$</td>
<td>$0 +$</td>
</tr>
</tbody>
</table>

Results are interesting and plausible and many parameters can be calculated empirically

BUT

Does not suggest how to incorporate multiple goods

Does not expand to multiple periods well

Does not incorporate risk aversion in a fully satisfying way

Not based on a utility maximization framework
Elements of a new model

Three kinds of goods
$X = \{X_1, X_2, \ldots, X_N\} = \text{health care goods indexed by } i$
$Y = \text{all other consumption goods}$
$Z = \text{spending on preventive care}$
$P_X, P_Y, P_Z = \text{prices of three types of goods}$
$\pi = \text{insurance premium}$
$I = \text{Income (later wealth)}$
$I = \pi + P_X X + P_Y Y + P_Z Z (1+r)$

Sequence of moves

1. Insurer chooses coinsurance rates $c_i$ for each service
2. Consumer chooses preventive care level $Z$ to maximize ex ante utility
3. Nature decides whether consumer is healthy or sick, and if sick, vector of random health shocks $\theta = \{\theta_1, \theta_2, \ldots, \theta_n\}$
4. Consumer pays for preventive care $Z$ and chooses quantities $X_i$ and $Y$ to maximize ex post utility.
5. If a dynamic model, then repeat only steps 3 and 4 (prevention is done one time in period 0).
Three key assumptions about utility structure made here

Usual model uses expected utility function

\[ E U = E \cdot U(Y, H(X, \theta)) \]

1. Is \( U_{YH} \leftrightarrow 0? \)

Popular assumption is that \( U_{YH} = 0 \)

Model used here has \( U_{YH} = 0 \) for full insurance, but \( U_{YH} < 0 \) with less than full insurance.

2. Is \( \frac{\partial X}{\partial I} > 0? \)

We use \( \frac{\partial X}{\partial I} = 0 \) (Cross sectional empirical studies suggest income elasticity of demand among well insured people is about .1

3. Properties of demand curves for \( X? \)

We use linear demand curve

\[ X_i = A_i - B_i P_i + \sum_{j \neq i} G_{ij} P_j \]

Assumed Effect of Income Changes on Optimal Consumption Bundles

- Ideal ICC
- Assumed ICC
Utility when healthy is

\[ V(I, P, \theta) = V\left( \frac{I - \pi - (1+r)P_ZZ}{P_y} \right) \]

\[ = V\left( \frac{J}{P_y} \right) \]

where \( J \) = disposable income after premium \( \pi \) and payment for preventive care from period 0.

Demand for each health service \( X_i \) when sick:

\[ X_i = A_i - B_i \frac{P_i}{P_y} + \sum_{j \neq i} G_{ij} \frac{P_j}{P_y} \]

Use Roy's identity to derive risk neutral utility function when sick

\[ \tilde{V}^S(I, P) = \frac{I}{P_y} + \sum_i \left[ \frac{B_i P_i^2}{2P_y^2} - A_i \frac{P_i}{P_y} - \sum_{j \neq i} G_{ij} \frac{P_i P_j}{2P_y^2} \right] \]

Introduce stochastic element to demand

\[ A_i = \mu_i + \theta_i \text{ where } \theta_i \sim F(\theta_i) \text{ with } E(\theta_i) = 0 \]
Normalize $P_y = 1$

Use $J = \text{income after premium and prevention}$

Allow $V$ to reflect risk aversion (\*\*Assume same as for healthy\*\*)

Add in an uncompensated loss from illness $h(\theta)$

$$V^S(J, P, \theta)$$

$$= V\left(J + \sum_i \left[ \frac{B_i P_i^2}{2} - \mu_i P_i - \theta_i P_i - \sum_{j \neq i} \frac{G_{ij} P_i P_j}{2} \right] \right) + h(\theta)$$

Normalize $P_i = c_i$ and $MC_i = 1$ so $P_i = c_i$

$$V^S(J, c, \theta)$$

$$= V\left(J + K(c) \cdot \sum_i [c_i \theta_i] \right) + h(\theta)$$

Assuming $J$ is high enough so that $Y > 0$ for all $\theta$.

Putting it all together for the one period case

$$E_g V = \alpha(Z) V^H(J) + (1 - \alpha(Z)) V^S(J, c, \theta)$$

$$= \alpha(Z) V(J) + (1 - \alpha(Z)) E_g \left\{ V\left(J + K(c) \cdot \sum_i [c_i \theta_i] \right) + h(\theta) \right\}$$

where

$J = I - \pi - (1 + r)P_Z Z$

$\pi = (1 - \alpha(Z))(1 + \delta) \sum_i [1 - c_i] (\mu_i - B_i c_i + \sum_{j \neq i} G_{ij} c_j)$

$K(c) = \sum_i \left[ \frac{B_i P_i^2}{2} - \mu_i P_i - \sum_{j \neq i} \frac{G_{ij} P_i P_j}{2} \right]$
Consumer choice of prevention

\[ EV = \alpha(Z)V(J) + (1-\alpha(Z))[E_\theta \{ V(J+K(c)-c\theta'\theta c) \} + E_\theta[h(\theta)] \]  
\[ \frac{\partial EV}{\partial Z} = \alpha'(Z) \left[ V^H - E_\theta V^S \right] \]
\[ - (1+r)P_z \{ \alpha(Z) V_i^H(J) + (1-\alpha(Z)) \left[ V_i^S(K) \right] \} = 0 \]

or

\[ \frac{\partial EV}{\partial Z} = \alpha'(Z) \left[ V^H - E[V^S] \right] - (1+r)P_z \{ E[V_i] \} = 0 \]

which can be rewritten as

\[ \frac{\alpha'(Z)}{E[V_i]} = \frac{(1+r)P_z}{V^H - E[V^S]} \]

Socially optimal prevention includes effect of Z on premium \( \pi \)

\[ EV = \alpha(Z)V(J) + (1-\alpha(Z))[E_\theta \{ V(J+K(c)-c\theta'\theta c) \} + E_\theta[h(\theta)] \]  
\[ \frac{\partial EV}{\partial Z} = \alpha'(Z) \left[ V^H - E_\theta V^S \right] \]
\[ - \left[ \frac{\partial \pi}{\partial Z} + (1+r)P_z \right] \{ \alpha(Z) V_i^H(J) + (1-\alpha(Z))V_i^S(K) \} = 0 \]

or

\[ \frac{\partial EV}{\partial Z} = \alpha'(Z) \left[ V^H - E_\theta V^S \right] - \left[ \frac{\partial \pi}{\partial Z} + (1+r)P_z \right] \{ E[V_i] \} = 0 \]

which can be rewritten as

\[ \frac{\alpha'(Z)}{E[V_i]} = \frac{\frac{\partial \pi}{\partial Z} + (1+r)P_z}{V^H - E[V^S]} \]

where

\[ \frac{\partial \pi}{\partial Z} = -\alpha'(Z)(1+\delta) \sum_i (1-c_i)(\mu_i-B_i c_i + \sum_{j=1} G_j c_j) \]
Optimal choice of Z differs from private choice in that private choice ignores change in premium

Compare $Z^o$ and $Z^{2nd}$

$$\frac{\alpha'(Z^o)}{E[V_{i1}]} = \frac{\partial \pi}{\partial Z} + (1+r)P_Z \quad , \quad \frac{\alpha'(Z^{2nd})}{E[V_{i1}]} = \frac{(1+r)P_Z}{\left[V^H - E[V^S]\right]}$$

- $Z^o > Z^{2nd}$ if $\alpha''(\bullet) < 0 \leftarrow$ most plausible case
- private choice results in too little prevention
- Therefore prevention services should be subsidized

Now consider optimal coinsurance rates $c_i^*$
Take a second-order Maclaurin expansion around $J+K(c)$,

$$E_\theta \left\{ V(J + K(c) - c\theta) + h(\theta) \right\}$$

$$\approx E_\theta \left\{ V(J + K(c)) - (c\theta) V_1 (J + K(c)) + \frac{(c\theta)^2}{2} V_{ii} (J + K(c)) + h(\theta) \right\}$$

$$= V(J + K(c)) + E_\theta \left\{ \frac{(c\theta)^2}{2} V_{ii} (J + K(c)) + h(\theta) \right\}$$

and then using a particular first order expansion

$$\approx V(J) + K(c)V_1 (J) + E_\theta \left\{ \frac{(c\theta)^2}{2} V_{ii} (J + K(c)) + h(\theta) \right\}$$
Putting this together with the utility when healthy
\[ E_\theta V \approx \alpha(Z) V(J) \]
\[ + (1 - \alpha(Z)) \left[ V(J) + K(c) \nu_i(J) + E_\theta \left( \frac{(c\theta)^2}{2} V_{ll}(J + K(c)) + h(\theta) \right) \right] \]
\[ = V(J) + (1 - \alpha(Z)) \left[ K(c) \nu_i(J) + V_{ll}(J + K(c)) E_\theta \left( \frac{(c\theta)^2}{2} \right) + L \right] \]

Would like for the terms in red to disappear,
on the argument that the second derivative is nearly constant near \( J \).
Alternatively, can assume \( V_{\text{III}} = 0 \) (CAR)

Suppose it is true that
\[ E_\theta V \approx V(J) + (1 - \alpha(Z)) \left[ K(c) \nu_i(J) + V_{ll}(J) E_\theta \left( \frac{(c\theta)^2}{2} \right) + L \right] \]
then the optimum \( c^* \) is where
\[ \frac{\partial E_\theta V}{\partial c_i} \approx (1 - \alpha(Z)) \left[ B_i c_i - \mu_i - \sum_{j \neq i} G_{ij} c_j \right] V_i(J) + V_{ll}(J) \sum_j \text{cov}(\theta_i, c_j\theta_j) \]
\[ - \left[ \frac{\partial E_\theta V}{\partial J} \frac{\partial \pi}{\partial c_i} \right] = 0 \]
where
\[ \frac{\partial \pi}{\partial c_i} = (1 - \alpha(Z))(1 + \delta) \left[ -\mu_i - B_i + 2B_i c_i - \sum_{j \neq i} (1 - 2c_j) G_{ij} \right] \]

One key issue is how close are \( V_i(J) \) and \( \frac{\partial E_\theta V}{\partial J} \).
Suppose $\delta=0$ and $V_t(J) = \frac{\partial E_0 V}{\partial J}$ as would be true with ideal, actuarially fair insurance.

$$(1-\alpha(Z)) \left[ B_i(1-c_i) - \sum_{j \neq i} G_{ij}(1-c_j) \right] - R^d \sum_j \text{cov}(\theta_i, c_j \theta_j) = 0$$

System is linear in $c_i$ and $c_j$ and hence easy to solve analytically.

Somewhat messy to interpret.

Rearranging

$$(1-\alpha(Z)) \left[ B_i c_i - \sum_{j \neq i} G_{ij} c_j \right] - \left[ B_i - \sum_{j \neq i} G_{ij} \right] - R^d \sum_j \text{cov}(\theta_i, c_j \theta_j) = 0$$

The term $\sum_j \text{cov}(\theta_i, c_j \theta_j)$ is the covariance of spending on service $i$ with total out-of-pocket spending.

Several results

$\Rightarrow$ Services with a lower higher covariance should have lower cost shares

Starting at $G_{ij} = 0$, as $G_{ij}$ increases, then $c_i$ has to increase,

$\Rightarrow$ less generous coverage for substitutes
Multi period model?

Have not worked out model fully. Believe that we can show
Services should have lower coinsurance when they are more highly
serially correlated over time.
Spending on certain services are much more highly serially
correlated than total spending.
Spending that is topcoded, as by a deductible, is much more highly
correlated over time (.7 to .5)
Highly correlated errors justify more complete insurance.

Glimpse at some empirical results
Trends in per person spending on inpatient, outpatient and pharmacy services, five-year continuously enrolled cohort age < 65, MEDSTAT Marketscan data 2000-2004 (N=1,335,448)

Coefficient of variation of inpatient, outpatient, pharmacy, and total spending
Correlations among three broad services, without top-coding, are not especially high

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<th>inpatient spending</th>
<th>outpatient spending</th>
<th>pharmaceutical spending</th>
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<td>outpatient</td>
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</tr>
<tr>
<td>pharmaceutical</td>
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5 Year autocorrelations

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<tr>
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<td>Total health spending</td>
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<td>0.223</td>
<td>0.248</td>
<td>0.304</td>
<td>0.418</td>
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</table>

Var(Σ(X_i)) = Var(X_i)*sum of all terms in correlation matrix

If uncorrelated, then Var (Σ(X_i) = 5 σ^2)

Actual sum above is 11.3

So variance of five year total is 11.3/5=2.26 times higher than an independent errors would result in.
### 5 Year autocorrelations

<table>
<thead>
<tr>
<th>Correlation Coefficients</th>
<th>( \rho(t, t-1) )</th>
<th>( \rho(t, t-2) )</th>
<th>( \rho(t, t-3) )</th>
<th>( \rho(t, t-4) )</th>
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<td>0.091</td>
<td>0.155</td>
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**Inpatient spending**

- Sum = 6.9
- Variance = \( 1.4 \sigma^2 \)

**Outpatient spending**

- Sum = 12.4
- Variance = \( 2.5 \sigma^2 \)

**Pharmaceutical spending**

- Sum = 18.5
- Variance = \( 3.7 \sigma^2 \)

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**Correlation terms of total out-of-pocket spending over time for various levels of deductibles**

MEDSTAT Marketscan commercially insured sample (N = 1,335,448)

![Graph showing correlation coefficients for different deductibles](image-url)
Effect of simple deductibles on correlations of out-of-pocket health care spending, three-year continuously enrolled cohort, age > 65 MEDSTAT Marketscan Medicare sample, 2002-2004
(N = 412,626)

Correlation Coefficient

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<th>Deductibles</th>
<th>Correlation Coefficient</th>
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<td>No insurance</td>
<td>0.8</td>
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<tr>
<td>$1,000</td>
<td>0.7</td>
</tr>
<tr>
<td>$2,000</td>
<td>0.6</td>
</tr>
<tr>
<td>$4,000</td>
<td>0.5</td>
</tr>
<tr>
<td>$6,000</td>
<td>0.4</td>
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<tr>
<td>$8,000</td>
<td>0.3</td>
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<tr>
<td>$10,000</td>
<td>0.2</td>
</tr>
<tr>
<td>$12,000</td>
<td>0.1</td>
</tr>
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</table>

US privately-insured health care spending, by age and by gender, 2004 MEDSTAT Marketscan data (N=14.6 million)

Source: Ellis, 2007
<table>
<thead>
<tr>
<th>Year</th>
<th>Total Exp</th>
<th>Inpatient Exp</th>
<th>Outpatient Exp</th>
<th>Pharmacy Exp</th>
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<tr>
<td>2003</td>
<td>0.418</td>
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<tr>
<td>2004</td>
<td>0.416</td>
<td>0.103</td>
<td>0.406</td>
<td>0.227</td>
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