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BUNDLING ECONOMICS UNDER ADVERSE SELECTION IN THE INDIVIDUAL HEALTH INSURANCE MARKET

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ABSTRACT

We examine the impact of bundling strategies on the level of consumer participation and premium rates realized in an individual health insurance market characterized by an adverse selection problem. In this context we show that society may use private insurers to attain universal coverage at equitable premiums under a pure bundling strategy, where insurers offer only a comprehensive policy to the market. This result is strengthened as the number of medical conditions covered in the comprehensive policy increases and as applicant risk aversion increases. When insurance applicants exhibit low levels of risk aversion a mixed bundling strategy (or offering single-disease policies along with the comprehensive policy) improves consumer participation and decreases premium rates when compared to a pure bundling strategy. In this case market performance is improved by increasing policy options offered to applicants. Alternatively, when insurance applicants exhibit moderate levels of risk aversion a mixed bundling strategy reduces consumer participation and increases premium rates when compared to a pure bundling strategy. In this case market performance is improved by reducing policy options offered to applicants. In addition, when insurance applicants exhibit sufficiently high levels of risk aversion the consumer participation and premium rates realized under a pure bundling strategy and mixed bundling strategy converge toward full market participation. Finally, under all levels of risk aversion we show that offering an exclusion policy along with the comprehensive policy decreases consumer participation.

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INTRODUCTION

As technological advances continue to improve individuals' assessments of their personal health risk factors, privacy legislation continues to restrict insurers' use of such information to design insurance policies. Advances in biological research and medical technology, through the advent of *genetic testing*, have provided individuals and their doctors with more accurate assessments of their genetic predisposition for a large and growing number of medical conditions (Murry, Wimbush, and Dalton 2001). Applicants may use this genetic information to purchase the most advantageous health insurance policy available to them in terms of premium rates and coverage levels. Alternatively, insurance companies able to access this information may engage in *genetic discrimination*, the practice of denying coverage to, or pricing policies for, individuals based on their genetic predispositions to certain medical conditions (Gostin 1991). However, industry regulators, consumer advocates, ethicists, and others argue that genetic discrimination is unfair to applicants who have inherited a genetic predisposition over which they have no control. Therefore, regulators at both the state and federal levels have implemented genetic privacy legislation that prohibits the discriminatory use of genetic information (e.g., genetic test results, family history, and medical history) by insurance companies (Baderian and Selzer 2001).

The information asymmetries created by these technological and regulatory trends may create an adverse selection problem in the individual health insurance market in which fewer individuals are covered by health insurance. In previous work we have shown that genetic privacy legislation will force lower risk individuals, who are no longer able to signal their low risk status to insurers and receive preferential policies, to obtain less coverage than they would in the absence of regulatory interference, while higher risk individuals continue to pay premiums that are not significantly better than they would have been without regulation. Essentially, no one is made better off under genetic privacy legislation, while some individuals are demonstrably made worse off (Clemons and Thatcher 1997; Thatcher 1998). In order to sustain the viability of the insurance market insurers must design a menu of insurance policy options to mitigate this adverse selection problem and to restore consumer participation at affordable premiums.

CONTRIBUTION

This paper makes a contribution to IS research in several ways. It contributes to our understanding of the economic impacts of the adverse selection problem created by recent technological and regulatory trends in the individual health insurance market. It also contributes to our understanding of the economics of bundling in this context, which has not yet been explored in the literature. Specifically, the model presented in this paper examines the use of bundling strategies by a regulated insurance company to maximize consumer participation in the individual health insurance market at affordable premiums. In this context marginal costs are high and vary discretely across insureds based on each insured's personal health risk factors. Counter to typical results in previous work, we show that, under certain conditions, a pure bundling strategy may dominate mixed bundling strategies. That is, providing health insurance applicants with more insurance choices and policy options may actually reduce individual and social welfare. In addition, this is the first economic analysis to our knowledge that models an insurance market using a repeated Cournot game not only to derive market equilibrium but also to characterize the market dynamics leading to equilibrium.

This research is expected to be interesting to researchers focusing on the economic impacts of information technology, the social costs of information privacy, bundling economics, and insurance economics. It is also expected to be interesting to managers in, and government regulators of, the individual health insurance market as they attempt to balance the genetic privacy of health insurance applicants with the availability and affordability of health coverage.

In this paper we are principally concerned with designing bundling strategies that will reduce adverse selection in the presence of information asymmetries and increase consumer participation (the percentage of conditions covered in the market) and market participation (the percentage of outcome risk covered in the market) in the context of the individual health insurance market. The goal of maximizing market participation is critical to public health officials and market regulators given the participation externalities caused by failure to treat communicable diseases, resulting in their transmission, or incomplete treatment, the principal driver for the development of drug-resistant strains of *super-bug* (see Clemons and Thatcher 1997, 2000; and Thatcher 1998 for a more detailed discussion of market participation as a measure of market efficiency).

We develop a model that assumes that applicants for individual health insurance are at risk for a large number of medical conditions, predictive genetic tests enable them to know their genetic predisposition to each condition, and regulatory policy prohibits insurance companies from engaging in genetic discrimination. Insurers may offer a set (or menu) of insurance policies, provided this same set is made available to all applicants at the same price. This menu may include a comprehensive policy (with full coverage), an exclusion policy (with a coverage for a single specified medical condition omitted from the coverage provided by the comprehensive policy), and a selection of single disease policies (with each policy providing coverage for a single medical condition). Under a *component selling strategy* the insurer offers a selection of single disease policies to the market; consumers may create their own customized bundles by purchasing any combination of policies or purchase nothing at all. Under a *pure bundling strategy* the insurer offers only a comprehensive policy to the market; consumers may purchase the comprehensive policy or nothing at all. Under a *mixed bundling strategy* the insurer offers a comprehensive policy and a selection of single disease policies to the market simultaneously; consumers may purchase the comprehensive policy, a customized bundle of single disease policies, or nothing at all. Finally, under what we term an *exclusion strategy* the insurer offers a comprehensive policy and an exclusion policy to the market simultaneously; consumers may purchase one of the policies or nothing at all. We examine the impact of each menu design on the purchasing decisions made by applicants, the premium rates charged by insurers, and the consumer participation realized in the market over a range of risk aversion levels. We model this problem as a repeated Cournot game and solve it through iterative numerical computation of the Nash equilibrium using the best response dynamic. Since the number of distinct populations is finite, equilibrium is reached in our repeated Cournot game in a finite number of moves. Significantly, although we use numerical methods, our solution represents an exact equilibrium and it is not a numerical approximation. Critical findings are summarized below:

- Insurers may attain universal coverage at equitable premiums under a pure bundling strategy. This result is strengthened as the number of medical conditions covered in the comprehensive policy increases and as applicant risk aversion increases.
- When insurance applicants exhibit low levels of risk aversion a mixed bundling strategy improves consumer participation and decreases premium rates when compared to a pure bundling strategy. In this context market performance is improved by *increasing policy options* offered to applicants.
- Alternatively, when insurance applicants exhibit moderate levels of risk aversion a mixed bundling strategy reduces consumer participation and increases premium rates when compared to a pure bundling strategy. In this context market performance is improved by *reducing policy options* offered to applicants.
- In addition, when insurance applicants exhibit sufficiently high levels of risk aversion the consumer participation realized under a pure bundling strategy and a mixed bundling strategy converge toward full market participation and the

premium for the comprehensive policy converges to the actuarially fair rate for the applicant population.

- Finally, under all levels of risk aversion an exclusion strategy decreases consumer participation when compared to a pure bundling strategy.

This analysis contributes to our understanding of the economics of bundling in a context not explored in previous work. Previous work has focused on the use of bundling strategies by multiple-product monopolists to maximize profits. Much of the work in the information technology (IT) literature has focused on the bundling of digital goods (e.g., on-line music) and assumes that marginal product costs are low (and the same for each product) and that consumer valuations for each product are continuously distributed across consumers (e.g., uniformally or normally). Moreover, in the context of music or other digital goods purchases, risk aversion is of course not the motivating force driving the purchase, and the impact of risk aversion can safely be ignored in these contexts. Recent work by others in this area demonstrates the dominance of mixed bundling strategies over pure bundling and component selling strategies in maximizing monopoly profits (Chuang and Sirbu 1999; Hitt and Chen 2000). In contrast, the model developed in this paper addresses a different, but complementary, problem context. Specifically, the differences include the following:

The model examines the use of bundling strategies by a *regulated insurance company* (restricted to zero profits) to *maximize market participation* at affordable premium rates.

- In the context of the individual health insurance market marginal costs of insurance provision are *high* and vary *discretely* across insureds based on each insured's risk portfolio for the covered set of medical conditions. Since applicants are generally either at high risk or at low risk for acquiring a specific medical condition, risk is discretely (as opposed to continuously) distributed across the applicant population. As a result, the marginal cost to the insurer of providing insurance coverage to an insured is the insured's expected medical costs.
- Applicants' valuations for insurance coverage also vary *discretely* across applicants based on applicants' risk portfolios, expected medical costs, and risk aversion levels.

In this very different context we show that the effectiveness of alternative bundling strategies in achieving regulatory goals of maximizing market participation at affordable premiums depends critically on the level of risk aversion exhibited by applicants.

LITERATURE REVIEW

Previous work in insurance economics has acknowledged that the presence of information asymmetries may lead to adverse selection and, in the worst case, complete market collapse. Much of this work examined the use of *price-quantity contracts* (i.e., a form of rationing in which the contract specifies both the premium rate applicants must pay and the deductible for which applicants are responsible) to mitigate adverse selection in insurance markets where applicants possess perfect and private information about their propensity to incur a *single* specified loss (Riley 1979; Miyasaki 1977; Wilson 1977; Rothschild and Stiglitz 1976). In these models insurance companies typically induce individuals to sort themselves into risk classes by their choice of contracts. High risks select full insurance coverage at actuarially fair rates (calculated for the pool of high-risk individuals) while low risks select partial insurance coverage but at lower average premium than that of high risks. The lower premium for low-risk individuals reflects both the lower degree of coverage and the lower average risk of applicants.

Other work addressed the adverse selection problem through *risk classification* – that is, offering different coverage levels and charging different premium rates to applicants based on observable characteristics such as genetic history or based on behaviors such as smoking (Bond and Crocker 1991; Crocker and Snow 1986). This work implies that insurance companies that are able to access genetic information (e.g., via genetic testing and data mining tools) should engage in genetic discrimination. However, industry regulators, consumer advocates, ethicists, and others argue that genetic discrimination is unfair to applicants who have inherited a genetic predisposition over which they have no control.

In order to avoid the perceived unfairness of risk classification based on genetic information Tabarrok (1994) proposed the implementation of *genetic insurance*. In this model all individuals purchase genetic insurance at a single premium and then undergo genetic screening. Their genetic insurance policies will pay them the expected increase in health insurance premiums that would result from the conditions detected during their genetic screening. The fully public results of their testing would then determine the actual cost of their health insurance in an efficient market. Unfortunately, genetic insurance would work only if participation could be made mandatory and universal; otherwise, it is prone to the same adverse selection problem that it is intended to correct in the health insurance markets. For example, individuals who do not observe a signal from their family or medical history regarding the presence of a genetic predisposition may find the genetic insurance overpriced and opt out of the genetic insurance market altogether.

Although the adverse selection problem presented in this paper is grounded in the insurance economics literature, we examine the economic impact of alternative bundling strategies (as opposed to price-quality contracts, risk classification, or genetic insurance) in the context of the individual health insurance market. Most of the bundling work in the marketing and IT literatures examines the use of bundling strategies by multi-product monopolists to maximize profits, capture consumer surplus, and reduce deadweight losses. While early work focused on 2-good bundling (Adams and Yellen 1996; Salinger 1995; Schmalensee 1984), more recent work has examined *N*-good bundling settings. For example, Bakos and Brynjolfsson (1999) examined the impact of bundling a large number of information (or digital) goods on the profits earned by a multi-product monopolist. They demonstrate that when marginal costs are very low, consumer valuations for the goods are of comparable value, and the correlation in demand for different goods is low, a multi-product monopolist may use a pure bundling strategy (i.e., selling the entire bundle of products at a single price) to increase profits, capture consumer surplus, and reduce dead weight losses. Chuang and Sirbu (1999) extended this work by developing an *N*-good bundling model to examine the optimal bundling strategy for publishers selling and delivering academic journal articles over the Internet. In this context they establish mixed bundling (i.e., offering both individual articles and journal subscriptions) as the dominant, profit-maximizing strategy. Hitt and Chen (2000) also demonstrate the dominance of mixed bundling strategies in certain monopoly markets. Assuming that costs of individual goods or services are strictly greater than zero (but low) they show that a monopolist will earn more and consumer satisfaction will increase by allowing customers to choose a fixed subset of a larger set of offerings. That is, both monopolist record clubs and consumers will be better off if consumers choose their 10 favorite recordings for a fixed price, rather than being required to purchase all available selections under the pure bundling case.

Thatcher (1998) and Thatcher and Clemons (2000) extended the bundling work to contexts outside of a multi-product monopolist. They considered a regulated individual health insurance market and examined the impact of a pure bundling strategy, in which the insurer offers only a comprehensive policy that covers a large number of medical conditions, on consumer participation in insurance markets. They found that if the number of conditions covered in the comprehensive policy is sufficiently large that a pure bundling strategy may reduce adverse selection and increase consumer participation in the market. This work examined the sensitivity of this result to a range of model parameters, including the number of conditions included in the comprehensive policy, the distribution of risk across the applicant population, and the size of the treatment costs. In this paper we extend this work by comparing the effectiveness of alternative bundling strategies (including a mixed bundling strategy and a component selling strategy) on consumer participation and policy premiums over a range of applicant risk aversion.

MODEL

Individuals are potential consumers of (or applicants for) private health insurance products and services. We assume that applicants are at risk for N insurable medical conditions, each of which has a genetic risk component and a known treatment cost, T. Each individual is endowed with either a high-risk status with probability λ, where $0 < \lambda < 1$, or a low-risk status with probability $(1-\lambda)$, for each medical condition through a set of N independent and identical Bernoulli trials. We assume a sufficiently large applicant population so that we may use the binomial distribution to approximate the distribution of risk types in the applicant population. Without loss of generality we normalize the number of potential consumers (or applicants for individual health insurance) in the market to 1. We define risk type *h* as those individuals endowed as high risk for h of the N medical conditions and, therefore, endowed as low risk for the remaining $(N-h)$ conditions. The proportion of the applicant population endowed as risk type *h* is

$$\alpha_h = binom(h, N, \lambda) = \frac{N!}{h!(N-h)!} \lambda^h (1-\lambda)^{(N-h)} \tag{1}$$

where $binom(h, N, \lambda)$ is the probability density function for the binomial distribution.

We assume that individuals are perfectly informed, through a set of free and perfectly accurate genetic tests, of their risk type h. The probability that an individual at low risk for a condition will develop that condition (and incur the associated treatment costs) is p_L and the probability that an individual at high risk for a condition will develop that condition is p_H, where $0 < p_L < p_H < 1$. These probabilities are fixed and not altered by individuals' behaviors. Individuals are identical except in their risk type, or the number of conditions for which they are at high risk. In addition, individuals are risk averse and possess the same underlying exponential utility function

$$U(x) = -e^{r\omega} \tag{2}$$

where *r* is the risk aversion parameter and ω is the applicant's wealth. The exponential utility function exhibits constant absolute risk aversion (CARA) as defined by Arrow (1971). The expected utility of risk type h remaining uninsured in any time period *t* is

$$EU_h^t = \sum_{x=0}^{h} \left(\frac{h!}{x!(h-x)!} {p_H}^x (1-p_H)^{h-x} \sum_{y=0}^{N-h} \frac{(N-h)!}{y!(N-h-y)!} {p_L}^y (1-p_L)^{N-h-y} U(\omega_0 - (x+y)T) \right) \tag{3}$$

where ω_0 is the initial wealth of applicants. Equation (3) calculates, for all combinations of *x* and *y*, the probability that risk type *h* will develop *x* of his *h* high risk conditions <u>and</u> *y* of his (*N*-*h*) low risk conditions, multiplies that probability by the utility associated with incurring the treatment costs for those (*x*+*y*) conditions, and sums the weighted utility calculations over all (*x*, *y*) combinations. This calculation generates the expected utility of risk type *h* remaining uninsured in any time period *t*.

This model considers a single, risk-neutral insurance company participating in a regulated insurance market in which genetic privacy legislation prevents the insurer from engaging in genetic discrimination, or targeting insurance policies to specific applicants based on genetic information. Therefore, the insurer offers a menu of policy options, specifying coverage levels and premium rates, from which insurance applicants may choose. We examine four menu designs (or bundling strategies).

- Component Selling Strategy (*CSS*) – the insurer offers a selection of single disease policies to the market; consumers may create their own customized bundles by purchasing any combination of policies or purchase nothing at all.
- Pure Bundling Strategy (*PBS*) – the insurer offers only a comprehensive policy to the market; consumers may purchase the comprehensive policy or nothing at all.
- Mixed Bundling Strategy (*MBS*) – the insurer offers a comprehensive policy and a selection of single disease policies to the market simultaneously; consumers may purchase the comprehensive policy, a customized bundle of single disease policies, or nothing at all.
- Exclusion Strategy (*ES*) – the insurer offers a comprehensive policy and an exclusion policy to the market simultaneously; consumers may purchase one of the policies or nothing at all.

We examine the impact of each menu design on the purchasing decisions made by applicants, the premium rates charged by insurers, and the consumer participation realized in the market. In the initial period the insurer must price the policies based on population statistics. However, after the initial period the insurer is permitted to engage in actuarially fair re-pricing based on the applicants' purchasing decisions and claims experience.

Component Selling Strategy (*CSS*): Defining the Adverse Selection Problem

Under *CSS* applicants may create their own customized bundle of insurance coverage by selecting any number of *N* single coverage policies, each covering a single condition at a fixed premium. Since genetic privacy legislation prevents the insurer from engaging in genetic discrimination, or targeting insurance policies to specific applicants based on genetic information, in the initial period the insurer must price the policies based on population statistics. Therefore, the initial premium charged for each of the *N* single-disease policies at time $t = 0$ is

$$P_S^0 = \left(\lambda p_H + (1-\lambda) p_L\right)T \tag{4}$$

From the uninformed insurer's perspective Equation (4) represents the expected claims experience of each applicant for each of the *N* medical conditions. For example, assume that 10% of applicants are at high risk for each medical condition (while 90% are at low risk) and that those applicants at high risk have a 20% chance of developing the condition while those at low risk have only a 5% chance of developing the condition. Also assume that an applicant who develops a medical condition will incur medical costs of 100. In this case, since the insurer does not have access to individuals' risk status, the insurer is initially forced to engage in a uniform pricing strategy. Therefore, from the insurer's perspective the expected claims experience for each applicant for each medical condition is 6.5.

Given that risk (and therefore, the realization of risk) is distributed independently and identically across the applicant population and assuming a sufficiently large applicant pool the claims experience across single-disease policies will be the same. Therefore, the premiums for policies covering each condition will have the same distribution and the same expected value. When applicants enter the market they observe the menu of single-disease policies offered by the insurance company that period. In the initial period, based on all available information (i.e., the realization of their risk type, h, and the premiums, $P_S{}^0$, charged by the insurer), expected utility maximizing applicants decide whether to purchase insurance or remain uninsured.

We assume that individuals possess a positive level of risk aversion $(r > 0)$. This assumption implies that individuals would rather purchase insurance priced at an actuarially fair rate for that individual than remain uninsured; that is,

$$p_i U(\omega - T) + (1 - p_i)U(\omega) < U(\omega - p_i T), \forall i \in [H, L] \tag{A1}$$

In addition, we assume that the level of risk aversion is reasonable. Specifically, we assume that an individual at low risk for a specific condition would prefer to remain uninsured than purchase insurance priced at the actuarially fair rate for the entire applicant population; that is,

$$U\left(\omega - P_S^{\ 0}\right) \le p_L U(\omega - T) + (1 - p_L)U(\omega) \tag{A2}$$

Together, Assumptions (A1) and (A2) limit the analysis to only ranges of positive risk aversion in which the adverse selection problem arises.

In the initial period each applicant, given $P_S^{\ 0}$, will purchase those policies that cover conditions for which he is at high risk (given Assumption $A(1)$) but will remain uninsured for his low-risk conditions (given Assumption $A(2)$). Specifically, applicants of risk type h will purchase a customized bundle of h policies, each covering one of the h high-risk conditions, and will remain uninsured for the $(N - h)$ low-risk conditions. Since applicants only cover their high-risk conditions and the insurer is permitted to re-price its menu of policies each period based on claims experience the equilibrium price realized under *CSS* for each single-disease policy is

$$P_S^* = p_H T \tag{5}$$

The expected utility of applicants of risk type h of purchasing this customized bundle of single-disease policies in equilibrium is

$$EU_{S,h}^* = \sum_{y=0}^{N-h} \frac{(N-h)!}{y!(N-h-y)!} p_L^{\ y} (1 - p_L)^{N-h-y} U\left(\omega - hP_S^* - yT\right) \tag{6}$$

Consumer participation is measured as the percentage of medical conditions covered by insurance while market participation is measured as the percentage of outcome risk covered by insurance. These equilibrium values will serve as a baseline with which to compare the effectiveness of the pure bundling, mixed bundling, and exclusion strategies in mitigating the adverse selection problem. Under *CSS* the equilibrium level of consumer participation is

$$CP^*(CSS) = \sum_{h=0}^{N} \alpha_h \left(\frac{h}{N}\right) \tag{7}$$

The equilibrium level of market participation is

$$MP^*(CSS) = \frac{\sum_{h=0}^{N} \alpha_h \left(\frac{h}{N}\right) h p_H T}{(\lambda p_H + (1 - \lambda) p_L) NT} \tag{8}$$

where the numerator is the claims experience of insureds who purchase single-disease policies (or the amount of outcome risk covered by insurance) and the denominator is the population’s claims experience (or the population’s total outcome risk exposure).

Pure Bundling Strategy (*PBS*)

Under *PBS* applicants are offered a comprehensive policy that covers the applicant for all insurable medical conditions at a single, fixed premium. Each applicant must decide whether to purchase the policy and become fully insured or remain uninsured. Due to genetic privacy legislation the initial premium charged for the comprehensive policy at time $t = 0$ is

$$P_C^0 = \left(\lambda p_H + (1-\lambda) p_L\right) NT \tag{9}$$

After the initial period the insurer will engage in actuarially fair pricing based on claims experience. Therefore, the premium charged for the comprehensive policy in time $t > 0$ is

$$P_C^t = \frac{\sum_{h=0}^{N} c_{h,t-1}\alpha_h \left(hp_H + (N-h)p_L\right)T}{\sum_{h=0}^{N} c_{h,t-1}\alpha_h}, \forall t > 0 \tag{10}$$

where $c_{h,t-1} = 1$ if risk type h purchases the comprehensive policy in time $(t-1)$ and $c_{h,t-1} = 0$ if risk type h remains uninsured. In Equation (10) the numerator is the claims experience of insureds who purchased the comprehensive policy in the previous time period and the denominator is the percentage of the population that purchased the comprehensive policy in the previous period (remember that we normalized the number of applicants to 1).

Based on all available information (the realization of their risk type, h, and the premium, $P_C{}^t$), applicants decide whether to purchase the comprehensive policy or remain uninsured. The expected utility of purchasing the comprehensive policy for risk type h in period t is

$$EU_C^t = U\left(\omega_t - P_C{}^t\right), \forall t > 0 \tag{11}$$

Under *PBS* the level of consumer participation in time t is

$$CP^t(PBS) = \sum_{h=0}^{N} c_{h,t}\alpha_h, \forall t > 0 \tag{12}$$

and the level of market participation is

$$MP^t(PBS) = \frac{\sum_{h=0}^{N} c_{h,t}\alpha_h \left(hp_H + (N-h)p_L\right)T}{\left(\lambda p_H + (1-\lambda)p_L\right)NT}, \forall t > 0 \tag{13}$$

where the numerator is the claims experience of insureds who purchased the comprehensive policy and the denominator is the population's claims experience (or the population's total outcome risk exposure). Overall, Equation (13) represents the percentage of outcome risk covered in the market at any time *t* under a *PBS*.

Mixed Bundling Strategy (*MBS*)

Under *MBS* applicants are offered a choice between a comprehensive policy and a selection of single disease policies. The mechanisms for pricing these policies and for calculating expected utilities associated with purchasing policies were presented earlier. Based on all available information (the realization of their risk type, h, and the premiums, $P_C{}^t$ and $P_S{}^*$), applicants decide whether to purchase the comprehensive policy, a customized bundle of single-disease policies, or remain uninsured. Under *MBS* the level of consumer participation in time t is

$$CP^t(MBS) = \sum_{h=0}^{N}\left(c_{h,t}\alpha_h + s_{h,t}\alpha_h\left(\frac{h}{N}\right)\right), \forall t > 0 \tag{14}$$

where $s_{h,t} = 1$ if risk type h purchases a customized bundle of single-disease policies covering high-risk conditions in time t and $s_{h,t} = 0$ otherwise. Note that applicants cannot over-insure such that $c_{h,t} + s_{h,t} \leq 1$. Finally, under *MBS* the level of market participation in time t is

$$MP^t(MBS) = \frac{\sum_{h=0}^{N}\left(s_{h,t}\alpha_h\left(\frac{h}{N}\right)hp_H T + c_{h,t}\alpha_h\left(hp_H + (N-h)p_L\right)T\right)}{\left(\lambda p_H + (1-\lambda)p_L\right)NT}, \forall t > 0 \tag{15}$$

where the numerator is sum of the claims experience of insureds who purchased either the single-disease policies or the comprehensive policy and the denominator is the population's claims experience (or the population's total outcome risk exposure).

Exclusion Strategy (*ES*)

Under *ES* applicants are offered a choice between a comprehensive policy and an exclusion policy. For the exclusion policy each applicant may decide which one of the N conditions to exclude from the policy coverage. Each applicant must decide whether to purchase the comprehensive policy, the exclusion policy, or remain uninsured. The mechanism for pricing the comprehensive policy and for calculating the expected utility associated with purchasing the policy was presented earlier. The initial premium charged for the exclusion policy at time $t = 0$ is

$$P_E^0 = \left(\lambda p_H + (1-\lambda)p_L\right)(N-1)T \tag{16}$$

After the initial period the insurer will engage in actuarially fair pricing based on claims experience. Therefore, the premium charged for the exclusion policy in time $t > 0$ is

$$P_E^t = \frac{\sum_{h=0}^{N}\left[e_{h,H,t-1}\alpha_h\left(\frac{h}{N}\right)\left((h-1)p_H + (N-h)p_L\right)T + e_{h,L,t-1}\alpha_H\left(\frac{N-h}{N}\right)\left(hp_H + (N-h-1)p_L\right)T\right]}{\sum_{h=0}^{N}\left(e_{h,H,t-1}\alpha_h\left(\frac{h}{N}\right) + e_{h,L,t-1}\alpha_h\left(\frac{N-h}{N}\right)\right)}, \forall t > 0 \tag{17}$$

where $e_{h,H,t-1} = 1$ if applicants who are risk type h purchase an exclusion policy and decide to omit a high-risk condition ($e_{h,H,t-1} = 0$ otherwise) and $e_{h,L,t-1} = 1$ if applicants who are risk type h purchase an exclusion policy and decide to omit a low-risk condition ($e_{h,L,t-1} = 0$ otherwise). Note that applicants may not over-insure such that $e_{h,H,t-1} + e_{h,L,t-1} + c_{h,t-1} \leq 1$. In Equation (17) the numerator is the claims experience of insureds who purchased the exclusion policy in the previous time period and the denominator is the percentage of the population that purchased the exclusion policy in the previous period.

Based on all available information (the realization of their risk type, h, and the premiums, $P_C^{\,t}$ and $P_E^{\,t}$), applicants decide whether to purchase the comprehensive policy, the exclusion policy, or remain uninsured. The expected utility of purchasing the exclusion policy in period t for an applicant of risk type h who is endowed as high risk (H) for the omitted condition is

$$EU_{E,h,H}^{t} = p_H U\left(\omega_t - P_t^E - T\right) + \left(1 - p_H\right) U\left(\omega_t - P_t^E\right), \forall t > 0 . \qquad (18)$$

The expected utility of purchasing the exclusion policy in period t for an applicant of risk type h who is endowed as low risk (L) for the omitted condition is

$$EU_{E,h,L}^{t} = p_L U\left(\omega_t - P_E^t - T\right) + \left(1 - p_L\right) U\left(\omega_t - P_E^t\right), \forall t > 0 \qquad (19)$$

Under *ES* the level of consumer participation in time t is

$$CP^t\left(ES\right) = \sum_{h=0}^{N} \left(c_{h,t}\alpha_h + \left(e_{h,H,t}\alpha_h + e_{h,L,t}\alpha_h\right)\left(\frac{N-1}{N}\right)\right), \forall t > 0 \qquad (20)$$

and the level of market participation in time t is

$$MP^t\left(ES\right) = \frac{\sum_{h=0}^{N}\left[e_{h,H,t}\alpha_h \left(\frac{h}{N}\right)\left((h-1)p_H + (N-h)p_L\right)T + e_{h,L,t}\alpha_h\left(\frac{N-h}{N}\right)\left(hp_H + (N-h-1)p_L\right)T + c_{h,t}\alpha_h\left(hp_H + (N-h)p_L\right)T\right]}{\left(\lambda p_H + (1-\lambda)p_L\right)NT}, \quad (21)$$
$$\forall t > 0$$

where the numerator is sum of the claims experience of insureds who purchased either the comprehensive policy or the exclusion policy and the denominator is the population's claims experience (or the population's total outcome risk exposure).

The Solution Mechanism

This model is a repeated Cournot game. In the game theory literature models of repeated Cournot games assume that demand functions are known to all players, that each player knows his own cost function, and that after each period the players are informed about their own profit and the decisions made by other players. These assumptions are consistent with our model. That is, the distribution of risk across the population is publicly known to the insurer and applicants alike (i.e., demand functions are known), each applicant has perfect knowledge of his own risk status and insurers observe realized claims at the end of each period (i.e., each player knows his own cost function), insurers observe purchasing decisions made by applicants in each period, applicants observe re-pricing decisions made by insurers in each period, and insurer and applicants alike observe their own profits in each period.

We solve for the Nash equilibrium of the game through iterative numerical computation based on the best response dynamic. The best response dynamic, which dates back to duopoly analysis by Cournot, assumes that players take actions that best respond to a competing player's last action. In our model applicants make purchasing decisions each period that best respond to the policy prices set by the insurer and the insurer makes pricing decisions each period that best respond, given regulatory restrictions, to applicants' purchasing decisions made in the previous period. Through iterative numerical computation of the best response dynamic, we derive the Nash Equilibrium from the repeated game where the insurer will not change its premiums unless applicants change their purchasing behavior and where no applicants, regardless of their risk type, will change their purchasing decision unless the insurer changes its prices. We derive the Nash equilibrium in this way due to the discrete (non-continuous) distribution of risk across the applicant population in this problem context. Table 1 provides an overview of the model parameters, decision variables, and outcome measures presented in this section.

Table 1. Model Parameters, Decision Variables, and Outcome Measures

N	Number of i.i.d. medical conditions for which applicants are at risk
T	Treatment cost for each medical condition
λ	Percentage of the population at high risk for each medical condition
h	Applicants of type *h* are at high risk for h of the N medical conditions
α_h	Percent of applicants of risk type h in the population
p_H	Probability an applicant at high risk will acquire a condition
p_L	Probability an applicant at low risk will acquire a condition
ω_t	Wealth of each applicant in period *t*
P_C^t	Premium for the comprehensive policy in period *t*
P_E^t	Premium for the exclusion policy in period *t*
P_S^t	Premium for each single disease policy in period *t*
$c_{h,t}$	$c_{h,t} = 1$ if type *h* applicants purchase the comprehensive policy in period *t*, $c_{h,t} = 0$ otherwise
$e_{h,H,t}$	$e_{h,H,t} = 1$ if type *h* applicants purchase the exclusion policy and omit a high-risk condition in period *t*, $e_{h,H,t} = 0$ otherwise
$e_{h,L,t}$	$e_{h,L,t} = 1$ if type *h* applicants purchase the exclusion policy and omit a low-risk condition in period *t*, $e_{h,L,t} = 0$ otherwise
$s_{h,t}$	$s_{h,t} = 1$ if type *h* applicants purchase a customized bundle of single disease policies to cover their *h* high-risk conditions in period *t*, $s_{h,t} = 0$ otherwise
$U(x)$	Utility function for applicants – $U(x) = -e^{rx}$
r	Applicant risk aversion parameter
EU_h^t	Expected utility (EU) for type *h* applicants of remaining uninsured in period *t*
EU_C^t	EU for applicants purchasing the comprehensive policy in period *t*
$EU_{E,h,H}^t$	EU for type *h* applicants at high risk for the exclusion of purchasing the exclusion policy in period *t*
$EU_{E,h,L}^t$	EU for type *h* applicants at low risk for the exclusion of purchasing the exclusion policy in period *t*
$EU_{S,h}$	EU for type *h* applicants of purchasing single disease policies to cover their high-risk conditions
$CP^t(i)$	Consumer participation realized under strategy $i \in [CSS, PBS, MBS, ES]$ in period t
$MP^t(i)$	Market participation realized under strategy $i \in [CSS, PBS, MBS, ES]$ in period t

OVERVIEW OF RESULTS

Below we briefly overview the findings derived in the following sections.

- **(Pure Bundling)**: We show that insurers may attain universal coverage at equitable premiums under *PBS*. This result is strengthened as the number of medical conditions covered in the comprehensive policy increases and as applicant risk aversion increases.
- **(Low Risk Aversion)**: When insurance applicants exhibit low levels of risk aversion *MBS* improves consumer participation and decreases premium rates when compared to *PBS*. In this context market performance is improved by *increasing policy options* offered to applicants.
- **(Moderate Risk Aversion)**: When insurance applicants exhibit moderate levels of risk aversion *MBS* reduces consumer participation and increases premium rates when compared to *PBS*. In this context market performance is improved by *reducing policy options* offered to applicants.
- **(High Risk Aversion)**: When insurance applicants exhibit sufficiently high levels of risk aversion the consumer participation realized under *PBS* and *MBS* converge to full market participation. In this context market performance is maximized when a comprehensive policy is included in the menu design and is not affected by the presence of single-disease policies in the menu.
- **(Exclusion Strategy)**: Finally, under all levels of risk aversion we show that compared to *PBS* implementing *ES* decreases consumer participation.

With this overview of critical findings in mind we present the detailed calculations of consumer choice under the four menu designs and examine the consumer participation that results from each as a function of risk aversion.

Table 2 presents the initial model parameters used to generate the findings presented in the following sections. Based on these initial parameters the expected medical cost for an individual at high risk for a medical condition is 20 per high-risk condition and the expected medical cost for an individual at low-risk for a medical condition is 5 per low-risk condition.

Table 2. Model Parameter Values

T	100
λ	0.10
p_H	0.20
p_L	0.05

PURE BUNDLING STRATEGY (*PBS*)

Figures 1a maps equilibrium consumer participation under *PBS* as a function of risk aversion over a range of N. This figure shows that the level of consumer participation increases with N. The intuition behind this result is that as the number of conditions covered in the comprehensive policy increases, individuals, who are heterogeneous in their risk exposure to each individual condition, become homogenous in their risk exposure to the entire bundle of conditions. That is, as N increases, individuals' expected treatment costs associated with acquiring the N conditions converge to a single value, the average expected treatment costs for the population (i.e., 6.5 per condition). Therefore, applicants' valuations for the comprehensive policy converge as well. If the number of conditions covered in the comprehensive policy is sufficiently large then a *PBS* simultaneously eliminates the adverse selection problem, maximizes consumer participation, and ensures premium equity across insureds. These results are accomplished without adversely affecting the viability of the insurer. We note that the convergence of applicant risk over large N occurs despite the discrete nature of the binomial distribution, which underlies individuals' risk exposure in this problem domain.

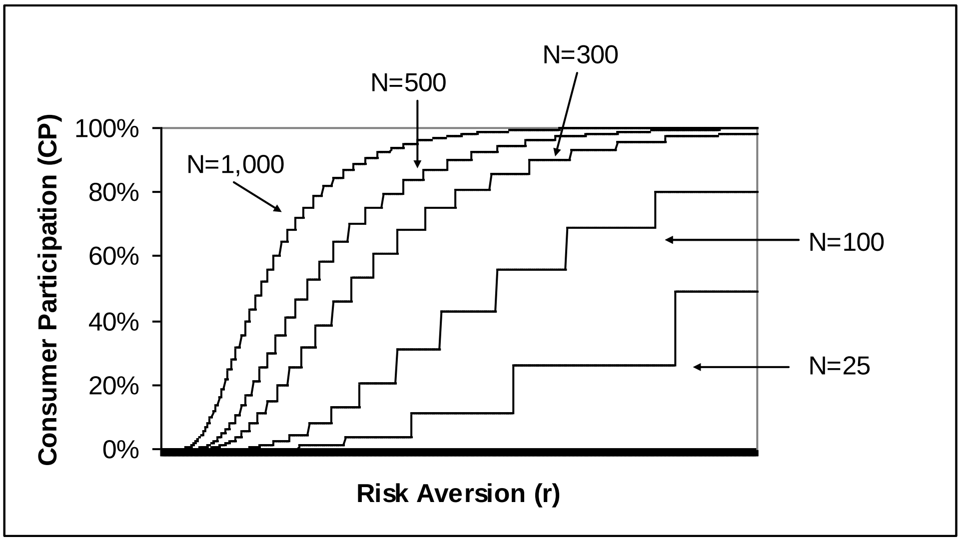

Figure 1a. Consumer Participation Under *PBS*. This figure compares the level of consumer participation realized in the individual health insurance market under a pure bundling strategy (PBS) over different assumptions about the level of consumer risk aversion (*r*) as the number of conditions covered in the bundled coverage increases.

Importantly, Figure 1a also shows that what defines a *sufficiently large* N depends on the level of applicant risk aversion. Specifically, the level of consumer participation under *PBS* increases monotonically with risk aversion. This finding is not surprising since applicants with higher risk aversion are willing to pay a higher risk premium to avoid uncertain losses associated with medical conditions for which they are at risk. In fact, extremely high levels of risk aversion would result in an applicant buying coverage to protect against almost all risk and almost irrespective of cost.

Proposition 1: Under *PBS* consumer participation approaches full participation and the premium rate for the comprehensive policy approaches the actuarially fair rate for the applicant population as the number of medical conditions covered in the comprehensive policy increases and as the level of applicant risk aversion increases.

We note that Proposition 1 holds not only under the assumption that applicants are homogeneous in their risk aversion levels (as assumed thus far) but also under the assumption that applicants are heterogeneous in their risk aversion levels. For example, Figure 1b compares the level of consumer participation realized under *PBS* as the number of conditions covered in the bundled coverage increases under three different assumptions of risk aversion: 1) applicant risk aversion is homogenous and high, 2) applicant risk aversion is homogenous and moderate, and 3) applicant risk aversion is heterogeneous and uniformally distributed across the applicant population. Figure 1b illustrates that consumer participation approaches full participation under a *PBS* as the number of medical conditions covered in the comprehensive policy increases even in the presence of heterogeneous applicant risk aversion.

PURE BUNDLING (*PBS*) VS. MIXED BUNDLING (*MBS*) VS. COMPONENT SELLING STRATEGY (*CSS*)

Figures 2 – 5 map the equilibrium consumer participation realized under three alternative menu designs (*PBS*, *MBS*, and *CSS*) as a function of risk aversion for $N \in [25{,}300{,}750{,}1000]$ assuming the model parameters values presented in Table 2. We use these figures to derive a series of propositions in this section.

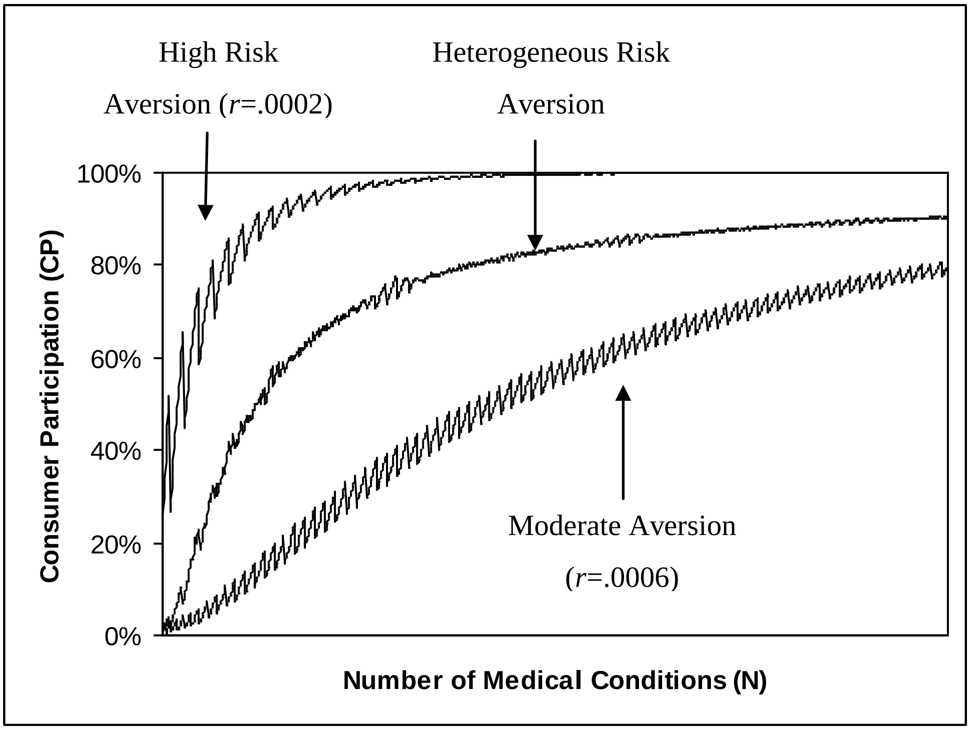

Figure 1b. Consumer Participation Under *PBS* (Under Three Different Risk Aversion Assumptions).

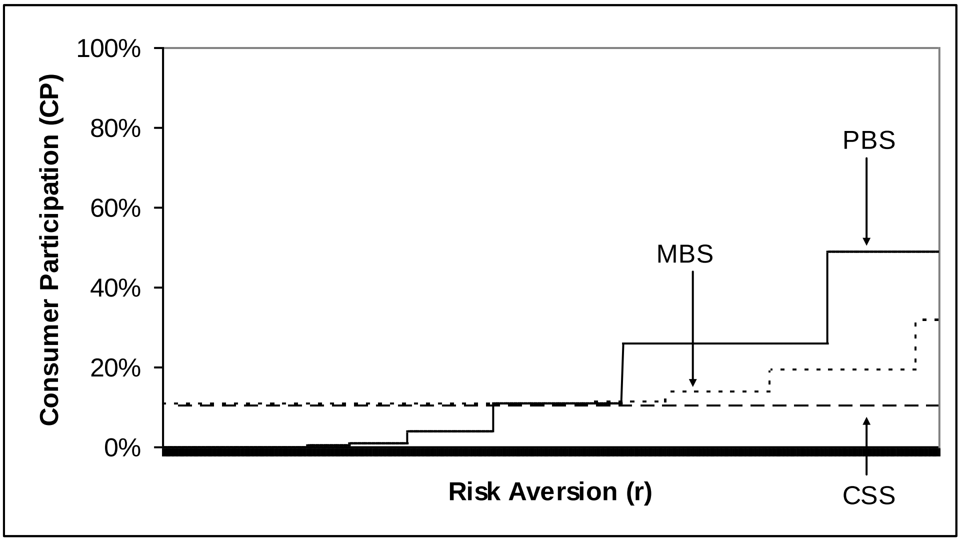

Figure 2. PBS, MBS, and CSS ($N = 25$). This figure compares the level of consumer participation realized in the individual health insurance market under a pure bundling strategy (PBS) and a mixed bundling strategy (MBS) over different assumptions about the level of consumer risk aversion (*r*) when consumers are at risk (and therefore seek coverage for) 25 health conditions.

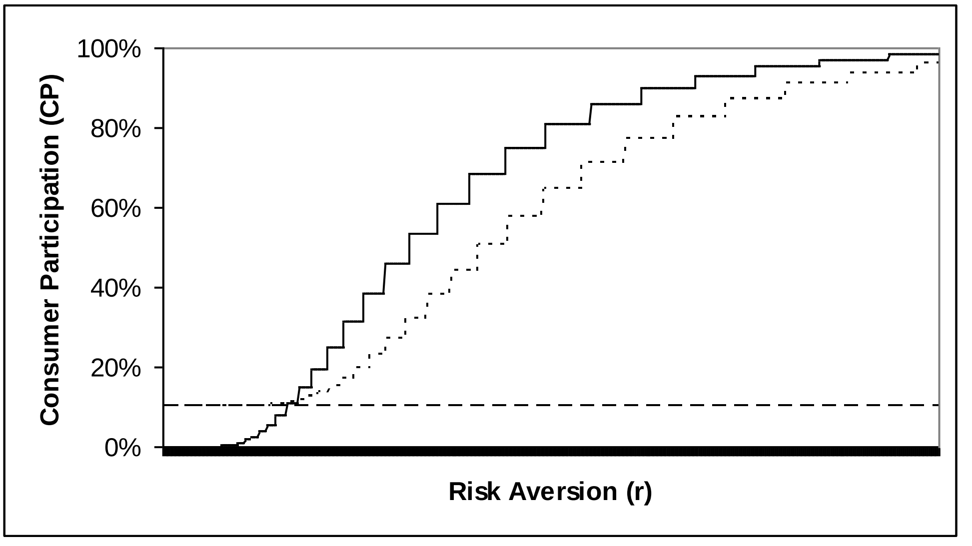

Figure 3. PBS, MBS, and CSS ($N = 300$). This figure compares the level of consumer participation realized in the individual health insurance market under a pure bundling strategy (PBS), a mixed bundling strategy (MBS), and a component selling strategy (CSS) over different assumptions about the level of consumer risk aversion (*r*) when consumers are at risk (and therefore seek coverage for) 300 health conditions.

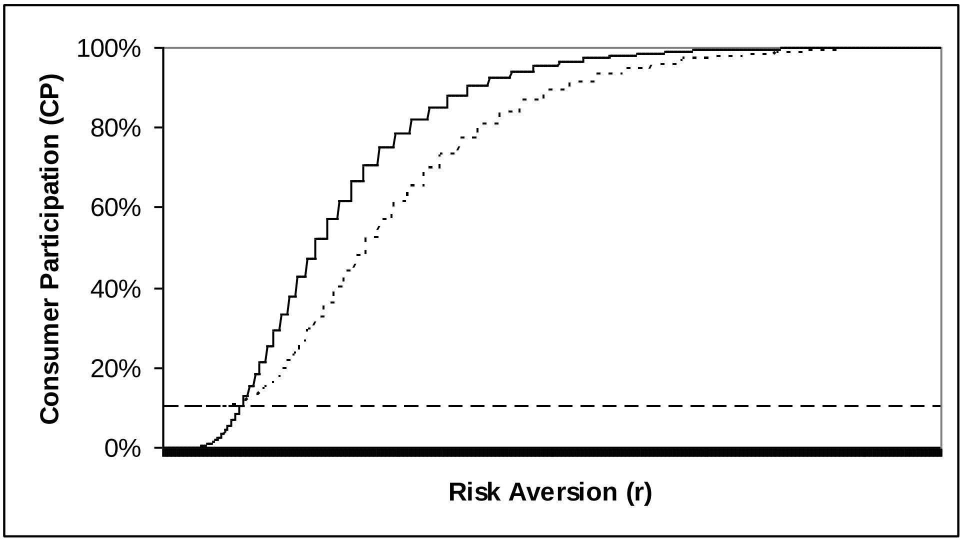

Figure 4. PBS, MBS, and CSS ($N = 750$). This figure compares the level of consumer participation realized in the individual health insurance market under a pure bundling strategy (PBS), a mixed bundling strategy (MBS), and a component selling strategy (CSS) over different assumptions about the level of consumer risk aversion (*r*) when consumers are at risk (and therefore seek coverage for) 750 health conditions.

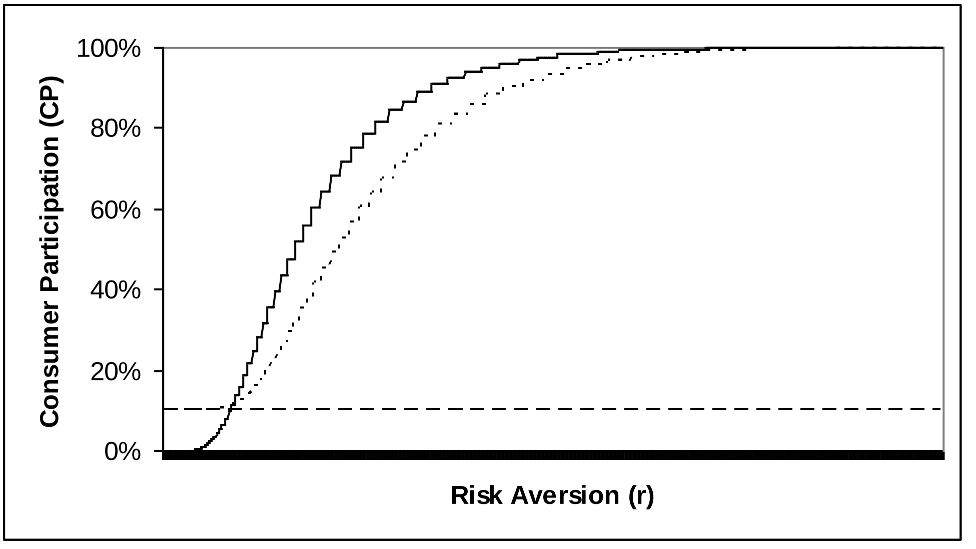

Figure 5. PBS, MBS, and CSS ($N = 1000$). This figure compares the level of consumer participation realized in the individual health insurance market under a pure bundling strategy (PBS), a mixed bundling strategy (MBS), and a component selling strategy (CSS) over different assumptions about the level of consumer risk aversion (*r*) when consumers are at risk (and therefore seek coverage for) 1000 health conditions.

Low Risk Aversion: $MP^*(CSS)$ dominates $MP^*_{LRA}(PBS)$

When insurance applicants exhibit low risk aversion *CSS* dominates *PBS* (see Figures 2 – 5). In this context the level of consumer participation is improved by increasing consumer choice. The intuition for this result is straightforward. As shown earlier, under *CSS* applicants will purchase single disease policies to cover their high-risk conditions given any risk aversion level satisfying Assumptions (A1) and (A2), resulting in consumer participation of 10% and market participation of 30.77%. However, as shown in Figures 1 – 5, under *PBS* comprehensive policies attract only a small number of very high-risk applicants while the majority of applicants opt out of coverage when risk aversion is low.

Table 3 shows the market dynamics that generate one of the equilibrium data points that make up the *PBS* step function in Figure 4. Specifically, it shows the market dynamics that lead to market equilibrium under *PBS* when $N = 750$ and risk aversion is very low – $r = .0002$. In this case equilibrium market participation is 3.41% and the equilibrium premium for the comprehensive policy is 5,159.31 (5.8% above the actuarially fair rate – 4,875.00 – for the population). Before describing the market dynamics leading to this equilibrium point for $N = 750$ and $r = .0002$ on Figure 4 we first define a term we will use to explain the dynamics. The term *Risk-Equivalent Sub-Pool* (Spool) will be used to refer to a sub-population of applicants that is homogeneous in personal riskiness (or of the same risk type h). In the dynamics presented in Table 3 there are 756 (or $N+1$) Spools since an applicant may be at high risk for as few as zero conditions and as many as 750 conditions.

In period 1 the spools of applicants at high risk for 73 or more medical conditions purchase the comprehensive policy while all other spools opt out of the market and remain uninsured. The expected medical cost for the 750 conditions for applicants in spool 73 is 4845.00 [EC = 4845]; the initial premium of the comprehensive policy is 4875.00, which is 0.62% higher than the actuarially fair rate for the spool. Given their risk status and the slight but positive level of risk aversion applicants in

Table 3. Market Dynamics under *PBS* $(N = 750, r = .0002)$

t	P_C^t	Who Buys C?	% of Population Buying C	$MP_{LRA}^t(PBS)$ (%)	Claims Experience for C
1	4875.00	$h \geq 73$	61.39%	62.35%	3039.61
2	4951.49	≥78	37.49%	38.45%	1874.54
3	5000.36	≥81	24.88%	25.69%	1252.21
4	5033.82	≥83	17.99%	18.66%	909.73
5	5057.44	≥85	12.48%	13.00%	633.98
6	5081.92	≥86	10.23%	10.69%	520.94
7	5094.45	≥87	8.29%	8.69%	423.52
8	5107.14	≥88	6.65%	6.99%	340.67
9	5119.98	≥89	5.28%	5.56%	271.11
10	5132.96	≥90	4.15%	4.38%	213.44
11	5146.07	≥91	3.22%	3.41%	166.25
12	5159.31	≥91	3.22%	3.41%	166.25

spool 73 and higher will decide to purchase the comprehensive policy. Alternatively, the comprehensive policy premium is 0.93% higher than the actuarially fair rate for spool 72 [EC = 4830]. Given their risk status and low level of risk aversion applicants in spool 72 and lower will find the comprehensive policy too expensive and will opt out of the market and remain uninsured. As shown in Table 3, this results in market participation of 61.39% in Period 1.

In period 2 the insurance company will raise (based on claims experience) the price of the comprehensive policy from 4875.00 to 4951.49 to account for the lower risk applicants opting out in Period 1. This price increase leads spools 74 – 77 [EC = 4860, 4875, 4890, 4905] to opt out of the market and become uninsured since the new higher price is too expensive given their risk status and low risk aversion. The new premium is 0.64% higher than the actuarially fair rate for spool 78 [EC = 4920]. Given their risk status and slight risk aversion applicants in spool 78 and higher continue to purchase the comprehensive policy despite the increase in the premium. Since spools 74 – 77 opt out of the market, market participation falls from 61.39% to 37.49%. In period 3 the insurance company raises the price of the comprehensive policy to 5000.36 leading spools 78 – 80 [EC= 4920, 4935, 4950] to opt out of the market, further reducing market participation from 37.49% to 24.88%. In period 4 the insurance company raises the premium (based on claims experience) to 5033.82 leading spools 81 and 82 [EC = 4965, 4980] to opt of coverage. As a result, market participation falls to 17.99% in period 4. This dynamic spiral in which the insurance company increases the premium and spools drop out of the market continues as shown in Table 3 until period 12. At this point a stable equilibrium is achieved with spools at high risk for 91 or more medical conditions purchasing the comprehensive policy at a price of 5159.31 (5.8% above the actuarially fair rate for the population), resulting in market participation of 3.41%, which is approximately one-tenth of the market participation realized under *CSS* – $MP^*(CSS) = 30.77\%$. The findings derived from Figures 2 – 5 and from the dynamics presented in Table 3 lead to Proposition 2.

> Proposition 2 (Low Risk Aversion): $MP^*(CSS) > MP_{LRA}^*(PBS)$: If insurance applicants exhibit low levels of risk aversion then *CSS* dominates (or generates more market participation than) the *PBS* since the market dynamics under the *PBS* result in an adverse selection *death spiral* for the comprehensive policy, which essentially destroys the insurance market.

Low Risk Aversion: $MP^{*}_{LRA}(MBS)$ converges to $MP^{*}(CSS)$

Under *MBS* the presence of a comprehensive policy may encourage a small number of high-risk applicants to purchase the comprehensive policy instead of a customized bundle of single-disease policies. As a result, consumer participation under *MBS* will be higher than that realized under *CSS*, but only very slightly; in fact, the difference in market performance between *MBS* and *CSS* converges as risk aversion decreases toward zero and is not discernable for low levels of risk aversion in Figures 2 – 5.

Table 4 shows the market dynamics that generate one of the equilibrium data points that make up the *MBS* step function in Figure 4. Specifically, it shows the market dynamics that lead to market equilibrium under *MBS* when $N = 750$ and risk aversion is very low – $r = .0002$. In this case equilibrium market participation is 30.83% (just 0.19% more than the equilibrium market participation realized under *CSS* – $MP^{*}(CSS) = 30.77\%$) and the equilibrium premium for the comprehensive policy is 5,310.53 (8.93% above the actuarially fair rate for the population and 2.9% above the equilibrium premium under *PBS*).

In this case all applicants cover their high-risk conditions. However, a very small percent of applicants (those in spools 102 and higher) also cover their low risk conditions by purchasing the comprehensive policy. Therefore, in this case market participation under *MBS* is slightly higher than under *CSS*. However, as risk aversion tends toward zero the market performances under *MBS* and *CSS* converge to $MP^{*}(CSS) = 30.77\%$. The market dynamics leading to equilibrium under

Table 4. Market Dynamics under *MBS* $(N = 750, r = .0002)$

t	P_C^t	Who Buys C?	% of Population Buying C	$MP_{LRA}^{t}(MBS)$ (%)	Claims Experience for C
1	4875.00	$h \geq 73$	61.39%	72.95%	3039.61
2	4951.49	≥79	37.49%	56.40%	1874.54
3	5000.36	≥82	21.26%	45.24%	1072.83
4	5045.51	≥85	12.48%	39.23%	633.98
5	5081.92	≥87	8.29%	36.38%	423.52
6	5107.14	≥89	5.28%	34.33%	271.11
7	5132.96	≥91	3.22%	32.94%	166.25
8	5159.31	≥92	2.48%	32.43%	128.11
9	5172.65	≥93	1.88%	32.03%	97.66
10	5186.09	≥94	1.42%	31.72%	73.65
11	5199.62	≥95	1.05%	31.47%	54.95
12	5213.25	≥96	0.78%	31.29%	40.57
13	5226.95	≥97	0.57%	31.15%	29.63
14	5240.72	≥98	0.41%	31.04%	21.41
15	5254.56	≥99	0.29%	30.96%	15.31
16	5268.47	≥100	0.21%	30.91%	10.83
17	5282.43	≥101	0.14%	30.86%	7.58
18	5296.45	≥102	0.10%	30.83%	5.25
19	5310.51	≥102	0.10%	30.83%	5.25

MBS when given $N = 750$ and $r = .0002$ are presented in Table 4 and summarized below.

In period 1 the spools of applicants at high risk for 73 or more medical conditions purchase the comprehensive policy (as was the case in period 1 under *PBS*) while all other lower-risk spools purchase customized bundles of single-disease policies to cover their high risk conditions (instead of remaining completely uninsured). This results in market participation of 72.95%. In period 2 applicants may either buy the comprehensive policy for 4951.49, buy a customized bundle of single-disease policies for 20/condition covered, or remain completely uninsured. Spools 73 – 77, which opted out of the comprehensive policy under *PBS*, will do the same under *MBS* but will cover their high-risk conditions with single-disease policies. As shown in Table 3, under *PBS*, assuming a little risk aversion spool 78 [EC = 4920] would prefer to purchase the comprehensive policy for 4951.49 rather than remain completely uninsured. However, under *MBS* applicants in spool 78 would prefer to opt out of comprehensive coverage and instead cover their 78 high-risk conditions for 1560.00 (which is the EC associated with those 78 conditions) and remain uninsured for the remaining 672 low-risk conditions; that is, $EU_{S,h=78} > EU_{C,h=78}^{t=2} > EU_{h=78}^{t}$. In total, spools 73 – 78 decide to purchase single-disease policies instead of the comprehensive policy, leading to a reduction in market participation from 72.95% to 56.40%.

In period 3 the insurance company raises the premium for the comprehensive policy to 5000.36 based on claims experience. In response applicants in spools 79 – 81 decide to opt out of the comprehensive policy and instead decide to purchase the customized bundle of single-disease policies. This dynamic spiral in which the insurance company increases the premium of the comprehensive policy and spools drop out of comprehensive coverage and into single-disease coverages continues until period 19, as shown in Table 4. At this point a stable equilibrium is achieved with spools at high risk for 102 or more medical conditions purchasing the comprehensive policy at a price of 5310.51 (approximately 8.9% above the actuarially fair rate for the population and 2.9% above the equilibrium premium realized under *PBS*), resulting in market participation of approximately 30.83%, which is about 0.19% higher that the equilibrium market participation realized under *CSS*. The findings derived from Figures 2 – 5 and from the market dynamics presented in Table 4 lead to Proposition 3.

Proposition 3 (Low Risk Aversion): $MP_{LRA}^{*}(MBS) \approx MP^{*}(CSS) > MP_{LRA}^{*}(PBS)$

If insurance applicants exhibit low levels of risk aversion then:

(i) *MBS* dominates *CSS* in terms of market participation, but just slightly. As risk aversion decreases to zero, the market dynamics under *MBS* result in an adverse selection *death spiral* for the comprehensive policy; as a result the market participation under *MBS* and *CSS* converge to $MP^{*}(CSS)$.

(ii) given Propositions 2 and 3(i), both *MBS* and *CSS* dominate *PBS*.

Moderate Risk Aversion: $MP_{MRA}^{*}(PBS)$ **dominates** $MP^{*}(CSS)$

When insurance applicants exhibit moderate risk aversion *PBS* dominates *CSS* (see Figures 2 – 5) – that is, unlike the case under low risk aversion, the level of consumer participation is improved by decreasing consumer choice. As shown in Figure 1, as risk aversion increases a growing number of applicants prefer comprehensive coverage to remaining uninsured. As risk aversion becomes sufficiently high equilibrium consumer participation realized under *PBS* will surpass that realized under *CSS*.

Moderate Risk Aversion: $MP_{MRA}^{*}(PBS)$ **dominates** $MP_{MRA}^{*}(MBS)$

When insurance applicants exhibit moderate risk aversion *PBS* dominates *MBS* (see Figures 2 – 5) – that is, unlike the case under low risk aversion, the level of consumer participation is improved by reducing consumer choice. Some applicants with a lower-risk portfolio of conditions who would purchase the comprehensive policy under *PBS* (instead of remaining uninsured) opt out of comprehensive coverage under *MBS* to purchase a customized bundle of single-disease policies. This leads not only to a reduction in consumer participation but also an increase in the premium paid by applicants that continue to purchase the comprehensive policy and an increase in the average premium paid per covered condition.

Tables 5 (6) show the market dynamics that generate one of the equilibrium data points that make up the *PBS* (*MBS*) step function in Figure 4. Specifically, these tables show the market dynamics that lead to market equilibrium under *PBS* and *MBS* when $N = 750$ and risk aversion is moderate – $r = .00095$. In this case, equilibrium market participation under *PBS* (94.18%) is higher than realized under *MBS* (89.42%). In addition, the premium for the comprehensive policy under *PBS* (4890.47) is lower than that realized under *MBS* (4908.26). Since in this case market equilibrium is realized very quickly, we do not provide a detailed explanation of the market dynamics presented in Tables 5 and 6.

The findings lead to Proposition 4.

Proposition 4 (Moderate Risk Aversion): $MP^*_{MRA}(PBS) > MP^*_{MRA}(MBS) > MP^*(CSS)$

If insurance applicants exhibit moderate levels of risk aversion then:

(i) PBS dominates MBS in terms of market participation and comprehensive policy premium rates. That is, under MBS some applicants who would choose to purchase the comprehensive policy rather than remain completely uninsured decide to opt out of comprehensive coverage to purchase a customized bundle of single disease policies.

(ii) both PBS and MBS dominate CSS. That is, given moderate levels of risk aversion the market dynamics under PBS and MBS do not degenerate into a death spiral for the comprehensive policy as was the case when risk aversion was assumed to be low.

High Risk Aversion: $MP^*_{HRA}(MBS)$ converges to $MP^*_{HRA}(PBS)$

When insurance applicants exhibit sufficiently high risk aversion the level of consumer participation under *MBS* converges to that under *PBS* (see Figures 4 and 5). In fact, when risk aversion is sufficiently high for a given (sufficiently high) *N* then market

Table 5. Market Dynamics under *PBS* $(N = 750, r = .00095)$

t	P_C^t	Who Buys C?	% of Population Buying C	$MP^t_{MRA}(PBS)$ (%)	Claims Experience for C
1	4875.00	$h \geq 62$	95.29%	95.53%	4657.27
2	4887.37	≥63	93.88%	94.18%	4591.39
3	4890.47	≥63	93.88%	94.18%	4591.39

Table 6. Market Dynamics under *MBS* $(N = 750, r = .00095)$

t	P_C^t	Who Buys C?	% of Population Buying C	$MP^t_{LRA}(MBS)$ (%)	Claims Experience for C
1	4875.00	$h \geq 65$	90.14%	93.03%	4415.23
2	4898.26	≥67	84.99%	89.42%	4171.75
3	4908.26	≥67	84.99%	89.42%	4171.75

participation under both strategies converges to full market participation. In this case consumers will prefer to purchase comprehensive coverage to protect themselves against the potential expense associated with even those conditions for which they know themselves to be low risk. That is, adding the alternative option to purchase single coverage instead of comprehensive coverage will attract fewer and fewer applicants as risk aversion increases (given risk aversion is sufficiently high). Of course, since market participation converges to full market participation under *PBS* and *MBS*, both strategies still dominate *CSS*. This leads to Proposition 5.

Proposition 5 (High Risk Aversion): $MP^*_{HRA}(PBS) \approx MP^*_{HRA}(MBS) > MP^*(CSS)$

If insurance applicants exhibit high levels of risk aversion then:

(i) *PBS* dominates *MBS* in terms of market participation, but just slightly. As risk aversion increases to very high levels, the market participation under *PBS* and *MBS* converge toward full market participation. That is, in this case the presence of single-disease policies in the menu does not affect consumers' purchasing decisions.

(ii) Consistent with the case of moderate levels of risk aversion *PBS* and *MBS* dominate *CSS*. That is, the market dynamics do not degenerate into a death spiral for the comprehensive policy.

All Risk Aversion Levels: $MP^*(PBS)$ dominates $MP^*(ES)$

Under *ES* applicants are faced with a choice between a comprehensive policy and a customized exclusion policy in which the applicant may choose the condition to be omitted from coverage. In this case all applicants who would purchase a comprehensive policy under *PBS* will, under *ES*, choose to purchase the exclusion policy instead and will choose to exclude a low-risk condition. This migration of insureds from the comprehensive policy to the exclusion policy leads to a decrease in consumer participation. In this case increasing the policy options offered to the market (i.e., offering an exclusion policy in addition to the comprehensive policy) results in applicants receiving less coverage.

Proposition 6 (All Levels of Risk Aversion): $MP^*(PBS) > MP^*(ES)$: The pure bundling strategy dominates the exclusion strategy in terms of market participation over all levels of risk aversion.

Summary of Critical Findings

Table 7 summarizes the critical findings presented in this section.

We have shown that in markets where consumers exhibit sufficiently low levels of risk aversion, *maximizing* the policy options available for individual choice *improves* market participation. If the insurance company is forced by regulators to offer only comprehensive policies, virtually all applicants will chose to remain uninsured as risk aversion goes to zero. However, for slightly positive levels of risk aversion a vanishingly small group of applicants at greatest overall risk will choose to purchase a comprehensive policy.

Table 7. Summary of Findings

Risk Aversion Level	*Market Efficiency Ordering*
Low Risk Aversion (r = .0002)	$MP^*_{LRA}(MBS) \approx MP^*(CSS) > MP^*_{LRA}(PBS)$
Moderate Risk Aversion (r = .00095)	$MP^*_{MRA}(PBS) > MP^*_{MRA}(MBS) > MP^*(CSS)$
High Risk Aversion (r = .002)	$MP^*_{HRA}(PBS) \approx MP^*_{HRA}(MBS) > MP^*(CSS)$

In markets where consumers exhibit moderate levels of risk aversion, *minimizing* the options available for individual choice *improves* market participation. That is, offering comprehensive policies improves market participation relative to that achieved by offering a selection of single-disease coverage policies. In fact, if the insurance company is forced by regulators to offer a selection of single-disease policies along with the comprehensive policy some applicants, who would purchase comprehensive coverage rather than remain completely uninsured, will decide to opt out of the comprehensive policy in favor of a customized bundle of single-disease policies. This increased set of choices results in a decrease in consumer participation and an increase in the premium charged for the comprehensive policy.

Alternatively, in markets where consumers exhibit a high degree of risk aversion, increasing consumer choice by offering a selection of single-disease policies along with the comprehensive policy does not adversely affect market participation. Finally, we show that offering an exclusion policy reduces market participation.

CONCLUSIONS

This paper uses a parsimonious model to examine the theoretical relationships among alternative bundling strategies, risk aversion, and market performance in the individual health insurance market. We note that there are limitations to the policy-relevance of these findings to the individual health insurance market since, as with any theoretical exercise, many assumptions were made. We have modeled a market where risk is identically and independently distributed across the applicant population, applicants possess private and perfect information regarding their risk status for a portfolio of medical conditions, applicants are identical except in their risk status, the treatments costs across conditions and applicants are identical, fixed, and known to applicants, and the form of applicant utility function is exponential.

Although our model is simplified, it is sufficiently robust for our analysis to make a significant contribution to our understanding of the economics of bundling in a context not explored in previous work. Specifically, previous work has focused on the use of bundling strategies by multiple-product monopolists to maximize profits and generally assumes that marginal product costs are low and that consumer product valuations are distributed continuously across consumers. Alternatively, the model developed in this paper examined the use of bundling strategies by a regulated insurance company (restricted to zero profits) to maximize consumer participation at affordable premium rates. In this context marginal product costs are high and vary discretely across insureds based on each insureds' risk portfolio for the covered set of medical conditions. Applicants' valuations for insurance coverage also vary discretely across applicants based on applicants' risk portfolio and risk aversion. In this very different context we show that the effectiveness of alternative bundling strategies in achieving regulatory goals of improving market participation at affordable premiums critically depends on the level of risk aversion exhibited by applicants.

REFERENCES

Adams, W. and J. Yellen, "Commodity bundling and the burden of monopoly," *Quarterly Journal of Economics*, 1996, 90:3, pp. 475-498.

Arrow, K., "The value of and demand for information," In *Essays in the Theory of Risk Bearing*, Markham, Chicago, 1971, pp. 268-278.

Baderian, S. and J. Seltzer, "Federal guidance needed in genetics debate," *Business Insurance*, 2001, 35:10, pp. 13-14.

Bakos, Y. and E. Brynjolfsson, "Bundling information goods: Pricing, profits and efficiency," *Management Science*, 1999, 45:12, pp. 1613-1630.

Bond, E. and K. Crocker, "Smoking, skydiving, and knitting: The endogenous categorization of risks in insurance markets with asymmetric information," *Journal of Political Economy*, 1991, 99:1, pp. 177-200.

Chuang, J. and M. Sirbu, "Optimal bundling strategy for digital information goods: Network delivery of articles and subscriptions," *Information Economics and Policy*, 1999, 11:2, pp. 147-176.

Clemons, E. and M. Thatcher, "Evaluating alternative information regimes in the private health insurance industry: Managing the social cost of private information," *Journal of Management Information Systems*, 1997, 14:2, pp. 9-31.

Crocker, K. and A. Snow, "The efficiency effects of categorical discrimination in the insurance industry," *Journal of Political Economy*, 1986, 94:21, pp. 321-343.

Gostin, L., "Genetic discrimination: The use of genetically based diagnostic and prognostic tests by employers and insurers," *The American Journal of Law and Medicine*, 1991, 17:(1 & 2), pp. 109-144.

Hitt, L. and P. Chen, "Bundling with customer self-selection: A simple approach to bundling low marginal cost goods," *Working Paper*, 2000, Operations and Information Department, The Wharton School at the University of Pennsylvania.

Miyasaki, H., "The rat race and internal labor markets," *Bell Journal of Economics*, 1977, 8:2, pp. 394-418.

Murry, W., J. Wimbush, and D. Dalton, "Genetic screening in the workplace: Legislative and ethical implications," *Journal of Business Ethics*, 2001, 29:4, pp. 365-378.

Riley, J., "Informational equilibrium," *Econometrica*, 1979, 47:2, pp. 331-359.

Rothschild, M. and J. Stiglitz, "Equilibrium in competitive insurance markets: An essay on the economics of imperfect information," *Quarterly Journal of Economics*, 1976, 90:4, pp. 629-649.

Salinger, M., "A graphical analysis of bundling," *The Journal of Business*, 1995, 68:1, pp. 85-98.

Schmalensee, R., "Gaussian demand and commodity bundling," *Journal of Business*, 1984, 57:(1, Part 2), pp. S211-S230.

Tabarrok, A., "Genetic testing: An economic and contractarian analysis," *Journal of Health Economics*, 1994, 13:1, pp. 75-91.

Thatcher, M. and E. Clemons, "Managing the costs of informational privacy: Pure bundling as a strategy in the individual health insurance market," *Journal of Management Information Systems*, 2000, 17:2, pp. 29-57.

Thatcher, M., "Information asymmetries, adverse selection, and the individual health insurance market: Alternative mechanisms for managing the cost of private information," *Doctoral Dissertation*, 1998, OPIM Department, The Wharton School, University of Pennsylvania.

Wilson, C., "A model of insurance markets with complete information," *Journal of Economic Theory*, 1977, 16:2, pp. 167-207.

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