Death Spirals, Switching Costs, and Health Premium Payment Systems

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ABSTRACT

This paper develops a model of health plan competition and pricing in order to understand the dynamics of health plan entry and exit, in the presence of switching costs and alternative health premium payment systems. We build an explicit model of death spirals, in which profit-maximizing competing health plans find it optimal to adopt a pattern of increasing relative prices culminating in health plan exit.

We find the steady-state numerical solution for the price sequence and the plan's optimal length of life through simulation and do some comparative statics. This allows us to show that using risk adjusted premiums and imposing price floors are effective at reducing death spirals and switching costs, while having employees pay a fixed share of the premium enhances death spirals and increases switching costs.

JEL Classification: I18, I11

Keywords: health insurance, switching costs, premiums payment systems, biased selection

*Support for this research has been provided by Fundação para a Ciência e Tecnologia, Programa POCTI - Formar e Qualificar - Medida 1.1., grant Praxis XXI/BD/19954/99

+Support for this research has been provided by the Agency for HealthCare Research and Quality (AHRQ), grant number R01-HS10620-01A

We are thankful to Ipek Gurol, Guillermo Caruana, Tom McGuire and Andy Weiss and seminar participants at Brown University, Boston University, Minnesota University and University United Methodist Church, Chapel Hill and Nova University of Lisbon for helpful discussion. The opinions expressed are the authors alone.

Table of Contents

Table of Tables

Table of Figures

Abbreviations and notation

Abbreviations and notation	Description
hat notation	Competitor defined value
star notation	Optimal values
AP	Average premium
ASWC	Average switching cost
AVC_t	Average cost in period t
BU	Boston University
C_M	Annual costs of enrolling a sick person
C_N	Annual costs of enrolling a healthy person
d	Rate at which employees leave the firm per year
FC	Annual fixed costs
f_t	Probability of not switching from a plan aged t
F_t	Cumulative probability of not switching from a plan aged t
HPPC	Health plan participation constraint
IHS	Involuntary healthy switchers
IS	Involuntary switchers
ISS	Involuntary sick switchers
k	(1-s)
l	(1-d)
M_t	Number of sick individuals
NE	New employees
N_t	Number of healthy individuals
P_{min}	Lowest premium charged by any competitor
P_t	premium charged by a plan aged t
s	Rate at which healthy employees become sick per year
SW_t	Expected number of people switching out of a t year old plan
T	Health plan´s life span
THC	Total health costs of the firm's employees
VHS	Voluntary healthy switchers
VS	Voluntary switchers
VSS	Voluntary sick switchers
V_t	Cumulative discounted profits from period t onwards
w	Switching cost
W	Maximum switching cost
α	Risk adjustment factor
Δ	Variation
λ	Proportion of premium payed by the employee under cost sharing
ρ	Discount factor
Ψ	Total number of plans offered by the employer
Π_t	Health plan profits in period t

1.1. Introduction

This paper is inspired in part by the history of health plan entry, exit and pricing in the Boston area. Both Boston University (BU) and Harvard University experienced rapid rates of premium escalation during the 1990's, culminating in numerous health plans being canceled by employers or plan providers. The Harvard University Experience is analyzed in Cutler and Reber [1], while the BU Experience is discussed further below.

We develop a model of health plan competition and pricing in order to understand the dynamics of health plan entry and exit, in the presence of switching costs and alternative health premium payment systems. Switching costs are defined as costs incurred by the enrollee of a health plan if and when he decides to change his health plan. These costs may result, among others, from required paper work, change in health care provider or information gathering. We build an explicit model of death spirals, defined as a pattern of increasing relative prices culminating in health plan exit, in which profit-maximizing competing health plans find it optimal to adopt such a pattern. Plans may be forced to enter such death spirals, because of the introduction of new plans that charge low premiums, thereby attracting the employees with lower switching costs.

In order to focus attention on pricing dynamics and plan switching, we construct a model in which all of the plans are *ex ante* identical. We fully appreciate that product differentiation is one factor in recent plan entry and exit, among various types of managed care plans. However, we believe that emphasis on these differences clouds the understanding of some of the basic forces driving pricing, entry and exit. Regardless of whether plans are identical or differentiated, entry of new plans creates an important asymmetry, changing the mixture of healthy and sick enrollees in each health plan. Plan entry and exit permits a recurring cycle of pricing, in which the costs of enrollees in existing plans are always increasing. Rather than product differentiation, our focus on identical plans emphasizes this process as a rationale for plan entry.

The existing insurance market literature has generally modeled equilibrium patterns of adverse selection without trying to model the dynamics of health plan entry and exit [2-7]. Rothschild and Stiglitz [2] analyze adverse selection equilibrium in multiple plan types, but without modeling the process of entry, exit, or changes in pricing over time. Neipp and Zeckhauser [8] introduce the notion of death spirals and examine the empirical patterns, but do not attempt to build an analytical model, and treat cost increases of existing plans as exogenous to pricing decisions. Keeler, Carter and Newhouse [9] develop a model of consumer choice among differentiated health plans, and use a dynamic process to understand equilibrium enrollments, premiums and social costs, however they do not attempt to model health plan entry and exit. Vistnes, Cooper and Vistnes [10] use a two period game in which health plans first compete to be selected by employers and, if selected, compete to be chosen by consumers, but it does not explore the dynamics of pricing or exit *per se*. Ellis and Ma [11] consider a related issue by analyzing the impact of employer provided health insurance on job turnover. The authors focus on the firms' insurance offer decision, while we focus on the health plans' offer decision.

In the non-health literature, a variety of models examine dynamic pricing strategies with switching costs. Our model shares some features with that of Beggs and Klemperer [12][1], but their framework focuses on two infinitely lived firms, and does not support death spirals in which plan prices increase as market share shrinks, to the point where a firm decides to exit. Gale and Rosenthal [13] develop a model of firms whose quality is only imperfectly observed[2].The model in this paper differs from theirs in that it focus on biased selection[3] rather than adverse selection.

Switching costs introduce the potential for biased enrollment, if they differ across enrollees and are correlated with health costs [1, 7]. Strombom *et al. [14]*, examine switching among employees of the University of California system during the mid 1990's. They find that, under a fixed contribution scenario, consumers price elasticity ranges from -1.8 to -10 indicating considerable price sensitivity but also a significant heterogeneity among consumers[4]. This finding, together with the fact that new employees are, on average, much healthier than existing enrollees, lays the basis for potentially severe biased selection[5].

Grönqvist [15] empirically analyses the biased selection problem, arguing that this can explain the limited empirical evidence for adverse selection in insurance markets in the literature, and presents a model of insurance choice focusing on the decision of whether to purchase

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[1] Beggs and Klemplerer examine the implications of switching costs in an infinite period market in which new consumers arrive each period that are not yet attached to a seller.

[2] In that model firms enter at a high quality and high price. Once they have established themselves to have this high quality and before exiting, firms switch to low quality, in order to take advantage of the greater profitability of charging high prices with low quality.

[3] Biased selection includes both favorable selection (which plans want) and adverse selection (which enrollees want individually).

[4] The analysis suggests that the healthiest enrollees may be four times as responsive to price differences as the sickest group of employees. This difference increases nine fold when they also allow for variation in age and employment tenure. Age and tenure are shown to significantly (and negatively) affect price sensitivity.

[5] Mean annual premiums in the Strombom *et al.* sample are approximately $3900, while employee annual spending on premiums averages just under $700 (18%). His demand model predicts that a $60 per year increase in the employee premium will result in a 50% reduction in the proportion of healthy individuals choosing a plan, versus only an 8.8% reduction for sick enrollees.

insurance, which is a complement to our analysis. Most recently, Cutler *et al.* [16] estimate the determinants of health plan switching (adverse selection, adverse retention, aging, demographics and the level of cost-sharing) and incorporate these in a simulation model to predict the long-term dynamics. Their analysis focuses on the determinants of switching between two different types of plans while we abstract from plan differences and focus instead on entry, exit and dynamic pricing behavior.

Several published empirical papers support the idea of death spiral and biased selection in the health insurance market [17-20]. Pauly *et al.* [21], on the other hand, argue that the phenomenon interpreted as death spiral may instead be an adjustment towards more preferred products which would have occurred even in the absence of adverse selection[6]. Our model provides a rational for death spirals even in the presence of identical plans.

Of direct relevance to our theoretical framework is the recently published article by Handle [22] who builds a structural model to empirically investigate consumer switching costs in the context of health insurance markets, accounting for potential adverse selection. The author estimates an average switching cost of $1,570 (75% of the average employee premium).

Fixed costs for health plans prevent plans from continuing to exist with minimal enrollments at very high prices, and are plausible given that certain transaction and administrative costs are independent of the number of plan enrollees. Biased selection and fixed costs are, thus, the driving forces of the health plan death spirals modeled here.

Death spirals are a consequence of how contracts are written between health plan providers and employers, not a characteristic of the plans themselves. Therefore, we model entry and exit of health plans to a given employer, not entry and exit of health plans overall. So, the same health plan can be a new entrant with one employer, while being a long time incumbent with other employers. Glazer and McGuire [23] have documented that health plans in the Boston area routinely charge different premiums for identical plans. Once plans are allowed to price discriminate between different employers, death spirals can occur, even when health plans are profitable.

Our model generates many insights. Plan deaths impose much higher switching costs than voluntary switches, since higher prices induce the lowest switching cost enrollees to switch

[6] Their conclusions are drawn from the fact that “implementing a significant risk adjustment had no discernable effect on adverse selection against the most generous indemnity insurance policy”

plans, while plan deaths force those with the highest switching costs to involuntarily change plans. We use the model to simulate how premium cost sharing schemes, risk-adjustment policies and the imposition of price floors, affect entry and exit, as well as health plan pricing and enrollee choice patterns.

Among our most interesting findings is the possibility that a first period price floor strategy can potentially be welfare improving. By reducing competition, the imposition of a price floor deprives health plans of aggressive loss leading entry. A price floor can potentially reduce the sum of switching costs plus premiums and soften death spirals at the same time, as it yields health plans positive intertemporal profits.

We also find that, in the presence of switching costs, cost sharing is welfare reducing, while, in contrast, risk adjustment yields lower total costs (switching costs plus premium costs) to consumers.

While the analysis has been inspired by the dynamics of entry and exit of health plans in the United States, lessons to be learned from this analysis are relevant to other countries, such as Portugal, where the employer-provided private insurance market is growing [24]. A proper health policy environment will minimize phenomena's such as "*churning*"[7] and death spirals observed in countries where health care is extensively financed through private health insurance.

The remainder of the paper is organized into four sections. In Section 1.2, a motivating example drawing upon empirical results from three markets in the United States is presented. Sections 1.3 and 1.4 describe the analytical model and discuss the attainable analytical results in a model with no closed-form solution. In Section 1.5 the four premium payment systems under consideration are presented in the context of the analytical model. In Section 1.6 we summarize the steady-state equilibrium solutions to our model under different premium payment systems and perform some sensitivity analysis. We conclude the paper with a discussion of the implications and limitations of our model.

[7] In general terms, "churning" refers to the following phenomenon: The insurance companies competing in prices enter the market with very aggressive prices that only cover the costs while the initial exclusion clauses are valid, but that are too low to cover the costs two years later, once these clauses are no longer applicable. The result is an abrupt rise in prices, one or two years after the product enters the market.

1.2. Motivating Evidence

Death spirals are not occurring in all employers or in all parts of the United States, but they do appear to be occurring under some contracts, and Boston University seems to be an example of this. Results in Cutler and Reber [1] and Yu, Ellis and Ash [25] suggest that the problems facing Boston University are similar to those experienced by other large employers in Massachusetts.

We present the evolution of total premiums for non-retired single employees at Boston University and compare it to two other markets: Minnesota and California premiums for state employees. A health plan is here defined as any separately, independently named and marketed insurance product for which a separate premium is charged. In many cases, the same insurance company offers multiple health plans.

1.2.1. Premium Patterns

Table 1 presents data on health plan entries (births) and exits (deaths) from the available portfolio of three employer markets (Boston University, Minnesota and California). The table reveals that the three employer markets have very different rates of entry and exit over time. Boston University has had the highest rates of entry and exit. California, despite having the largest number of health plans offered to its state employees, has the lowest rate of exit, and Minnesota lies in between the two.

Table 1: Key Descriptive Statistics

	Sample Period	Years	Plan Births	Plan Deaths	Average Number of Plans	Average Plan Births per Year	Average Plan Deaths per Year	Average Percentage of Plans Dying each Year
Boston University	1987-2001	14	11	9	6.10	0.79	0.64	10.5%
Minnesota	1984-1995	12	3	6	8.00	0.25	0.50	6.3%
California	1984-1995	12	6	2	22.70	0.50	0.17	0.7%

Changes in premium cost sharing occurring in each region during the sample periods are shown on the top of Figure 1 to Figure 4. The figures suggest that those changes may have a significant impact on premiums dispersion and exit rates.

1.2.1.1. *Boston University*

Boston University has offered fifteen different health plans over the 14 year period from 1987-2001. There were eleven new plans offered, and nine plan deaths. The overall number of plans has remained relatively constant at five or six per year, implying a plan death rate of about 10.5 percent per year.

Figure 1 illustrates the three primary features that we model:

1. New plan entrants are generally priced lower than existing plans[8].
2. Existing plans tend to increase their premiums relative to the average
3. Higher premium plans have a greater probability of exiting than low premium plans.

Indeed, except in 1992[9], average premiums among exiting plans were always above average premium of those not exiting.

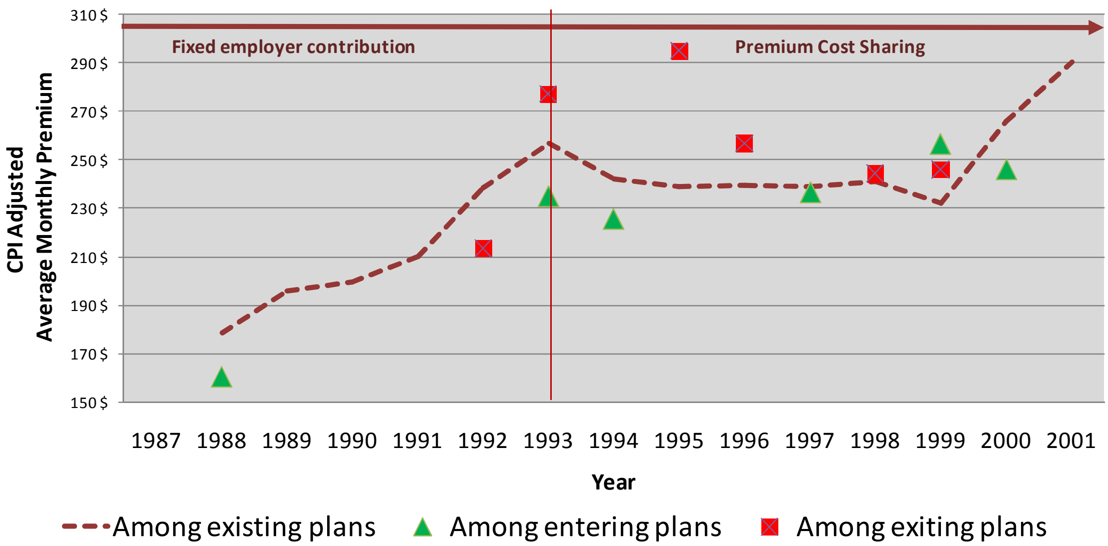

Figure 1: Boston University Average Single Premiums 1987-2001

From 1987 to 1992, BU made level premium contributions towards the six health plans that were offered at that time. As a result, employees faced the full cost burden of premium differences across plans. In 1993, BU changed its premium cost sharing so that, instead of level contributions, BU paid a fixed percentage of all premiums[10]. Greater dispersion in premiums across plans in their real costs in 2001 is evident in Figure 2.

[8] The only entrance above average occurred in 1999 with a plan which was offered for a single year.

[9] This was the average of two plan deaths, only one of which was priced below the average premium of exiting plans.

[10] BU also adopted a strategy of freezing enrollment in two health plans, the highest cost FFS plan (BCBS Comprehensive) and the highest cost HMO (Tufts). Except for those already enrolled in these plans, employees are not allowed to join them. BU also decided to enter the market in 2000 with its own plan, the BU Medical Center Preferred HMO. We do not try to model these alternative employer strategies.

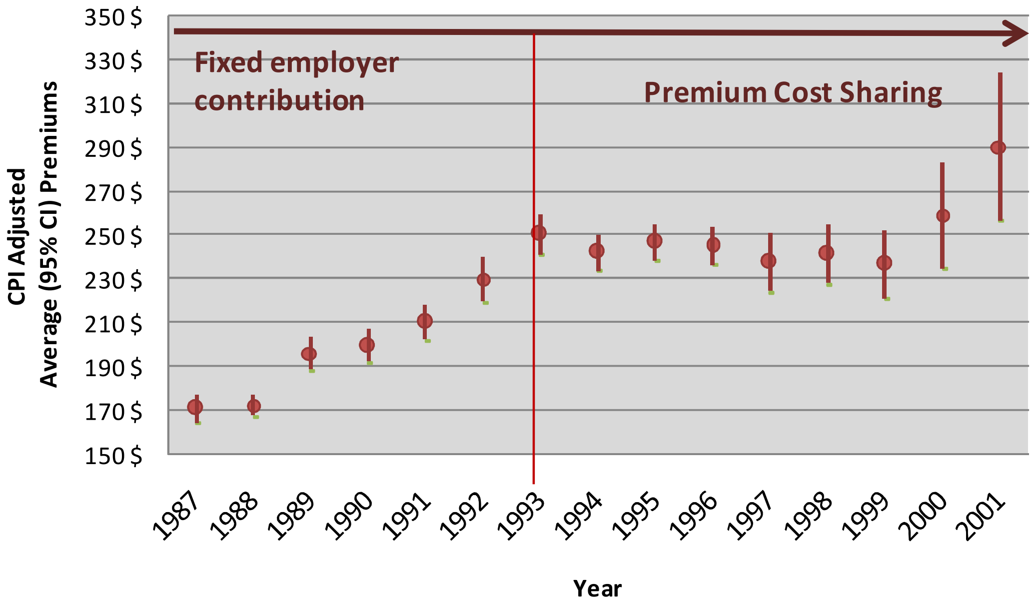

Figure 2: Boston University Average (95% CI) Single Premiums

1.2.1.2. *Minnesota*

Minnesota offered twelve different health plans to its state employees over the sample period ranging from 1984 to 1995. There were only three plan births versus six plan deaths[11] implying a plan death rate of 6.3 percent per year, and suggesting some evidence of death spirals. However, the most evident plan deaths occurring above the average premium happened in 1989. This was a year after Minnesota changed its health premium payment system, moving from a price floor system to a level premium contribution. Under the new system, employer contributions are calculated as equal to the premium of the lowest cost plan. Figure 3 shows premiums tracking together very closely from 1984-1988, at which point an enormous change in the dispersion of premiums occurred, quickly resulting in three plan deaths (marked with stars). This increased dispersion is plausible due to Minnesota switching from a price floor regimen to a fixed employer contribution.

[11] Several of which reflect mergers rather than true plan exits.

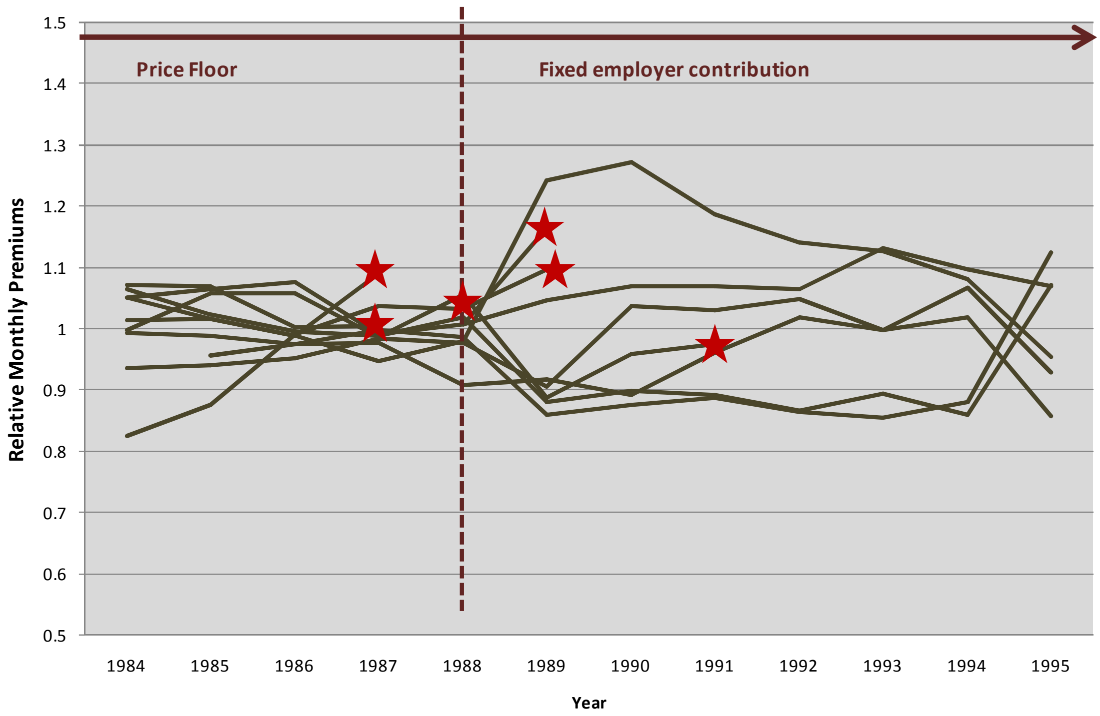

Figure 3: Minnesota Relative Single Premiums 1984-95

1.2.1.3. *California*

California offered 26 plans over the twelve years for which we have premium data. There were six plan births and two plan deaths, implying an annual plan death rate of only 0.7 percent. There is no evidence of death spirals in the California sample: the (only) two plan deaths in our sample period were at average rather than high premiums.

California had consistently maintained a system where the state's contribution is not tied to the lowest cost premium. California premiums contributions are such that employees pay no premium for all but the top four of its twenty three plans in 1996. This fact may be linked to the striking pattern shown in Figure 4: the high number of premiums clustered at the price floor imposed by the state. Moreover, even plans charging premiums higher than the price floor seem to survive for many years rather than dying, as was the case in Massachusetts and Minnesota.

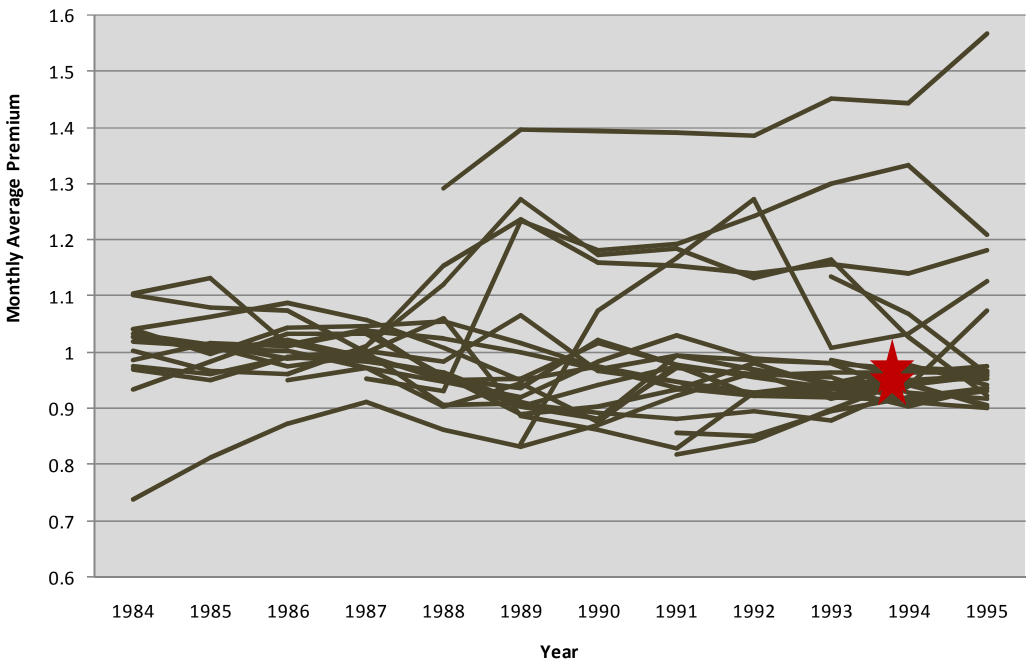

Figure 4: California Relative Single Premiums 1984-95

With no intention of generalizing based on only three markets, the premium patterns above suggest four patterns. First, death spirals do occur under some circumstances. Second, proportional premium cost sharing is associated with increases in the dispersion of premiums across plans. Third, maintaining a price floor is associated with lower rates of plan exit and slower rates of premium growth. Fourth, years in which the premium payment system is changed causes enormous turmoil in health plan pricing, entry and exit.

1.3. Model

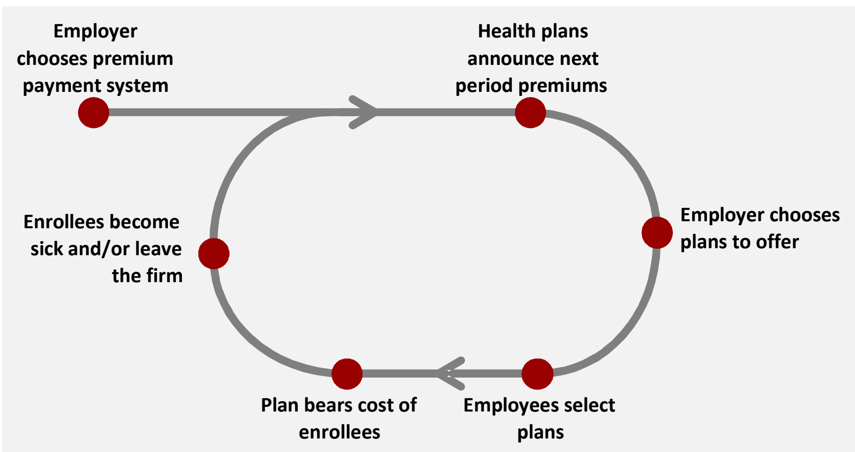

Figure 5: Timing

We model the process as a repeated game, as represented by Figure 5. At time 0, the employer chooses a premium payment system, which is to say a mechanism for making payments to health plans and charging premiums to employees. This decision is made only once, at the beginning of the process, and we model how plans and consumers respond to this premium payment system in equilibrium, without trying to model how agents would react to changes in the premium payment system.

In each period thereafter, there are five stages. During the first stage both potential new entrants and incumbent health plans simultaneously announce their premiums. Existing plans, which are unable to find a price yielding a nonnegative expected sum of future profits, exit.

In the next stage, the employer chooses which plans to offer. Since all plans are, *a priori*, alike, the main reason for the employer to offer a new plan is to enable price competition among plans and keep premiums down. Among several potential new plans, the employer chooses one new entrant each period - the entrant announcing the lowest first period premium. If several plans offer the same lowest price, the employer randomly picks one.

In the third stage of the process, each employee selects one of the offered health plans. Since all plans offer identical benefits, the only information employees use when choosing plans is the premium they will have to pay for each plan and the switching costs they will have to incur, should they switch plans.

Once employees have made their choice, the next step is for plans to bear the costs of treating health care needs according to health status of their enrollees. The fifth, and final stage, occurs after costs are borne by the plans but before the prices are chosen for the next period. Chance determines whether a healthy consumer becomes sick and/or departs the firm, and whether a sick enrollee leaves the employer. The five stages are repeated in each subsequent period.

1.3.1. Employers

The employers are assumed to care about the sum of total premium payments plus total switching costs. Even though employers do not directly bear the burden of switching costs, they should care about the value of the health plan benefits for their employees. The employer is assumed not to care about switching costs borne by employees leaving the firm.

The employer benefits from competition among potential entrants, but cannot force any plan to commit to a price beyond the current period. If plans are *ex ante* identical, the employer's best strategy is to select only one new entrant each period - the health plan announcing the lowest first period premium. This will avoid duplication of fixed costs and induce Bertrand competition among potential new entrants[12].

1.3.2. Employees

There are only two types of employees: low cost (healthy) and high cost (sick). By sick employees, we mean chronically ill patients. All other employees are considered healthy. All new employees are assumed to be healthy and we normalize the number of new employees to be one. Each employee has single coverage: family contracts are not modeled. Healthy employees become sick at the rate s per year, while sick employees never recover to become healthy again. All employees leave the firm at the rate d per year, for reasons that are independent of their health status[13]. Employees leave the firm for reasons that are exogenous and independent of plan prices and enrollee switching costs.

From the consumer's point of view, all plans offer the same coverage and give the consumer the same utility, except that consumers bear a switching cost when changing from their current plan to another. Consequently, when switching, consumers always choose the health plan charging the lowest premium. If, the optimal price sequence is increasing in time, the health plan charging the lowest premium will always be the youngest plan.

A more general model would consider heterogeneity in switching costs. For the time being, we assume that each time an employee, either healthy or sick, abandons a health plan and joins a new one, she is assigned a switching cost w, where w is uniformly distributed over the interval $[0, W]$.

The structure we have just described implies that we can take expectations across all individuals in a health plan and represent the expected number of individuals in the plan at time t as the vector $\{M_t, N_t\}$, where N_t is the number of healthy individuals, and M_t is the number of sick individuals.

In the absence of any plan switching, the stochastic process can be represented by the following stationary transition matrix A:

[12] Not offering a new plan each year is never optimal since existing firms will raise premiums even more. We do not model the optimal length of a period.

[13] We have also experimented with departure rates that are correlated with health states. This added complexity with few new insights. Ellis and Ma (2011) show that the higher job turnover of young employees more than offsets the predictable turnover of the older retirees.

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = A \begin{bmatrix} N_{t-1} \\ M_{t-1} \end{bmatrix}$$

where, $A = \begin{bmatrix} (1-s)(1-d) & 0 \\ s(1-d) & (1-d) \end{bmatrix}$. With plan switching, the transition matrix is no longer stationary. In this case, the transition matrix, A_t, will be:

$$A_t = f_t\, A$$

where f_t is the probability of a current enrollee not switching from a plan of age t. The complete specification of this probability depends on the premium payment system as described in Section 1.5. The expected number of people switching out of a t year old health plan, SW_t, can be written as:

$$SW_t = [A - A_{t-1}] \begin{bmatrix} N_{t-1} \\ M_{t-1} \end{bmatrix}$$

Equation 1: Expected number of people switching out of a *t* year old plan

1.3.3. Health Plans

Every year, many potential new entrant health plans compete *à lá Bertrand* to gain access to the market. Since only one new health plan is selected each year, as long as there are at least two potential new entrants, first period premiums are bid down to the point where the sum of discounted profits over the life span of the plan is exactly zero; unless a first period price floor is set by the employer.

Insurance companies are assumed not to be allowed by employers to charge different premiums to different individuals in the same plan. However, because of switching costs, plans are not perfect substitutes and, consequently, each plan faces a downward sloping demand curve. Insurance companies are thus price setters, and each year they choose the premium to charge all enrollees from a given employer.

Health plan profits in period t ($\prod_t$) can be written as:

$$\prod\nolimits_t = (P_t - C_N)N_t + (P_t - C_M)M_t - FC$$

where P_t is the premium charged by a plan aged t, FC are the fixed costs, and C_N and C_M are the one year costs of enrolling a healthy person and a sick person, respectively. Cumulative discounted profits from period t onwards, V_t, is given by:

$$V_t = \sum_{i=t}^{T} \rho^{i-t} \prod_i$$

where ρ is the discount factor and T is the health plan´s optimally chosen life span.

At any age t, if V_t is negative, it is optimal for the plan to exit. Consequently, in order for the plan to remain active at age t, the following health plan participation constraint (HPPC) has to be satisfied:

$$HPPC: V_t \geq 0$$

1.4. Results

Given the structure of our model, with one unit of healthy new employees arriving each period, the proportion s of existing healthy employees becoming sick each period, and the proportion d of existing healthy employees departing each period, then the steady-state total number of healthy enrollees, (N), that will be choosing among all of the health plans is:

$$N = \frac{1}{(1-kl)}$$

Equation 2: Steady-state total number of healthy enrollees

where, $k = (1-s)$ and $l = (1-d)$. Similarly, since a proportion s of healthy workers are becoming sick each period, and a proportion d of both newly sick and previously sick are departing the firm, then the steady-state total number of sick employees in the firm at any moment, (M), must be:

$$M = \frac{l}{(1-l)} - \frac{kl}{(1-kl)}$$

Equation 3: Steady-state total number of sick employees

Regardless of how workers distribute themselves among the total number of plans offered by the employer (Ψ), total health costs (THC) of the firm's employees will be:

$$Total\ Health\ Costs = \frac{1}{(1-kl)} * C_N + \left[\frac{l}{(1-l)} - \frac{kl}{(1-kl)}\right] * C_M + \Psi * FC$$

1.4.1. The Social Optimum

It is straightforward to see that the social optimum would have only one plan (and hence plan lifetime, T , will be infinite), and it would charge a constant premium over time. Having a constant premium guarantees that consumers have no incentive to switch plans, thereby minimizing switching costs. From Equation 1 it can be seen that switching costs would be zero. Having a single health plan also minimizes the fixed costs. Hence we have:

$$P^{FB} = \frac{\frac{1}{(1-kl)} * C_N + \left[\frac{l}{(1-l)} - \frac{kl}{(1-kl)}\right] * C_M + FC}{\frac{1}{1-l}}$$

$$T^{FB} = \infty$$

1.4.2. Competitive Solution

As described in Section 1.3.3, in the absence of a price floor, competition among potential entrants reduces overall discounted profits to zero. The first period price (P_1) is thus implicitly defined by:

$$(P_1 - C_N)N_1 + (P_1 - C_M)M_1 - FC + \sum_{t=2}^{T} \rho^{i-t} \prod_t = 0$$

Equation 4: Lifetime profit

In order to solve Equation 4, three preliminary steps are required: The first is the specification of the optimal sequence of prices and profits, given T; the second is the definition of the vector $\{N_1, M_1\}$, also for a given life span, T; The third, and final step, is the determination of the optimal life span. We turn to these issues next.

1.4.3. The Optimal Price Sequence

The optimal price sequence is the solution to the following optimization problem:

$$\underset{\{P_1,\ldots,P_T\}}{Max} \quad V_t$$

$$s.t. \begin{cases} HPPC \\ P_t, N_t, M_t \geq 0 \end{cases}$$

We assume Bertrand pricing behavior. Let the hat notation define variables set by competitors and let $\widehat{P_{Min}}$ be the lowest premium charged by any competitor. As shown in Appendix I, the number of healthy and sick enrollee at any moment in time is a function of the parameters $\widehat{P_{Min}}$, P_t, and P_1, and of $\{N_1, M_1\}$. $\{N_t\}$ and $\{M_t\}$, are independent of any other past premiums charged by the plan.

Claim:

$$X_t \equiv \begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} F_t l^{t-1} k^{t-1} N_1 \\ F_t l^{t-1}\{M_1 + [1 - k^{t-1}] N_1\} \end{bmatrix}$$

Equation 5: Number of healthy and sick employees in a given plan at time t

where the cumulative probability of not switching up to period t is $F_t \equiv \prod_{i=1}^{t} f_i = \frac{W - P_t + \widehat{P_{Min}}}{W}$.

Proof: See Appendix I.

This result implies that the premium charged by the health plan at any moment t will have no impact on future profits. Consequently, the optimization problem can be solved one period at a time through T- 1 problems of the form:

$$Max_{\{P_t\}} \quad (P_t - C_N)N_t + (P_t - C_M)M_t - FC$$

$$s.t. \begin{cases} \Pi_t \geq 0 \\ P_t, N_t, M_t \geq 0 \end{cases}$$

Problem 1: Maximization problem for period t

This problem is solved by assuming that all restrictions are met, and then verifying if they are indeed met. By solving Problem 1, we obtain the equation defining $P_t, \forall\ t = 2, .., T$.

Claim:

$$P_t = \frac{\left(W + \widehat{P_{Min}}\right)}{2} + \frac{AVC_t}{2}$$

where $AVC_t \equiv \frac{\{C_N k^{t-1} N_1 + C_M [M_1 + (1-k^{t-1}) N_1]\}}{N_1 + M_1}$ and $\widehat{P_{Min}}$ is the lowest premium charged by any competitor.

Equation 6: Optimal price at $t > 1$

Proof: See Appendix I.

Moreover, the expression for the optimal price depends on time, exclusively through average costs. Consequently, as long as $\mathrm{AVC_t}$ is increasing in time, so is $\mathrm{P_t}$. As shown in Appendix I, it is easily verified that: $\mathrm{AVC_t} > AVC_{t-1}, \forall_t$, as long as $\mathrm{C_M} > \mathrm{C_N}$.

Claim: The optimal price sequence $\{P_2, \dots, P_T\}$ is strictly increasing in t.

Proof: From Equation 6, it is clear that P_t is increasing in AVC_t , the average cost at time t:

$$\frac{\partial P_t}{\partial AVC_t} = \frac{1}{2} > 0$$

The intuition behind the above claim is the following: in our model, two forces cause health plan average costs, and hence health plan premium, to increase as a plan ages. First, new enrollees are healthier than average and perfectly price elastic: they always join the lowest premium plan, lowering the new plan costs relative to existing plans. Secondly, even in the absence of plan switching, the healthy get sicker, raising plan costs over time[14].

The fact that the optimal sequence of prices is increasing in t has an important consequence to our model. In Section 1.3.2 we argued that switchers would always select the health plan with the lowest premium. If prices are increasing with time, this implies that all employees deciding to switch will select the youngest plan ($\widehat{P_{Min}} = P_1$). Equation 6 may, then, be rewritten as:

$$P_t = \frac{W + \widehat{P_1}}{2} + \frac{AVC_t}{2}$$

Equation 7: Equilibrium optimal price at time $t > 1$

Consequently, changes in pricing by incumbents older than t do not affect the pricing decision of a firm of age t. After establishing its market share in the first period, and given the premium

[14] Cutler and Reber (1998) highlight the importance of the third factor, which they term "adverse retention." The classic Rothschild and Stiglitz (1976) frameworks focus on the adverse selection resulting from the fact that healthier employees are more likely to switch plans. This fact would occur in our framework if heterogeneity in switching costs was included.

charged by the youngest plan, P_1, the health plan tries to extract the highest possible rent from consumers over which it has market power due to switching costs, *i.e.* its enrollees. Equation 7 is analogous to the well-known monopolist optimal price with $(W + P_1)$ as the consumer's reservation price. Indeed, once we have solved Equation 5 for P_t, it becomes obvious that $(W + P_1)$ may be interpreted as the consumer's reservation price.

This notation for the reservation price also creates a useful criterion of the firms exit decision. Note that the average cost is a deterministic function of the parameters C_N, C_M, k and the initial enrollments N_1 and M_1. The firms exit decision will be when $P_{Max} \equiv W + \widehat{P_1} < AVC_t + AFC_t$. This can be simplified to yield the following exit condition:

$$Exit\ when\ W + \hat{P}^1 < \frac{C_N k^{t-1} N_1 + C_M[M_1 + (1 - k^{t-1})N_1]}{N_1 + M_1} + \frac{FC}{l^{t-1}(N_1 + M_1)}$$

Equation 8: Exit condition

This equation shows that there are two reasons why firms exit: One is because of the increase in the average variable cost of their enrollees as the proportion of healthy enrollees declines relative to the sick (aging); The other is due to the increase in average fixed costs as total plan enrollment declines. This equation makes it clear that in this model, firm exit is exogenous to the pricing strategy of any firm other than the new entrant, which sets $\widehat{P_1}$.

From Equation 8, it can be seen that firm lifetime will decrease as FC increases, plan departure rate increases ($l \equiv 1 - d$ decreases), rate of becoming sick increases, and the maximum support for switching costs increases.

As shown in the Appendix I, substituting Equation 7 back in the objective function of Problem 1, we obtain an expression for the optimal period t profit.

$$\prod_t = \frac{l}{4W}\ (N_1 + M_1)[W + P_1 - AVC_t]^2 - FC$$

Equation 9: Profit in period t

Claim: Profits, after the first period, are decreasing in t.

Proof: In the optimal profit expression (Equation 9), we see that profit at time t depends on t exclusively through AVC_t and, as it can easily be verified, $AVC_t > AVC_{t-1}, \forall_t$.

Substituting Equation 9 back in Equation 4 yields:

$$P_1 = AVC_1 + \frac{\sum_{t=1}^{T} \rho^{t-1} FC}{N_1 + M_1} - \frac{1}{4W} \sum_{t=2}^{T} \rho^{t-1} l^{t-1} [(W + \widehat{P_1}) - AVC_t]^2$$

Equation 10: Optimal first period price

Proof: See Appendix I.

Equation 10 reveals that P_1, as a function of N_1 and M_1, is actually quite simple. P_1 is the average marginal cost in period one, plus the sum of discounted fixed costs per initial enrollee, less the sum of future profits each person will, on average, generate. Thus, for a given $\{N_1, M_1\}$ vector, the more profitable each person is in the future (because new plans enter less aggressively), the more willing the plan is to incur losses in its first period. As a result, high first period prices are not sustainable in equilibrium unless a price floor is set.

1.4.4. The Optimal Vector of First Period Enrollees

Our next step is to find expressions defining the vector of first period enrollees, $\{N_1, M_1\}$. Since, all switchers and all new employees select the youngest plan, N_1 will be the sum of new employees (NE), plus involuntary healthy switchers (IHS), plus voluntary health switchers (VHS). IHS are employees who, due to their high switching costs, chose never to switch out of the plan that just died, but instead were forced to switch when the plan exited. VHS are enrollees who choose to switch while their health plan was still available. They have, of course, lower switching costs than IHS.

$$N_1 = NE + IHS + VHS = 1 + kl\, N_t + \sum_{t=1}^{T-1} k^t l^t\, \widehat{F_t} \left(1 - \widehat{f_{t+1}}\right) N_1$$

Equation 11: Number of healthy enrollees in year 1

where,

$$\widehat{f_{t+1}} = \frac{W - \widehat{P_t} + P_1}{W - \widehat{P_{t-1}} + \widehat{P_1}} \text{ and } \widehat{F_t} = \frac{W - \widehat{P_t} + \widehat{P_1}}{W}.$$

When a plan exits, all its former enrollees are forced to switch, thus the probability of not switching, $\widehat{f_{T+1}}$, is zero. Including this, Equation 11 simplifies to:

$$N_1 = 1 + \sum_{t=1}^{T} k^t l^t \widehat{F_t}\left(1 - \widehat{f_{t+1}}\right)\widehat{N_1}$$

Equation 12: N_1

The derivation of M_1 follows approximately the same reasoning as that of N_1, except that, because all new entrants are assumed healthy, the new plan's market share of sick enrollees is simply the sum of involuntary sick switchers (ISS) and voluntary sick switchers(VSS) it is able to "steal" from existing plans:

$$M_1 = ISS + VSS = M_t l + slN_t + \sum_{i=1}^{T-1}\left(\widehat{M_i} l + sl\widehat{N_i}\right)(1 - f_{i+1})$$

Equation 13: Number of sick enrollees in year 1

$$\Leftrightarrow M_1 = \sum_{i=1}^{T}(\widehat{M}_i l + sl\widehat{N}_i)(1 - \widehat{f_{i+1}})$$

Equation 14: M_1

1.4.5. The Determination of the Optimal Life Span

Results derived until now have all been conditional on T, the optimal lifespan of a plan. The procedure for the determination of the optimal life span is explained in more detail in Appendix I, but we turn next to a brief description of it.

At the beginning of each period, the plan will determine the price that maximizes its profits, according to the HPPC, $V_t \geq 0$, if no price yields non-negative profits, the plan will exit. The determination of the steady-state optimal life span, T, requires, nevertheless, one additional condition: that it would not have been feasible for the health plan to select the optimal price sequence of any other life span. Any $\tilde{T} > T$ would not be feasible because the HPPC would not have been satisfied for all t, and $\tilde{T} < T$ would not be feasible because P_1 is decreasing in T. Bertrand competition among potential entrants implies that the lowest possible P_1, yielding zero intertemporal profits will be selected.

1.4.6. The Steady-State Competitive Equilibrium

Because one plan is added to the menu of choices each year and one plan dies, the optimal life span, T, is also the number of plans offered by the employer at any moment in time. Moreover, by symmetry, the steady-state equilibrium $N_1 = \widehat{N_1} = N_1^*$, $M_1 = \widehat{M_1} = M_1^*$ and $P_t = \widehat{P_t} = P_t^*, \forall_t$, where the star indicates equilibrium values.

Imposing the equilibrium conditions on Equation 12, Equation 14, Equation 10 and Equation 7 and then substituting this last one on the first three, we obtain the system of equations defining the first period variables of interest, from which all others may be obtained. This system does not have a closed-form solution. Instead, we use it to simulate the model as described in the next section.

$$\begin{cases} \mathrm{P}_1^* = AVC_1^* + \dfrac{\sum_{t=1}^{T} \rho^{t-1} FC}{N_1^* + M_1^*} - \dfrac{1}{4w} \sum_{t=2}^{T} \rho^{t-1} l^{t-1} [(W + \mathrm{P}_1^*) - AVC_t^*]^2 \\ N_1^* = \dfrac{2W}{(1 - kl) \sum_{i=1}^{T} k^{t-1} l^{t-1} (W + P_1^* - AVC_t^*)} \\ M_1^* = \dfrac{N_1^* \sum_{i=1}^{T} [l^t (1 - k^t) - l^{t-1} (1 - k^{t-1})] (W + P_1^* - AVC_t^*)}{(1 - l) \sum_{i=1}^{T} l^t (W + P_1^* - AVC_t^*)} \\ (P_1^* - C_N) N_1^* + (P_1^* - C_M) M_1^* - FC + \\ + \sum_{t=2}^{T} \rho^{t-1} \left\{ \dfrac{l}{4W} (N_1^* + M_1^*) [(W + P_1^*) - AVC_t^*]^2 - FC \right\} = 0 \end{cases}$$

Equation 15: Equilibrium conditions

In the price floor scenario, the system is precisely the same, except for the third equation: the equation defining P_1. We assume the price floor is such that first period profits are zero. Consequently,

$$P_1^* = AC_1 + \frac{FC}{N_1^* + M_1^*}$$

1.5. Premium Payment Systems

We consider four possible premium payment systems: Base Case, Cost Sharing, Risk Adjustment and Price Floor.

1.5.1. Base Case

Our base case assumption is that employers make level contributions toward all the health plans offerings, so that employees bear the full cost differential of any premium charges made by health plans. For simplicity, we assume that employees pay the entire premium in this case, and ignore the well-known problem of tax exempt health care spending. In the absence of any discounting, this assumption also implies that total lifetime premiums exactly equals total treatment costs, hence comparisons of pricing paths under this assumption focus on differences in total switching costs.

Since under this system employees pay the full premium, a given employee will choose to switch out of a plan in period t if $P_t > \widehat{P_{Min}} + w$, where P_t is the premium charged by a plan of vintage t and $\widehat{P_{Min}}$ is the lowest premium charged by any competitor. The switching cost, w, is uniformly distributed over the interval $[0, W]$, hence the probability that a current enrollee will not switch from a plan aged t, denoted by f_t, is:

$$f_t = \begin{cases} \dfrac{W - P_t + \widehat{P_{Min}}}{W - P_{t-1} + \widehat{P_{Min}}} & if \;\; W \geq P_t - \widehat{P_{Min}} \wedge P_t \geq P_{t-1} \\ 0 & if \; W < P_t - \widehat{P_{Min}} \wedge P_t \geq P_{t-1} \\ 1 & if \; P_t < P_{t-1} \end{cases}$$

Equation 16: Probability of not switching at time t

Under our model assumptions, it turns out that in equilibrium conditions $W \geq P_t - \widehat{P_{Min}}$ and $P_t \geq P_{t-1}$ are both satisfied. As described in the Section 1.3.3, existing plans are unable to charge a price that yields strictly positive profits in the forthcoming periods exit in stage 2. This implies that the first condition defined, $W \geq P_t - \widehat{P_{Min}}$, will always be met for an active plan because if it were not, all enrollees would switch and fixed costs would imply negative profits. The second condition, $P_t \geq P_{t-1}$, means that prices are non-decreasing over time. As we show in Section 1.4.2 this condition is also met in equilibrium.

Intuitively one would expect the probability of switching to be decreasing in W. For a given price sequence, this is easily confirmed by taking the partial derivative of $(1 - f_t)$ with respect to W. However, W will have an impact on the optimal price sequence and possibly on the optimal life span. Without an analytical solution to our model, the total effect has to be simulated, and this is done in Section 1.6.

Switching costs depend on the prices, the number of healthy and sick people in each vintage plan, and especially on how many people are in a plan when it dies. The expected switching cost of enrollees leaving a plan at age t is:

$$\frac{P_t - \widehat{P_{Min}} + P_{t-1} - \widehat{P_{Min}}}{2}[A - A_t]\begin{bmatrix} N_{t-1} \\ M_{t-1} \end{bmatrix}$$

Equation 17: Expected switching cost at *t*

1.5.2. Cost Sharing

The second premium payment system we consider is proportional premium cost sharing. In this system, employees pay only the proportion λ, with $0 < \lambda < 1$, of the full premium P_t, while the employer pays the remaining $(1 - \lambda)P_t$. Since employees pay only a proportion of the total plan premium, their willingness to switch health plans will depend on $\lambda(P_t - \widehat{P_{Min}})$ rather than $(P_t - \widehat{P_{Min}})$, as occurs in the base case. With cost sharing, the probability of a current enrollee not switching from a plan aged t, denoted by f_t^{CS}, is defined as:

$$f_t^{CS} = \frac{W - \lambda(P_t - \widehat{P_{Min}})}{W - \lambda(P_{t-1} - \widehat{P_{Min}})} = \frac{\frac{W}{\lambda} - P_t + \widehat{P_{Min}}}{\frac{W}{\lambda} - P_{t-1} + \widehat{P_{Min}}}$$

Equation 18: Probability of not switching under CS

The probability described in Equation 18 is identical to f_t, the probability of not switching in our base case, after replacing W with $W^{CS} = \frac{W}{\lambda}$. Hence, with regard to the probability of switching, premium cost sharing is equivalent to increasing switching costs.

1.5.3. Risk Adjustment

The third premium payment system considered involves risk adjustment. Risk adjustment is a supply side payment system that uses signals predictive of enrollee health costs to, partially or fully, compensate health plans for predictable differences in the expected cost of their enrollees. Risk adjustment does not directly affect demand responsiveness or switching, however, it does change the relative profitability of healthy and sick consumers. We implement imperfect risk adjustment in our model by assuming that the employer is able to observe a signal that is imperfectly correlated with enrollee costs. They use this signal to increase payments to the sick and reduce them to the healthy. Hence, under imperfect risk adjustment, health plan profits at time t can be written as:

$$\prod_t^{RA} = (P_t - C_N + \gamma_N)N_t + (P_t - C_M + \gamma_M)M_t$$

Taking expectations, the effect of risk adjustment is to reduce the profitability of healthy enrollees and reduce losses on sick enrollees. We simulate this effect by assuming that $\gamma_N = \alpha(C_N - \bar{C})$ and $\gamma_M = \alpha(C_M - \bar{C})$. Since $C_N < \bar{C} < C_M$, then $\gamma_N < 0 < \gamma_M$. That is, risk adjustment raises the cost of enrolling healthy people and lowers the cost of enrolling sick people. We model the effect of risk adjustment by replacing C_N with $C_N^{RA} = (1 - \alpha)\, C_N + \alpha\bar{C}$, and replacing C_M with $C_M^{RA} = (1 - \alpha)\, C_M + \alpha\bar{C}$.

Reflecting the fact that existing risk adjustment formulas are imperfect, in our simulations we assume $\alpha = 0\,.1$; that is, risk adjustment moves costs only ten percent of the way towards fully compensating health plans for enrolling sicker than average enrollees[15].

Risk adjustment affects only the supply side of the market, and does not affect demand responsiveness or plan switching, other than through its effect on pricing behavior. Consequently, the probability of a current enrollee not switching from a plan of vintage t is precisely the same as in the base case scenario.

1.5.4. Price Floor

The fourth and final premium payment system we consider is a price floor on first period premiums. By price floor we mean a minimum premium such that, if a health plan charges a lower premium, employees do not reap any of the reduction. Price floors arise naturally when employers choose a base plan for calculating their employee contribution which is not the lowest premium health plan. While price floors are generally considered bad by economists, in our context they serve the useful purpose of thwarting the ability of the entrant plan to attract the healthiest employees.

In our simulations, the first period price floor value is the price yielding zero profits in the first period. This would be feasible if employers have some, but not full, power to negotiate first period prices. If employers know the true costs of first period plan entrants, for instance, then they might be able to enforce zero profits in the first period, even if they cannot enforce zero profits in subsequent periods.

1.6. Simulation Results

In order to simulate the model, we selected values for the parameters and used Mathematica 4.0® to find the steady-state equilibrium in each of the four premium payment systems considered. Comparative statics is performed by linearizing the system and then, applying the

[15] We are using conventional, not optimal risk adjustment here, as Glazer and McGuire (2000) define it. That is, we assume that the employer does not use its knowledge of the demand model of how consumers are selecting health plans to risk adjust payments.

implicit function theorem, again use Mathematica 4.0®, to understand the impact of each parameter on the equilibrium. This analysis is, obviously, performed locally around the equilibrium found, which itself depends on the values selected for the parameters. We conclude this section with some sensitivity analysis meant to verify the degree of dependence of our results on the parameter values chosen.

1.6.1. Starting Values

Table 2: Simulation Parameters

	Sample Period	Years
Number of New Entrants Each Period	**NE**	1
Proportion of Healthy Who Become Sick	**s**	0.03
Proportion of Employees Departing the Firm	**d**	0.1
Annual Medical Cost per Healthy Enrollee	**CN**	1,000
Annual Medical Cost per Sick Enrollee	**CM**	2,000
Maximum Switching Cost	**W**	1,000
Plan Fixed Cost per Year	**FC**	100
Discount Factor	**ρ**	1

Table 2 displays the assumed values of our base case simulation model. Healthy enrollees are assumed to cost $C_N = \$1{,}000$ per year, with sick enrollees costing twice as much $C_M = \$2{,}000$. The maximum price differential that will result in all enrollees switching is $W = \$2{,}000$. Employees, both healthy and sick, are assumed to leave the firm at the rate $d = 0.1$. The rate at which healthy people become sick was selected to insure that there were a total of eight units of healthy employees and two units of sick employees. From Equation 2 and Equation 3, we obtained $k = \frac{7}{8l}$, which is to say that healthy people become sick at a rate, s, of approximately three percent. Health plans are assumed to have fixed costs of $FC = \$100$ per plan/year. We assume no discounting for our baseline. These six parameters $(C_N, C_M, W, s, d, FC, \rho)$ fully characterize our model for a given premium payment system.

With eight units of healthy employees and two units of sick employees, the average treatment costs will be:

$$\frac{8 * 1000 + 2 * 2000}{10} = \$1200$$

Once fixed costs are added, we obtain the social optimum premium that one (single) plan could charge and achieve zero profits:

$$P^{SO} = 1200 + \frac{100}{10} = 1210$$

1.6.2. Competitive Equilibrium Simulation Results

In this section we provide an overview of the simulation results obtained from dozens of reasonable combinations of the six parameters $\{s, l, W, C_N, C_M, CF\}$. In almost all the sets of parameters chosen, the model has one (unique) solution yielding real, positive values for all variables. The exception occurs for low values of W (the highest possible switching cost) in which case no solution exists. We believe that this is due to the fact that for low values of W, the model reaches close to the Bertrand paradox, where the first order conditions no longer hold.

We discuss the simulation results by first commenting on the determination of the optimal life span (Section 1.6.3) and then on the equilibrium values of our base case (Section 1.6.4). Once the main features of our model are presented, the comparison of equilibria under the four systems (Section 1.6.5) should run smoothly.

1.6.3. Determination of the optimal life span

In all but the price floor scenario, the determination of the optimal life span of the plan follows the following steps (exemplified in Table 3):

1. Assume the life span is $\tilde{T} = 2$
2. Find the steady-state optimal stream of prices and profits given that $\tilde{T} = 2$
3. If at time $\tilde{T}$, profits are positive, assume the life span is $\tilde{T} = 3$
4. Find the steady-state optimal stream of prices and profits given that $\tilde{T} = 3$
5. If at time $\tilde{T}$, profits are positive, assume the life span is $\tilde{T} = 4$

This loop goes on until the optimal price strategy yields negative profits at time $\tilde{T}$. When it occurs, it means the optimal life span, T, is $T = \tilde{T} - 1$

Table 3: Determination of T

	Life Span	3	4	5	6	7	8	9	10	11
	Average Premium	$1,397	$1,422	$1,439	$1,451	$1,462	$1,472	$1,481	$1,490	$1,499
	Average Switching Cost	$240	$202	$176	$157	$142	$130	$120	$111	$104
	Average Premium plus Average Switching Cost	$1,637	$1,624	$1,614	$1,608	$1,604	$1,602	$1,601	$1,602	$1,603
	Inv. Healthy Switchers	1.24	0.89	0.67	0.52	0.41	0.33	0.27	0.22	0.18
	Inv. Sick Switchers	0.42	0.32	0.26	0.22	0.18	0.16	0.14	0.12	0.11
	Vol. Healthy Switchers	2.67	2.48	2.34	2.23	2.14	2.06	1.98	1.92	1.86
	Vol. Sick Switchers	0.71	0.64	0.58	0.53	0.49	0.46	0.43	0.40	0.38
	% Inv. Switchers	16.6%	12.1%	9.3%	7.4%	6.0%	4.9%	4.1%	3.4%	2.9%
	% Vol. Switchers	33.8%	31.2%	29.2%	27.6%	26.3%	25.1%	24.1%	23.2%	22.4%
	Cost Inv. Healthy Switchers	$1,007	$735	$560	$439	$350	$283	$231	$191	$158
	Cost Inv. Sick Switchers	$341	$268	$220	$185	$158	$136	$118	$104	$91
	Cost Vol. Healthy Switchers	$830	$806	$782	$758	$736	$714	$693	$672	$652
	Cost Vol. Sick Switchers	$221	$207	$195	$183	$173	$163	$154	$146	$139
Premium	1	$986	$941	$912	$893	$880	$873	$868	$867	$867
	2	$1,598	$1,572	$1,554	$1,541	$1,532	$1,525	$1,520	$1,516	$1,514
	3	$1,609	$1,583	$1,565	$1,552	$1,543	$1,536	$1,531	$1,528	$1,526
	4		$1,594	$1,576	$1,563	$1,554	$1,547	$1,542	$1,539	$1,537
	5			$1,587	$1,574	$1,565	$1,558	$1,553	$1,550	$1,548
	6				$1,584	$1,575	$1,569	$1,564	$1,561	$1,559
	7					$1,585	$1,579	$1,574	$1,571	$1,569
	8						$1,589	$1,584	$1,581	$1,579
	9							$1,594	$1,591	$1,589
	10								$1,600	$1,599
	11									$1,608
N	1	4.91	4.37	4.01	3.75	3.55	3.39	3.25	3.14	3.04
	2	1.67	1.41	1.26	1.15	1.08	1.03	0.99	0.96	0.94
	3	1.42	1.20	1.06	0.98	0.92	0.87	0.84	0.81	0.80
	4		1.02	0.90	0.83	0.78	0.74	0.71	0.69	0.67
	5			0.76	0.70	0.66	0.62	0.60	0.58	0.57
	6				0.59	0.55	0.53	0.51	0.49	0.48
	7					0.47	0.45	0.43	0.42	0.41
	8						0.38	0.36	0.35	0.34
	9							0.31	0.30	0.29
	10								0.25	0.25
	11									0.21
M	1	1.13	0.96	0.84	0.75	0.68	0.61	0.56	0.52	0.48
	2	0.44	0.36	0.31	0.27	0.24	0.22	0.21	0.19	0.18
	3	0.43	0.35	0.30	0.26	0.24	0.22	0.20	0.19	0.18
	4		0.33	0.29	0.25	0.23	0.21	0.20	0.18	0.18
	5			0.27	0.24	0.22	0.20	0.19	0.18	0.17
	6				0.23	0.21	0.19	0.18	0.17	0.16
	7					0.19	0.18	0.17	0.16	0.15
	8						0.17	0.16	0.15	0.14
	9							0.14	0.14	0.13
	10								0.13	0.12
	11									0.11
Profit	1	-$1,316	-$1,376	-$1,367	-$1,331	-$1,281	-$1,225	-$1,166	-$1,107	-$1,049
	2	$719	$554	$459	$400	$362	$335	$317	$304	$296
	3	$596	$453	$372	$322	$289	$266	$251	$240	$233
	4		$369	$299	$256	$227	$208	$195	$186	$180
	5			$237	$200	$176	$159	$148	$141	$136
	6				$153	$132	$118	$109	$102	$98
	7					$95	$83	$75	$70	$67
	8						$54	$47	$43	$40
	9							$24	$20	$17
	10								$1	**-$1**
	11									**-$17**

In the absence of a first period price floor, as shown in Table 3 and Figure 6, the longer health plans intend to live, the more aggressive they will enter the market, *i.e.* P_1 is decreasing in T. This occurs because health plans are willing to "pay" more (in the form of a first period price even lower than marginal cost) for potential consumers, if they expect to extract future rents over a longer life span.

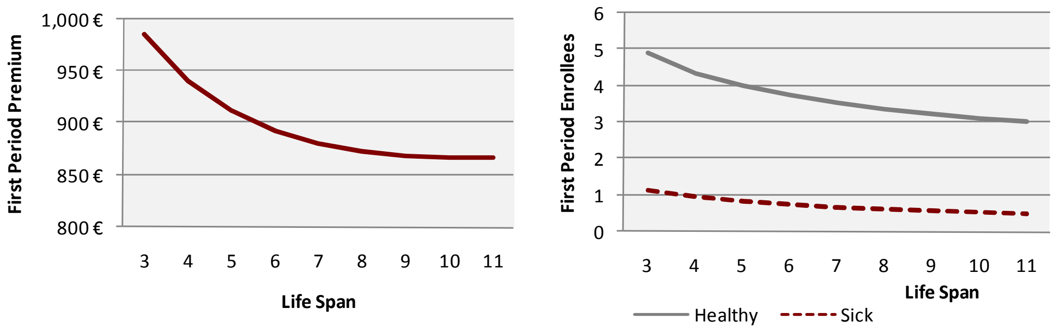

Figure 6: First Period Premium, Number of Healthy and Number of Sick Enrollees for Different Life Spans

As P_1 decreases in T, one might expect to find higher market shares and bigger losses in the first period as T increases. However, that is not the case (Figure 6). As Table 3 shows, the number of (healthy and sick) enrollees in the first year of the plan's life is decreasing in T, and so is the loss incurred in that period. In our model, the life span equals the number of plans in any given period, meaning that longer life spans correspond to a higher degree of competition among existing plans. Although the loss per enrollee in the first period is higher, with more plans in the menu of choices and a constant number of employees, each plan will have less enrollees and lower losses in the first period.

Table 3 and Figure 7 also show that the average premium is increasing in T. For all T, prices increase sharply from period one to period two and only slightly after that, so the increase in average price, as T increases, simply reflects the fact that P_1 weighs less as plans live longer. In fact, the average premium, excluding the first period price is slightly decreasing in T. When plans live longer, less switching will occur especially among involuntary switchers, who are also the ones with the higher switching cost. Table 3 shows that, in our base case, the percentage of switchers decreases from 50% to 27% as the life span increases from three to ten, and that the largest relative reduction occurred among involuntary switchers. The decrease in average switching cost is also mainly driven by the significant reduction (78%) in switching costs of involuntary switchers.

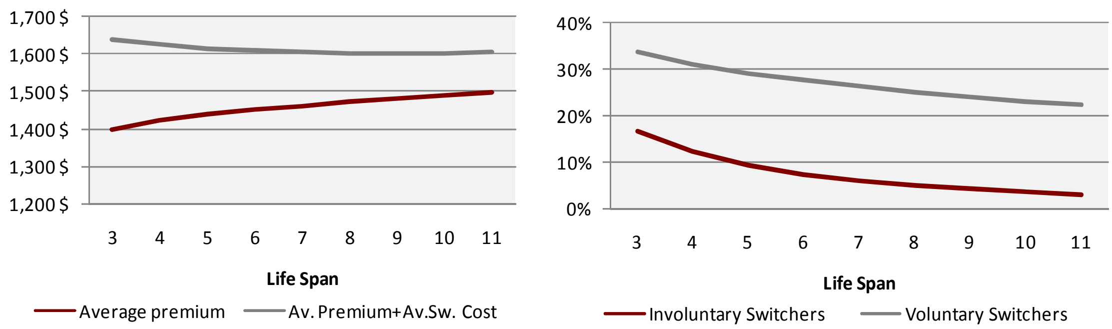

Figure 7: Average Premium, Average Total Cost to Consumers and Percentage of Switchers, for Different Life Spans

While switching costs of voluntary switchers are taken into account by health plans that have to set premiums sufficiently low to compensate for switching costs, switching costs of involuntary switchers do not affect demand. It is true that, once forced to switch, involuntary switchers will select the plan offering the lowest premium but ***all*** involuntary switchers will select the youngest plan, even if its premium is just slightly below the cheapest of the remaining premiums.

With average premiums increasing and average switching costs decreasing as plans live longer, it is not clear what will happen to the total cost borne by consumers (average premium plus average switching cost). Our simulations show that the total cost has a minimum at some $\tilde{T} < T$, where T is the steady-state equilibrium life span (Table 3).

1.6.4. Base Case Competitive Equilibrium Simulation Results

Table 4 presents the steady-state competitive equilibria of our model. There are four blocks (premium, profit, healthy and sick) with four columns each. Each column shows the simulation results for one premium payment system. Our base case competitive equilibrium results, discussed in this Section, are presented in column "BC" in each block. Comparison of the results for the different premium payment systems is performed in 1.6.5.

Table 4: Equilibrium Solution under Different Premium Payment Systems

	Premium				Profit				Nt				Mt			
Year	**BC**	**CS**	**RA**	**PF**	**BC**	**CS**	**RA**	**PF**	**BC**	**CS**	**RA**	**PF**	**BC**	**CS**	**RA**	**PF**
1	$867	$823	$867	$1,155	-$1,107	-$1,276	-$1,123	$0	3.14	3.16	3.13	2.23	0.519	0.523	0.515	0.289
2	$1,516	$1,544	$1,518	$1,647	$304	$332	$299	$484	0.96	0.95	0.96	0.99	0.191	0.189	0.189	0.160
3	$1,528	$1,556	$1,528	$1,659	$240	$265	$238	$401	0.81	0.81	0.81	0.85	0.190	0.188	0.188	0.165
4	$1,539	$1,567	$1,538	$1,671	$186	$209	$186	$330	0.69	0.68	0.69	0.72	0.185	0.183	0.184	0.166
5	$1,550	$1,578	$1,548	$1,682	$141	$161	$143	$269	0.58	0.58	0.58	0.62	0.177	0.177	0.177	0.163
6	$1,561	$1,589	$1,558	$1,693	$102	$121	$105	$217	0.49	0.49	0.50	0.53	0.168	0.168	0.169	0.159
7	$1,571	$1,599	$1,567	$1,704	$70	$86	$74	$172	0.42	0.42	0.42	0.45	0.158	0.159	0.160	0.152
8	$1,581	$1,609	$1,576	$1,714	$43	$57	$47	$134	0.35	0.35	0.36	0.39	0.148	0.148	0.149	0.145
9	$1,591	$1,619	$1,585	$1,724	$20	$33	$24	$101	0.30	0.30	0.30	0.33	0.137	0.138	0.139	0.137
10	$1,600	$1,628	$1,593	$1,734	$1	$12	$5	$73	0.25	0.25	0.26	0.28	0.126	0.128	0.129	0.128
11				$1,743				$48				0.24				0.120
12				$1,753				$28				0.21				0.111
13				$1,762				$10				0.18				0.103

Note: BC: Base Case; CS: Cost Sharing; RA: Risk Adjustment; PF: Price Floor; Nt: Number of healthy employees at time *t*; Mt: Number of sick employees at time *t*

For any given life span, the optimal price sequence is always increasing and the correspondent sequence of profits is strictly decreasing, which confirms our analytical results presented earlier. More specifically, prices are below average cost in the first period, increase abruptly from the first to the second period and only slightly after that. Health plans have losses in the first period in order to establish their market share. Then, at vintage two, plans have their best opportunity to recover losses incurred in the previous period, because that is when the price differential with respect to the youngest plan is lowest and fewest enrollees have become sick.

As plans become older, healthy enrollees become sick raising plan costs and prices over time. With higher costs, not only are plans incapable of attracting (healthy) incoming employees but they are also unable to hold their enrollees with lower switching costs. It is thus predictable, and Table 4 confirms it, that the number of healthy enrollees (N_t) decreases as the plan grows older.

As to the evolution of the number of sick enrollees with time, the results are not so obvious. On one hand, two forces drive the number of sick enrollees down. First, employees leave the firm at a rate d; Second, as the price differential between their current premium and the premium charged by the youngest plan increases, more and more sick enrollees will find it profitable to switch. On the other hand, healthy enrollees become sick, thus increasing the number of sick enrollees and it is not clear which force will *a priori* prevail. However, in all our simulations (even with s much higher than d) the price spiral was steep enough to imply a decrease in the number of sick employees over time.

Having summarized the main features, common to all simulations carried out and before we proceed to the comparison of the steady-state equilibria of the four premium payment system considered, it is interesting to do some comparative statics. As described in Section 1.4, with no closed-form solution to our model, comparative statics is performed locally. Table 5 shows the impact of a 0.1 increase in k and l, a 10% increase in W,C_N and C_N on the equilibrium value of our dependent variables, the price sequence and first period market shares, for our base case. In performing such analysis, we have kept constant the life span. This implies that we are possibly comparing optimal solutions to non-optimal ones (accounting for the change in the optimal life span is performed in Section 1.7). Because the model is well-behaved, interpretation of the results presented in Table 5 shares much in common to the discussion presented in Section 1.7. Consequently, in order to avoid repetition we refer the reader to that Section.

Table 5: Analysis of the Impact of the Parameters on the Equilibrium Values

	Δk = - 0,1	Δl = - 0,1	ΔW = +10%	ΔCN = +10% & ΔCM = - 10%
Ntotal	4.61	4.46	7.87	7.87
Mtotal	5.39	0.54	2.13	2.13
ΔN1	1.16	2.12	0.00	0.00
ΔM1	-1.60	1.10	0.00	0.00
ΔP1	-$576	-$10	-$0.44	$0.60
ΔP2	-$536	$81	$0.28	$0.63
ΔP3	-$570	$79	$0.28	$0.61
ΔP4	-$603	$76	$0.28	$0.58
ΔP5	-$634	$74	$0.28	$0.56
ΔP6	-$663	$72	$0.28	$0.54
ΔP7	-$689	$70	$0.28	$0.52
ΔP8	-$714	$68	$0.28	$0.50
ΔP9	-$738	$66	$0.28	$0.48
ΔP10	-$760	$64	$0.28	$0.46

1.6.5. Competitive Equilibrium Simulation Results Under Different Premium Payment Systems

Table 4 presents the steady-state competitive equilibria of our model, under each of the four premium payment systems considered, while Figure 8 graphs the correspondent price sequences. The first column refers to our base case, in which consumers pay the full premium; the second describes the equilibrium with costs sharing, assuming that employees pay ninety percent of the premium; column three provides the steady-state values under risk adjustment; and finally, the last column shows the results in the presence of a first period price floor yielding zero profit in the first period.

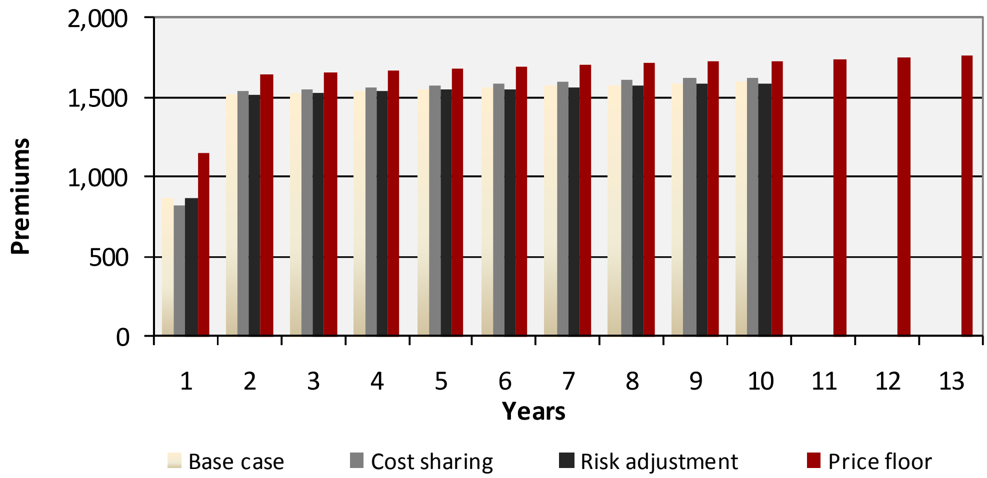

Figure 8: Optimal Price Sequences under Different Payment Systems

Column two of each block in Table 4 provides the steady-state equilibrium values of our variables of interest, in the context of premium cost sharing. To make the results comparable to the risk adjustment scenario, we chose to model the very modest change of imposing only ten percent premium cost sharing. That is, whereas in our base case model we have the consumer paying one hundred percent of the difference between the lowest cost plan and all other plans, here we have the consumer paying ninety percent of this difference. The employer is sharing the cost of the premiums by paying ten percent of the difference. As discussed above, ten percent premium cost sharing is equivalent in our framework to having switching costs that are approximately ten percent higher, and hence, we conducted the simulation by assuming $W = \$1{,}100$.

In our model, switching costs are the reason for plans to have market power. Higher switching costs mean that health plans are able to extract higher rents from their enrollees. The results in column two of each block of Table 4 reflect precisely that. If plans have more market power, they charge higher premiums. This ability to charge higher premiums in the future enhances first period competition and lowers the first period premium, which in turn attracts more healthy employees and implies bigger losses. The difference in premiums with respect to the first, $P_t - P_1$, is higher in all periods than in the base case. This causes much more switching than in the base case and, as a result, the cost of voluntary switchers is substantially higher with cost sharing (Table 6). The consequences of cost sharing, just described, prevailed in all simulations performed[16] indicating that, in the presence of switching costs, cost sharing as a

[16] In simulations performed with a lower proportion of healthy to sick, cost sharing did increase the optimal life span of the plan, but still at higher average premium plus average switching cost.

premium payment system enhances death spirals and total costs borne by consumers, with no additional increase in plans' profits.

As discussed in our model section, risk adjustment in our framework is equivalent to considering moving both C_N and C_M towards the population average ($C = 1{,}200$). We chose to reflect the empirical observation that risk adjustment appears to only move payments about ten percent of the distance toward perfectly reflecting costs. Consequently, the simulation results presented in column three of each block of Table 4 were obtained assuming the cost of healthy and sick people as $C_N = 0.9 * \$1{,}000 + 0.1 * \$1{,}200 = \$1{,}020$ and $C_M = 0.9 * \$2{,}000 + 0.1 * \$1{,}200 = \$1{,}980$, respectively.

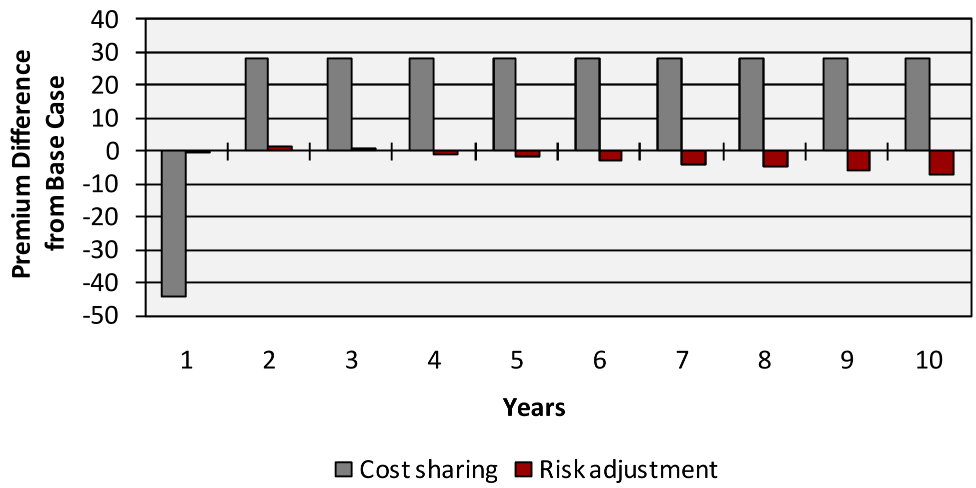

Figure 9: Premium Difference Cost Sharing and Risk Adjustment

Figure 9 compares price paths under risk adjustment and cost sharing with our base case. This figure shows that risk adjustment helps health plans by improving their resistance to death spirals. Health plans charge a first period premium only slightly lower than in our base case but prices increase less after the first period, implying a lower average premium for the same life span. With risk adjustment, there is less switching and the average switching cost is lower, as shown in Figure 8 and Table 6.

Although the results presented do not reflect a significant impact of risk adjustment, it should be said that, qualitatively, the effects described were present in all simulations performed. Moreover, the magnitude of these effects increases as the proportion of sick employees in the total population increases. Indeed, with a higher prevalence of illness among employees, risk adjustment allows plans to live longer than in the base case.

Even when risk adjustment increases the optimal life span, the sum of average premium plus average switching cost is lower than in our base case, while intertemporal profits are equally null (Table 6). Thus, our simulations indicate that risk adjustment is welfare improving.

The last premium payment system considered in our simulations is a price floor. Our discussion in Section 1.2 seems to indicate that death spirals are less frequent when a price floor is established by the employer. As our model exemplifies, health plans enter the market with an extremely aggressive first period price, in the prospect of making use of their future market power, over their enrollees, to extract rents. In the following periods, faced with new health plans entering equally aggressively, the health plans' best strategy is to "*take advantage while they can*", *i.e.* rapidly increase premiums to make up for first period losses, while able to retain some enrollees. The abrupt premium increase culminates in death spirals with huge switching costs to consumers. The rationale behind the price floor premium payment system is to curtail first period competition, in the hope of eliminating the need to drastically increase premiums in the following periods.

The final column in each block of Table 4 presents the steady-state equilibrium values under a price floor premium payment system. The increase in prices is substantially lower than in all other systems considered. Not only do premiums, from the first to the second period, increase substantially less in the second period but plans also choose to live three additional years. Consequently, the proportion of switchers is almost half that of the base case and average switching costs decreases from $111 to $56 (Table 6).

Table 6: Comparing Switchers, Switching Costs, Premiums and Profits for Different Payment Systems

	Base Case	Cost Sharing	Risk Adjustment	Price Floor
Life Span	10	10	10	13
Inv. Healthy Switchers	0.22	0.22	0.22	0.15
Inv. Sick Switchers	0.12	0.12	0.12	0.10
Vol. Healthy Switchers	1.92	1.94	1.90	1.07
Vol. Sick Switchers	0.40	0.40	0.39	0.19
% Inv. Switchers	3.4%	3.4%	3.5%	2.5%
% Vol. Switchers	23.2%	23.4%	23.0%	12.7%
Cost Inv. Healthy Switchers	$191	$201	$194	$124
Cost Inv. Sick Switchers	$104	$109	$106	$78
Cost Vol. Healthy Switchers	$672	$748	$663	$297
Cost Vol. Sick Switchers	$146	$161	$143	$58
Average Switching Cost (ASWC)	**$111**	**$122**	**$110**	**$56**
Average Premium (AP)	**$1,490**	**$1,511**	**$1,488**	**$1,665**
ASWC+AP	**$1,601**	**$1,633**	**$1,598**	**$1,720**
Sum of Profits	**$0**	**$0**	**$0**	**$2,265**

In Table 6, it is possible to compare average switching costs and average premiums for the four premium payment systems considered. Indeed, average premiums plus average switching costs are $118 per person/year higher with a price floor than in our base case, but profits are also substantially higher. While in all other scenarios the sum of discounted profits over the life span of the plan was zero, in the price floor case health plans have an overall profit of $2.265, *i.e.* a profit of $226.5 per employee. This means that there is margin for Pareto movements, when comparing our base case (or, actually, any of the other three premium payment systems) with the price floor scenario.

Figure 10 illustrates the evolution of the ratio of healthy to sick enrollees over time, in each of the four scenarios. The horizontal line at four identifies the population average ratio for healthy and sick employees. Points above that line reflect a favorable selection of enrollees, while points below indicate adverse selection. Under all four of the scenarios, new entrants attract favorable selections. In all but the price floor scenario, health plans have a favorable selection for only three periods. Both cost sharing and risk adjustment yield a more favorable (or less adverse) ratio than the base case in all periods, but the magnitude is bigger in the second (the difference is decreasing in time). Although risk adjustment somewhat slows down switching, it is not enough to maintain a favorable selection for more periods than cost sharing or the base case. The price floor scenario has the slowest rate of deterioration, with enrollments being above the average for four periods. After that, the ratio of healthy to sick falls below the population average but remains less adverse than in the other three cases.

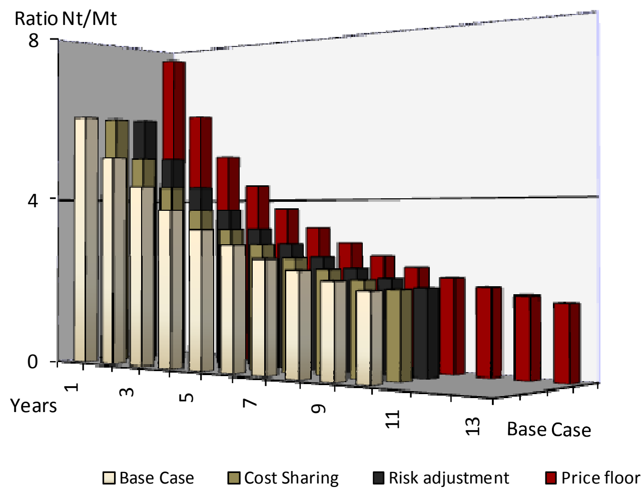

Figure 10: Ratio of Healthy to Sick for Four Premium Payment Systems

1.7. Sensitivity Analysis

In Table 7 to Table 12, we provide the results of the sensitivity analysis. In each table, we allow one parameter to vary and keep the remaining parameters at their baseline values. In each table, we consider two alternative values for the parameter under analysis: one below the baseline value and one above it. For comparison, all tables include the baseline itself.

Different parameter values result not only in different equilibrium values for $\{N_t\}$, $\{M_t\}$, $\{P_t\}$ and $\{\Pi_t\}$ but also in distinct optimal life spans. In Table 7, we provide an example of how the optimal life span is obtained in each sensitivity analysis table. This is done by solving the model for a sequence of possible life spans (three to seven years are shown in that table). Obviously, not all life spans considered are optimal life spans, in the sense that a profitable deviation might exist, but each column shows the optimal price sequence, given the life span. For example, as shown in Table 7, for a fixed cost of $500, a life span of 6 years yields a negative profit in the last year (-69\$), which indicates that the optimal lifespan is 5 years.

Table 7: Equilibrium Results under Different Fixed Costs Values

Life Span		3			4			5			6			7		
FC	**Period**	**0**	**100**	**500**	**0**	**100**	**500**	**0**	**100**	**500**	**0**	**100**	**500**	**0**	**100**	**500**
	1	$956	$986	$1,110	$901	$941	$1,111	$862	$912	$1,131	$833	$893	$1,164	$810	$880	$1,207
	2	$1,583	$1,598	$1,659	$1,552	$1,572	$1,656	$1,530	$1,554	$1,662	$1,512	$1,541	$1,674	$1,498	$1,532	$1,692
	3	$1,594	$1,609	$1,670	$1,563	$1,583	$1,667	$1,541	$1,565	$1,673	$1,523	$1,552	$1,686	$1,509	$1,543	$1,703
P	4				$1,574	$1,594	$1,678	$1,552	$1,576	$1,684	$1,534	$1,563	$1,697	$1,520	$1,554	$1,714
	5							$1,562	$1,587	$1,695	$1,545	$1,574	$1,707	$1,531	$1,565	$1,725
	6										$1,555	$1,584	$1,718	$1,541	$1,575	$1,736
	7													$1,551	$1,585	$1,746
	1	4.99	4.91	4.62	4.49	4.37	3.94	4.17	4.01	3.45	3.94	3.75	3.07	3.78	3.55	2.76
	2	1.63	1.67	1.82	1.37	1.41	1.57	1.21	1.26	1.42	1.11	1.15	1.32	1.03	1.08	1.25
	3	1.38	1.42	1.56	1.16	1.20	1.34	1.02	1.06	1.21	0.93	0.98	1.13	0.87	0.92	1.07
N	4				0.98	1.02	1.15	0.87	0.90	1.03	0.79	0.83	0.96	0.73	0.78	0.91
	5							0.73	0.76	0.88	0.67	0.70	0.82	0.62	0.66	0.78
	6										0.56	0.59	0.70	0.52	0.55	0.67
	7													0.44	0.47	0.57
	1	1.15	1.13	1.05	0.99	0.96	0.85	0.88	0.84	0.70	0.80	0.75	0.59	0.73	0.68	0.50
	2	0.43	0.44	0.48	0.35	0.36	0.39	0.30	0.31	0.34	0.26	0.27	0.30	0.24	0.24	0.27
	3	0.42	0.43	0.47	0.34	0.35	0.38	0.29	0.30	0.33	0.25	0.26	0.29	0.23	0.24	0.26
M	4				0.32	0.33	0.37	0.28	0.29	0.32	0.24	0.25	0.29	0.22	0.23	0.26
	5							0.26	0.27	0.31	0.23	0.24	0.27	0.21	0.22	0.25
	6										0.22	0.23	0.26	0.20	0.21	0.24
	7													0.18	0.19	0.23
	1	-$1,421	-$1,316	-$928	-$1,532	-$1,376	-$818	-$1,575	-$1,367	-$658	-$1,589	-$1,331	-$487	-$1,589	-$1,281	-$320
	2	$769	$719	$539	$600	$554	$395	$502	$459	$324	$439	$400	$291	$396	$362	$279
	3	$652	$596	$390	$506	$453	$267	$422	$372	$207	$368	$322	$179	$331	$289	$171
Profit	4				$427	$369	$157	$354	$299	$106	$308	$256	$84	$277	$227	$77
	5							$298	$237	$20	$258	$200	$1	$231	$176	-$3
	6										$216	$153	-$69	$193	$132	-$72
	7													$161	$95	-$131
%IS		16%	17%	18%	12%	12%	14%	9%	9%	11%	7%	7%	9%	6%	6%	7%
%VS		35%	34%	29%	33%	31%	24%	32%	29%	21%	30%	28%	18%	30%	26%	15%
AVSWC		$245	$240	$222	$209	$202	$175	$185	$176	$142	$169	$157	$116	$156	$142	$96

Note: FC=fixed cost, N=Healthy enrollees, M=Sick enrollees, IS=Involuntary sw itchers, VS=voluntary sw itcher, AVSWC=average sw itching cost

The optimal life span is highly sensitive to the value of fixed costs (Table 7). If no fixed costs are present, plans tend to live "forever" with minimal enrollments. But with fixed costs as low as one hundred (ten percent of treatment cost of a healthy enrollee), plans die after ten periods.

Overall, the model is "well-behaved" in that if an increase in a given parameter yields a decrease in one independent variable, it does so regardless of the parameters’ chosen value or of how much it increases. To get a feel for how to interpret these tables, we describe the results from Table 8 in detail, and then focus on only the interesting features of the remaining tables.

Table 8: Equilibrium Results under Different Probabilities of Becoming Sick

s	0.01				0.03				0.1			
Ntotal	9				8				5			
Mtotal	1				2				5			
Life Span	T*=11				T*=10				T*=7			
	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal
t=1	$750	-$1,146	358	238	$876	-$1,107	398	268	$1,182	-$1,095	508	388
t=2	$1,408	$263	118	88	$1,516	$304	128	108	$1,827	$401	148	148
t=3	$1,412	$218	98	88	$1,528	$240	108	108	$1,857	$280	108	138
t=4	$1,417	$179	88	88	$1,539	$186	98	98	$1,883	$189	88	128
t=5	$1,421	$144	78	88	$1,550	$141	78	98	$1,906	$122	68	118
t=6	$1,426	$114	68	88	$1,561	$102	68	98	$1,926	$71	48	108
t=7	$1,430	$87	68	78	$1,571	$70	58	88	$1,945	$33	38	88
t=8	$1,435	$64	58	78	$1,581	$43	48	88				
t=9	$1,439	$43	48	78	$1,591	$20	48	78				
t=10	$1,444	$25	48	78	$1,600	$1	38	78				
t=11	$1,448	$10	38	68								
	Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary	
Switchers	21%		3%		23%		3%		29%		5%	
Sw. Costs	$718		$277		$818		$295		$1,076		$443	
Average Sw. Costs	$100				$111				$152			

Table 8 provides the solution to our model, assuming $\{l, W, C_N, C_M, CF, \rho\} = \{0.9, 1000, 1000, 2000, 100, 1\}$ and considering three possible values for s, $\{0.01, 0.03, 0.1\}$. Each of the three blocks in Table 8 provides the solution to the model under one value of s. The second block, where $s = 0.03$, corresponds to our baseline. Each block has four columns providing the results for the four equilibrium series: $\{N_t\}$, $\{M_t\}$, $\{P_t\}$ and $\{\Pi_t\}$. Because varying s and d alters the (steady-state) total number of healthy (N) and sick employees (M) in the firm, Table 8 and Table 9 include two extra rows with the corresponding N and M. The third column, where $s = 0.1$, is of especial interest because it yields an equal number of healthy and sick employees in the firm, which allows us to isolate the effect of biased arrival *per se*.

For a given life span, an increase in s is associated with steeper spirals (defined as a higher difference between the price in the first period and prices in subsequent periods)[17] and higher percentage of voluntary switchers. Nevertheless, because varying s, changes the ratio of healthy to sick employees, an increase in s changes the optimal life span and results in a mixed effect on death spirals steepness. Note that, for the optimal life span associated with each value of s (as shown in Table 8), the percentage increase in price from the first to the second period is decreasing in s while the percent increase in price in subsequent periods is increasing in s. The first effect results from the fact that a market where individuals become sick at a lower rate is a more attractive one and plans are thus more willing to forgo profits in the first period. The second effect is a consequence of the fact that with a higher proportion of sick enrollees average cost increases faster. The overall effect results in a lower percentage of voluntary

[17] Results not shown.

switching for more favorable healthy to sick ratio (lower s). Because a lower probability of becoming sick allows plans to live longer (the optimal life span is decreasing in s) the percentage of involuntary switchers also decreases and, as a result, average switching costs ($AVSWC$) are lower for low values of s.

Table 9: Equilibrium Results under Different Probabilities of Leaving the Firm

d	0.05				0.1				0.15			
Ntotal	13				8				6			
Mtotal	7				2				1			
Life Span	T*=15				T*=10				T*=7			
	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal
t=1	$892	-$2,255	328	228	$867	-$1,107	398	268	$883	-$730	468	318
t=2	$1,589	$406	98	78	$1,516	$304	128	108	$1,502	$264	158	138
t=3	$1,599	$350	88	78	$1,528	$240	108	98	$1,514	$190	128	138
t=4	$1,608	$300	78	78	$1,539	$186	98	98	$1,526	$131	98	128
t=5	$1,618	$255	68	68	$1,550	$141	78	98	$1,538	$84	78	118
t=6	$1,627	$215	68	68	$1,561	$102	68	88	$1,549	$46	68	108
t=7	$1,636	$180	58	68	$1,571	$70	58	88	$1,560	$16	58	98
t=8	$1,644	$148	58	68	$1,581	$43	48	78				
t=9	$1,653	$120	48	58	$1,591	$20	48	78				
t=10	$1,661	$95	48	58	$1,600	$1	38	68				
t=11	$1,669	$73	38	58								
t=12	$1,677	$53	38	58								
t=13	$1,684	$36	38	48								
t=14	$1,691	$20	28	48								
t=15	$1,698	$6	28	48								
	Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary	
Switchers	21%		3%		23%		3%		25%		5%	
Sw. Costs	$1,658		$469		$818		$295		$540		$256	
Average Sw. Costs	$106				$111				$119			

In Table 9, we see that plans enter more aggressively (the entering price is lower) as d increases, which might seem unlikely. Why would plans be more willing to incur losses if they are less likely to be able to retain their enrollees? The reason being that the ratio of healthy to sick also changes; in particular the ratio is increasing with d. At $d = 0.15$ the ratio is six, making this market a quite attractive one. This "healthier market" implies that, even at a lower first period price, losses incurred in the first period are lower than losses incurred when entering at a higher price with a less attractive ration of healthy to sick. Obviously, plans live longer when d is low.

With respect to Table 11 and Table 12, it is worth mentioning that as health costs of healthy and sick become closer, spirals become less steep ($P_T - P_1$ is smaller). There is also less switching and lower average switching cost.

Table 10: Equilibrium Results under Different maximum Switching Costs Values

W	$400				$1,000				$1,500			
Life Span	T*=5				T*=10				T*=12			
	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal
t=1	$1,116	-$371	498	418	$867	-$1,107	398	268	$639	-$1,827	388	238
t=2	$1,356	$171	178	178	$1,516	$304	128	108	$1,647	$410	118	88
t=3	$1,367	$111	148	168	$1,528	$240	108	98	$1,659	$338	98	88
t=4	$1,378	$63	118	148	$1,539	$186	98	98	$1,670	$275	88	88
t=5	$1,388	$25	98	138	$1,550	$141	78	98	$1,682	$222	78	88
t=6					$1,561	$102	68	88	$1,692	$176	68	88
t=7					$1,571	$70	58	88	$1,703	$137	58	78
t=8					$1,581	$43	48	78	$1,713	$104	48	78
t=9					$1,591	$20	48	78	$1,723	$75	48	68
t=10					$1,600	$1	38	68	$1,733	$50	38	68
t=11									$1,742	$29	38	68
t=12									$1,751	$11	28	58
	Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary	
Switchers	28%		9%		23%		3%		23%		3%	
Sw. Costs	$378		$298		$818		$295		$1,208		$335	
Average Sw. Costs	$68				$111				$154			

Table 10 shows the solution under three possible values for the maximum switching cost (W). As clearly shown in the table, price escalation is highly associated with the presence of switching costs. As expected, for higher values of W, plans are more willing to invest in the first period because higher switching costs will allow them to compensate for initial losses, through higher future prices. Moreover, plans will not only charge higher prices but also survive longer, which, again, creates an incentive for aggressive entrance.

Table 11: Equilibrium Results under Different Cost of Healthy Enrollees

CN	$100				$1,000				$1,500			
Life Span	T*=8				T*=10				T*=11			
	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal
t=1	$154	-$1,106	448	328	$867	-$1,107	398	268	$1,268	-$1,131	378	238
t=2	$798	$371	148	128	$1,516	$304	128	108	$1,923	$268	118	88
t=3	$819	$274	118	118	$1,528	$240	108	98	$1,929	$220	108	98
t=4	$840	$196	98	118	$1,539	$186	98	98	$1,935	$178	88	98
t=5	$861	$133	78	108	$155	$141	78	98	$1,940	$142	78	88
t=6	$881	$82	68	98	$1,561	$102	68	88	$1,946	$111	68	88
t=7	$900	$41	58	88	$1,571	$70	58	88	$1,951	$84	58	88
t=8	$919	$9	48	78	$1,581	$43	48	78	$1,956	$60	58	78
t=9					$1,591	$20	48	78	$1,961	$40	48	78
t=10					$1,600	$1	38	68	$1,966	$22	38	78
t=11									$1,970	$6	38	68
	Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary	
Switchers	27%		4%		23%		3%		21%		3%	
Sw. Costs	$994		$369		$818		$295		$728		$274	
Average Sw. Costs	$136				$111				$100			

Table 12: Equilibrium Results under Different Cost of Sick Enrollees

CM	$1,100				$2,000				$4,000			
Life Span	T*=12				T*=10				T*=7			
	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal	Prem.	Profit	Nt/ Ntotal	Mt/ MTotal
t=1	$691	-$1,149	368	78	$867	-$1,107	398	268	$1,305	-$921	468	368
t=2	$1,353	$236	118	88	$1,516	$304	128	108	$1,934	$450	158	148
t=3	$1,354	$201	98	88	$1,528	$240	108	98	$1,968	$309	128	138
t=4	$1,356	$169	88	88	$1,539	$186	98	98	$2,000	$200	98	118
t=5	$1,357	$140	78	88	$1,550	$141	78	98	$2,032	$116	78	108
t=6	$1,358	$115	68	88	$1,561	$102	68	88	$1,064	$53	68	98
t=7	$1,359	$92	58	88	$1,571	$70	58	88	$1,094	$5	48	78
t=8	$1,360	$72	58	78	$1,581	$43	48	78				
t=9	$1,361	$54	48	78	$1,591	$20	48	78				
t=10	$1,362	$38	48	78	$1,600	$1	38	68				
t=11	$1,363	$23	38	68								
t=12	$1,364	$10	38	68								
	Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary	
Switchers	20%		3%		23%		3%		30%		4%	
Sw. Costs	$656		$253		$818		$295		$1,113		$400	
Average Sw. Costs	$91				$111				$100			

Table 11 and Table 12 provide the results of the sensitivity analysis to the cost of healthy and sick enrollees. Higher costs of healthy enrollees, while maintaining the cost of sick enrollees at its base value, reduces the cost disadvantage between incumbent and new entrants, thereby allowing plans to live longer. By the same token, reducing the cost of sick enrollees allows plans to live longer.

As expected, for the same life span, if discounting is included (not shown) and the future is worth less, plans are less willing to incur losses in the first period and will set a higher first period price. This will, in turn, generate lower first period market shares, lower profits and lower switching.

1.8. Discussion

This paper has examined the implications of a premium payment system in a model in which identical health plans attract different mixes of healthy and sick enrollees, according to how long a health plan has been offered by an employer. We first reviewed some empirical evidence that highlights that some insurance organizations, namely the Blue Cross Blue Shield plans, have been regularly exiting and entering with different health plan options, as our theoretical model would predict.

The experience at Boston University, Minnesota and California also differs in that the highest rates of exit and entry and greatest dispersion of pricing have occurred with partial premium cost sharing, and the lowest rates have occurred with premium price floors. Clearly, there are a great many other changes taking place in these markets for health plans, however our model provides a rationale for this empirical evidence and our simulations confirm it.

Our model shows that, in the presence of switching costs, cost sharing is potentially harmful because it increases plans' market power.

In our simulations, we show that, by contradicting the forces driving prices up, the increase in costs due a deterioration of the mix of enrollees, risk adjustment creates the right incentives for plans not to follow a death spiral pattern. Slowing down death spirals, risk adjustment also decreases switching costs, thus increasing consumers' welfare with no impact on profits.

Price floors were found to be extremely effective at reducing switching costs. They are also found to increase average premiums and profits but, at least in our simulations, the increase in profits is higher than the increase in total costs to consumers, implying a margin for welfare improvement. We are perfectly aware of the fact that our simple model may not capture many relevant aspects and that simulations are simulations. However, the possibility for price floors to be welfare improving exists, and it is our hope that this paper will stimulate further research on the subject.

Such research will shed light on the full policy implications of our findings. The "*churning*" phenomenon, widely referred to in the health policy literature [26, 27], has led some States in the United States of America to administratively establish an upper limit to price increases in health plan premiums. More often than not, such policy has led the insurance companies to anticipate product removal from the market, thereby generating elevated switching costs to consumers. If, as suggested by our model, price floors are found to be more effective than current approaches aimed at minimizing the impact of *"churning"* and death spirals, than such option should be tested and implemented.

What is more, lessons to be learned from such analysis are relevant to other countries, such as Portugal, where the employer-provided private insurance market is growing [24]. Because death spirals are a consequence of how contracts are written between health plan providers and employers, awareness of both the consequences and the mechanisms to minimize such consequences, will be useful in setting the appropriate grounds on which the employer-provided private insurance market is to grow.

The model we use is limited in a number of ways that could be relaxed and studied in future research. We mention a few that seem particularly important to us. The first, which we have mentioned previously, is that it assumes an equal distribution of switching costs for healthy and sick enrollees. One would expect that a consumer who visits his physician quite often to be less willing to change provider than someone who almost never makes use of his insurance plan. Second, we focus on the simple case in which there are only two types of consumers, healthy and sick, whereas in the real world there are a continuum of types, with different demand responsiveness and treatment costs. Health care spending is stochastic and, for this reason, consumers may need to make choices prior to knowing their health costs needs. We focus on the case in which plans are all identical, and the only switching cost is a fixed cost for changing plans. An alternative framework, that might be interesting to contemplate, is one that is closer to a matching model, in which consumers derive utility each period that depends on the quality of their match with a health plan. Finally, there is no moral hazard problem in our paper, and plans do not explicitly adopt strategies to affect health plan choices other than through pricing. If service distortion and/or explicit dumping are permitted, it would clearly change the optimal pricing, entry, and exit decisions.

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Appendix I

Proof on the Expressions for Healthy and Sick

Claim: $X_t \equiv \begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} F_t l^{t-1} k^{t-1} N_1 \\ F_t l^{t-1}\{M_1 + [1-k^{t-1}]N_1\} \end{bmatrix}$

Remark: $f_1 \equiv F_1 \equiv 1; f_{T+1} \equiv F_{T+1} \equiv 0$

Proof:

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} f_t lkN_{t-1} \\ f_t l(M_{t-1} + sN_{t-1}) \end{bmatrix} <=>$$

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-1} + \widehat{P_{Min}}} lk \left(\dfrac{W - P_{t-1} + \widehat{P_{Min}}}{W - P_{t-2} + \widehat{P_{Min}}} lkN_{t-2} \right) \\ \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-1} + \widehat{P_{Min}}} l \left\{ \dfrac{W - P_{t-1} + \widehat{P_{Min}}}{W - P_{t-2} + \widehat{P_{Min}}} l(M_{t-2} + sN_{t-2}) + s\left(\dfrac{W - P_{t-1} + \widehat{P_{Min}}}{W - P_{t-2} + \widehat{P_{Min}}} lkN_{t-2} \right) \right\} \end{bmatrix} <=>$$

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-2} + \widehat{P_{Min}}} l^2 k^2 N_{t-2} \\ \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-2} + \widehat{P_{Min}}} l^2 (M_{t-2} + sN_{t-2} + skN_{t-2}) \end{bmatrix} <=>$$

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-3} + \widehat{P_{Min}}} l^3 k^3 N_{t-3} \\ \dfrac{W - P_t - \widehat{P_{Min}}}{W - P_{t-3} + \widehat{P_{Min}}} l^3 \{M_{t-3} + s(N_{t-3} + kN_{t-3} + k^2 N_{t-3})\} \end{bmatrix} <=>$$

Recursively substituting up to period 1 results in:

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} \dfrac{W - P_t - \widehat{P_{Min}}}{W} l^{t-1} k^{t-1} N_1 \\ \dfrac{W - P_t - \widehat{P_{Min}}}{W} l^{t-1} \{M_1 + s(1 + k + k^2 + \cdots + k^{t-2})N_1\} \end{bmatrix} <=>$$

$$\begin{bmatrix} N_t \\ M_t \end{bmatrix} = \begin{bmatrix} F_t l^{t-1} k^{t-1} N_1 \\ F_t l^{t-1}\{M_1 + [1-k^{t-1}]N_1\} \end{bmatrix}$$

Proof on the Cumulative Probability of Not Switching

Claim: $F_t \equiv \prod_{i=1}^{t} f_i = \frac{W - P_t + \widehat{P_{M\iota n}}}{W}$

Switching costs $w \sim U[0,1]$ and consumers will switch if $P_t > \widehat{P_{M\iota n}} + w$

Thus, the probability of not switching in period t, considering that they did not switch in the previous period is:

$$f_t = P(\overline{Sw_\iota}|\overline{Sw_{\iota-1}}) = P\left(w > P_t - \widehat{P_{M\iota n}}|w > P_{t-1} - \widehat{P_{M\iota n}}\right) = \frac{W - \left(P_t - \widehat{P_{M\iota n}}\right)}{W - \left(P_{t-1} - \widehat{P_{M\iota n}}\right)}$$

So,

$$F_t = \prod_{i=2}^{t} P(\overline{Sw_\iota}|\overline{Sw_{\iota-1}}) = \frac{W - P_t + \widehat{P_{M\iota n}}}{W - P_{t-1} + \widehat{P_{M\iota n}}} \frac{W - P_{t-1} + \widehat{P_{M\iota n}}}{W - P_{t-2} + \widehat{P_{M\iota n}}} \dots \frac{W - P_2 + \widehat{P_{M\iota n}}}{W}$$

$$= \frac{W - P_t + \widehat{P_{M\iota n}}}{W}$$

Proof of the Average Cost Expression

Claim: $AVC_t = \frac{C_N k^{t-1} N_1 + C_M\left[M_1 + \left(1 - k^{t-1}\right)N_1\right]}{N_1 + M_1}, \forall_{t=2,\dots,T}$

Proof:

$$AVC_t = \frac{C_N N_\text{t} + C_M \text{M}_\text{t}}{N_\text{t} + M_\text{t}} = \frac{C_N(F_t l^{t-1} k^{t-1} N_1) + C_M(F_t l^{t-1}\{M_1 + [1 - k^{t-1}]N_1\})}{N_\text{t} + M_\text{t}}$$

$$<=> AVC_t = \frac{F_t l^{t-1}[C_N k^{t-1} N_1 + C_M(M_1 + [1 - k^{t-1}]N_1)]}{F_t l^{t-1}[k^{t-1} N_1 + (M_1 + [1 - k^{t-1}]N_1)]}$$

$$<=> AVC_t = \frac{[C_N k^{t-1} N_1 + C_M(M_1 + [1 - k^{t-1}]N_1)]}{[k^{t-1} N_1 + (M_1 + [1 - k^{t-1}]N_1)]}$$

$$<=> AVC_t = \frac{[C_N k^{t-1} N_1 + C_M(M_1 + [1 - k^{t-1}]N_1)]}{N_1 + M_1}$$

Proof of N_1^*

Claim: $N_1^* = \frac{1}{(1-kl)\sum_{t=1}^{T} k^{t-1} l^{t-1} F_t^*}$

Proof:

$$N_1 = NE + IHS + VHS$$

$$<=> \mathrm{N_1} = 1 + \mathrm{klN_t} + \sum_{t=1}^{T-1} k^t l^t \mathrm{F_t}(1 - \mathrm{f_{t+1}})\mathrm{N_1} <=> 1 + \mathrm{k^T l^T F_T N_1} + \sum_{t=1}^{T-1} k^t l^t \mathrm{F_t}(1 - \mathrm{f_{t+1}})\mathrm{N_1} <=>$$

$$<=> \mathrm{N_1} = 1 + \sum_{t=1}^{T} k^t l^t \mathrm{F_t}(1 - \mathrm{f_{t+1}})\mathrm{N_1} <=> 1 + \mathrm{k^T l^T F_T N_1} + \sum_{t=1}^{T-1} k^t l^t \mathrm{F_t}(1 - \mathrm{f_{t+1}})\mathrm{N_1} <=>$$

$$<=> \mathrm{N_1^*} = \frac{1}{1 - \sum_{t=1}^{T} k^t l^t (\mathrm{F_t^*} - \mathrm{F_{t+1}^*})} <=> \mathrm{N_1^*} = \frac{1}{1 - \{\mathrm{k^0 l^0 F_1^*} + \sum_{t=1}^{T} (k^t l^t - k^{t-1} l^{t-1})\mathrm{F_t^*}\}}$$

$$<=> \mathrm{N_1^*} = \frac{1}{\sum_{t=1}^{T} (k^t l^t - k^{t-1} l^{t-1})\mathrm{F_t^*}}$$

Note that: $N_1^* = \frac{1}{(1-kl)\sum_{t=1}^{T} k^{t-1} l^{t-1} F_t^*} \Rightarrow N^* = \frac{1}{(1-kl)}$

Proof of M_1^*

Claim: $M_1^* = \frac{N_1^* \sum_{t=1}^{T} [l^t(1-k^t) - l^{t-1}(1-k^{t-1})] F_t^*}{(1-l)\sum_{t=1}^{T} l^{t-1} F_t^*}$

Proof:

$$M_1 = M_T l + slN_T + \sum_{i=1}^{T-1} (M_i l + slN_i)(1 - f_{i+1})$$

$$<=> M_1 = F_T l^T \{M_1 + [1 - k^{T-1}]N_1\} + sF_T l^T k^{T-1} N_1 + \sum_{t=1}^{T-1} (F_i l^t \{M_1 + [1 - k^{T-1}]N_1\} + sF_t l^t k^{t-1} N_1)(1 - f_{t+1})$$

$$<=> M_1 = F_T l^T\{M_1 + [1 - k^{T-1} + sk^{T-1}]N_1\} + \sum_{t=1}^{T-1} l^t(M_1 + [1 - k^{t-1}]N_1 + sF_t l^t k^{t-1} N_1)(F_t - F_{t+1})$$

$$<=> M_1 = F_T l^T\{M_1 + [1 - k^T]N_1\} + \sum_{i=1}^{T-1} l^t(M_1 + [1 - k^t]N_1)(F_t - F_{t+1})$$

$$<=> M_1 = N_1\left\{F_T l^T(1 - k^{T-1}) + \sum_{i=1}^{T-1} l^t(1 - k^t)(F_t - F_{t+1})\right\} + M_1\left\{F_T l^T + \sum_{i=1}^{T-1} l^t(F_t - F_{t+1})\right\}$$

$$M_1^* = \frac{N_1^*\{F_T^* l^T(1 - k^{T-1}) + \sum_{i=1}^{T-1} l^t(1 - k^t)(F_t^* - F_{t+1}^*)\}}{\{1 - F_T^* l^T - \sum_{i=1}^{T-1} l^t(F_t^* - F_{t+1}^*)\}}$$

$$<=> M_1^* = \frac{N_1^*\{F_T^* l^T(1 - k^T) + [-l^{T-1}(1 - k^{T-1})F_T^* + \sum_{i=1}^{T-1}[l^t(1 - k^t) - l^{t-1}(1 - k^{t-1})]F_t^*]\}}{\{1 - F_T^* l^T - [1 - l^{T-1}F_T^* + \sum_{i=1}^{T-1}(l^t - l^{t-1})F_t^*]\}}$$

$$<=> M_1^* = \frac{N_1^*\{F_T^* l^T(1 - k^T) + [-l^{T-1}(1 - k^{T-1})F_T^* + \sum_{i=1}^{T-1}[l^t(1 - k^t) - l^{t-1}(1 - k^{t-1})]F_t^*]\}}{\{1 - F_T^* l^T - [1 - l^{T-1}F_T^* + \sum_{i=1}^{T-1}(l^t - l^{t-1})F_t^*]\}}$$

$$<=> M_1^* = \frac{N_1^*\{F_T^*[l^T(1 - k^T) - l^{T-1}(1 - k^{T-1})] + \sum_{i=1}^{T-1}[l^t(1 - k^t) - l^{t-1}(1 - k^{t-1})]F_t^*\}}{\{-F_T^* l^T + l^{T-1}F_T^* + \sum_{i=1}^{T-1}(l^{t-1} - l^t)F_t^*\}}$$

$$<=> M_1^* = \frac{N_1^*\{F_T^*[l^T(1 - k^T) - l^{T-1}(1 - k^{T-1})] + \sum_{i=1}^{T-1}[l^t(1 - k^t) - l^{t-1}(1 - k^{t-1})]F_t^*\}}{\{F_T^*(l^{T-1} - l^T) + \sum_{i=1}^{T-1}(l^{t-1} - l^t)F_t^*\}}$$

$$<=> M_1^* = \frac{N_1^* \sum_{i=1}^{T}[l^t(1 - k^t) - l^{t-1}(1 - k^{t-1})]F_t^*}{\sum_{i=1}^{T}(l^{t-1} - l^t)F_t^*}$$

Note that: $M_1^* = \frac{N_1^* \sum_{t=1}^{T}[l^t(1-k^t) - l^{t-1}(1-k^{t-1})]F_t^*}{(1-l)\sum_{t=1}^{T} l^{t-1}F_t^*} \Rightarrow M^* = \frac{l}{1-l} - \frac{kl}{(1-kl)}$

Proof of Optimal P_t

Claim: $P_t = \frac{(W+\widehat{P_{M\imath n}})}{2} + \frac{AVC_t}{2}$

Proof: Because of the simplification made to the model, profit in any period $t = 2,\dots,T$ does not depend on any past period prices. Therefore, maximizing Π_t yields the same result as maximizing $\sum_{i=t}^{T} \Pi_i$, so the problem resumes to static maximization. For $t = 2,\dots,T$

$$\Pi_t = (P_t - C_N)N_t + (P_t - C_M)M_t - FC$$

$$<=> \Pi_t = (P_t - C_N)\frac{W - P_t + \widehat{P_{M\imath n}}}{W} l^{t-1}k^{t-1}N_1 + (P_t - C_M)\frac{W - P_t + \widehat{P_{M\imath n}}}{W} l^{t-1}(M_1 + (1 - k^{t-1})N_1) - FC$$

$$<=> \Pi_t = \left[-P_t^2 + P_t\left(W - \widehat{P_{M\imath n}} + C_N\right) - C_N\left(W + \widehat{P_{M\imath n}}\right)\right]\frac{l^{t-1}k^{t-1}N_1}{W} + \left[-P_t^2 + P_t\left(W - \widehat{P_{M\imath n}} + C_M\right) - C_M\left(W + \widehat{P_{M\imath n}}\right)\right]\frac{l^{t-1}}{W}(M_1 + (1 - k^{t-1})N_1) - FC$$

$$<=> \Pi_t = \frac{l^{t-1}}{W}\{-P_t^2[N_1 + M_1] + P_t\left[\left(W + \widehat{P_{M\imath n}}\right)(N_1 + M_1) + C_N k^{t-1}N_1 + C_M(M_1 + (1 - k^{t-1})N_1)\right] - \left(W + \widehat{P_{M\imath n}}\right)[C_N k^{t-1}N_1 + C_M(M_1 + (1 - k^{t-1})N_1)]\} - FC$$

$$<=> \Pi_t = \frac{l^{t-1}}{W}\left\{-P_t^2[N_1 + M_1] + P_t\left[\left(W + \widehat{P_{M\imath n}}\right)(N_1 + M_1) + \frac{\widetilde{TC_t}}{l^{t-1}}\right] - \left(W + \widehat{P_{M\imath n}}\right)\frac{\widetilde{TC_t}}{l^{t-1}}\right\} - FC$$

$$<=> \Pi_t = \frac{l^{t-1}}{W}(N_1 + M_1)\{-P_t^2 + P_t\left(W + \widehat{P_{M\imath n}}\right) + AC_t - \left(W + \widehat{P_{M\imath n}}\right)AC_t\} - FC$$

$$\frac{\vartheta \Pi_t}{\vartheta P_t} = 0 <=> \frac{l^{t-1}}{W}(N_1 + M_1)\{-2P_t^2 + \left(W + \widehat{P_{M\imath n}}\right) + AC_t\} = 0$$

$$<=> P_t = \frac{\left(W + \widehat{P_{M\imath n}}\right)}{2} + \frac{AVC_t}{2}$$

Proof of Optimal Profit Expression

Claim: $\prod_t = \frac{l^{t-1}}{4W}(N_1 + M_1)\left[\left(W + \widehat{P_1}\right) - AVC_t\right]^2 - FC$

Proof:

$$\Pi_t = \frac{l^{t-1}(M_1+N_1)}{W}\left[P_t\left(\left\{\widehat{P_1}+W\right\}+AC_t\right) - \left\{\widehat{P_1}+W\right\}AC_t - P_t^2\right] - FC$$

$$\Leftrightarrow \Pi_t = \frac{l^{t-1}(M_1+N_1)}{W}\left[\left(\frac{W+\widehat{P_1}}{2}+\frac{AC_t}{2}\right)\left(\left\{\widehat{P_1}+W\right\}+AC_t\right) - \left\{\widehat{P_1}+W\right\}AC_t - \left(\frac{\left\{\widehat{P_1}+W\right\}}{2}+\frac{AC_t}{2}\right)^2\right] - FC$$

$$\Leftrightarrow \Pi_t = \frac{l^{t-1}(M_1+N_1)}{W}\left[\frac{1}{2}\left(\left\{\widehat{P_1}+W\right\}+AC_t\right)^2 - \left\{\widehat{P_1}+W\right\}AC_t - \frac{1}{4}\left(\left\{\widehat{P_1}+W\right\}+AC_t\right)^2\right] - FC$$

$$\Leftrightarrow \Pi_t = \frac{l^{t-1}(M_1+N_1)}{W}\left[\frac{1}{4\lambda}\left(\left\{\widehat{P_1}+W\right\}+AC_t\right)^2 - \left\{\widehat{P_1}+W\right\}AC_t\right] - FC$$

$$\Leftrightarrow \Pi_t = \frac{l^{t-1}(M_1+N_1)}{4W}\left(\left\{\widehat{P_1}+W\right\}-AC_t\right)^2 - FC$$

Proof of the Optimal Entry Price

Claim: $P_1 = AVC_1 + \frac{\sum_{t=1}^{T}\rho^{t-1}FC}{N_1+M_1} - \frac{1}{4w}\sum_{t=2}^{T}\rho^{t-1}l^{t-1}\left[\left(W+\widehat{P_1}\right) - AVC_t\right]^2$

Proof: Bertrand competition prior to entry forces $\sum_{t=1}^{T}\rho^{t-1}\prod_t = 0$ so:

$$\Pi_1 + \sum_{t=2}^{T}\rho^{t-1}\Pi_t = 0$$

$$\Leftrightarrow \left[(P_1 - C_N)N_1 + (P_1 - C_M)M_1 - FC + \sum_{t=2}^{T}\rho^{t-1}\left(\frac{N_1+M_1}{4W}l^{t-1}\left[\left(W+\widehat{P_1}\right)-AC_t\right]^2 - FC\right) = 0\right] = 0$$

$$\Leftrightarrow \left[P_1N_1 - C_NN_1 + M_1P_1 - M_1C_M - FC' + \frac{N_1+M_1}{4W}\sum_{t=2}^{T}\rho^{t-1}l^{t-1}\left[\left(W+\widehat{P_1}\right)-AC_t\right]^2 - \sum_{t=2}^{T}\rho^{t-1}FC\right] = 0$$

$$\Leftrightarrow \left[P_1(N_1+M_1) - (C_NN_1 + M_1C_M) + \frac{N_1+M_1}{4W}\sum_{t=2}^{T}\rho^{t-1}l^{t-1}\left[\left(W+\widehat{P_1}\right)-AC_t\right]^2 - \sum_{t=1}^{T}\rho^{t-1}FC\right] = 0$$

$$\Leftrightarrow P_1 = AC_1 - \frac{1}{4W}\sum_{t=2}^{T}\rho^{t-1}l^{t-1}\left[\left(W+\widehat{P_1}\right)-AC_t\right]^2 + \frac{\sum_{t=1}^{T}\rho^{t-1}FC}{N_1+M_1}$$

Determination of the Optimal Steady-State Live Span

Our model is a free terminal time discrete optimal control problem[18]. Unlike its continuous counterpart, there is no terminal condition uniquely defining T, the optimal time period [19].

In the presence of switching costs, plan owners know they will have market power over consumers once these are "captured". This implies that plans are willing to incur losses to attract potential consumers because they will be able to recover those losses in future years. If no restriction is imposed on first period profits (as it occurs in our price floor scenario), it is fairly intuitive to expect a pattern of profits beginning with negative profits in the first year, in order to establish market share, and positive profits in all subsequent years (recall that, by assumption, any plan unable to reach expected positive profits in the forthcoming year, exits at the begging of that year). Moreover, the longer plans live, the more profitable their market share will become. Thus, we expect P_1^* to be decreasing in T. Section 1.6, confirms this result.

Claim: T is optimal life span in steady-state equilibrium if the $HPPC$ is not satisfied at $T+1$, given the optimal price sequence for a life span of T and if the optimal sequence of profits for any life span $\tilde{T} > T$ yields a negative profit for some $t > 1$.

First note that, if given the optimal price sequence for a T life span, $\exists_{P_{T+1}}: \prod_{T+1} > 0$, there would be an incentive to offer the plan one more year and T would not be optimal to begin with. This is, thus, a necessary, although no sufficient, condition for equilibrium.

Now, suppose T was the optimal life span in the steady-state but the optimal sequence of prices and profits for plans living $\tilde{T}$ yielded positive profits in all periods beyond the first. Each year, the employer selects one plan from among the potentially many entrants. This "*pre-entrance*" competition implies that, if a plan announces a first period premium yielding zero intertemporal profits for a life span of T, some other plan could announce a (lower) first period price, equally generating zero intertemporal profits and satisfying the $HPPC$ but over a longer life span. And this last plan would be selected. Thus T could not be the optimal life span.

[18] We chose a discrete time model to capture the fact that health plan pricing decisions and commercial plan enrollment decisions are each made only once a year.

[19] For a discussion on terminal conditions in discrete optimal problems, we refer the reader to Ried, W. Health Economics, 1996. 5: p. 447-468, Grossman, M., The Human Capital Model, in Handbook of Health Economics, J.A. Culyer and J.P. Newhouse, Editors. 2000, Elsevier: Amsterdam and Eisenring, C., Health Economics, 2000. 9(8): p. 669-680.
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