Insurer Commitment and Dynamic Pricing Pattern: Theory and Evidence*

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Abstract

A central issue in dynamic contracting is the type of inter-temporal pricing pattern. Some insurance products exhibit a highballing (front-loaded) pattern, others lowballing (back-loaded), and still others are flat. In this paper, we develop a unified competitive dynamic insurance model with asymmetric learning to investigate the inter-temporal pricing pattern under different types of insurer’s commitment. The model predicts that the equilibrium contract exhibits highballing under one-sided commitment and lowballing under no commitment. We then use a unique empirical design of two products from one insurer to test our theoretical predictions, eliminating heterogeneity in firm, market, time horizon, and learning environment. We find that the dynamic contracts exhibit (i) a lowballing pattern in group critical illness insurance, a no commitment scenario and (ii) a highballing pattern in loaner’s personal accident insurance, a one-sided commitment scenario. These findings confirm our theoretical predictions.

Keywords: dynamic contract; commitment; asymmetric learning; information asymmetry; inter-temporal pricing

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Introduction

Multi-period dynamic relationships are prevalent in insurance markets and appreciated by both policyholders and insurers. The policyholder is willing to pay more for long-term coverage (Kunreuther and Michel-Kerjan, 2015) and the insurer is willing to provide more comprehensive coverage if the long-term insurance relationship is sustainable (Crocker and Moran, 2003). Dynamic insurance contracting is also economically relevant given that the majority of insurance products, either long-term or short-term with renewals, involve multi-period dynamic relationships.

The dynamic nature of multi-period insurance contracting, which is absent in a static setup, motivates theoretical and empirical investigations in the shape of the inter-temporal pricing pattern. Premiums can be different from one period to the next, either through a pre-agreed premium schedule under a long-term contract or through premium adjustments at the renewals of short-term contracts. The seminal models predict different inter-temporal pricing patterns, which can be categorized as lowballing (or back-loaded, Kunreuther and Pauly, 1985), highballing (or front-loaded, Cooper and Hayes, 1987), and flat (Watt and Vazquez, 1997) as depicted in Figure 1.

Previous studies suggest that the theoretical predictions of dynamic pricing pattern are sensitive to the commitment to contract of contractual parties and to the type of information asymmetries (see Table 1). The commitment to contract refers to insurer’s and policyholder’s ability to leave or modify the contract at the end of each period. The typical forms of insurer’s commitment include long-term contract and short-term contract with guaranteed renewability; insurer’s lack of commitment associates with renewable short-term contract. The information asymmetry regarding policyholder’s risk type involves two layers: information asymmetry between the policyholder and the insurer when signing the contract, and that between the incumbent insurer and its competing insurers. Different theoretical predictions based on various assumptions of commitment and information fueled empirical investigations of the dynamic pricing pattern in several insurance markets (see Table 2).

Focusing on the competitive insurance market, we first comprehensively review and structuralize the extant theoretical models and empirical evidence in dynamic insurance contracting. We then develop

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1 For example, Swiss insurers usually give a premium discount to policyholders that accept three- to five-year contracts, indicating a strong preference in long-term coverage.

2 It is less common to observe single-period insurance relationships in practice. Even for project based coverage, such as protections for construction projects or satellite launch, the project owner tends to continuously work with the same insurer for one project after another and hence it is essentially a multi-period dynamic relationship.

3 Another direction of multi-period contracting research concerns with the risk based dynamic selection (Finkelstein, McGarry, and Sufi, 2005). See Hendel (2016) for a survey on this topic.

4 The highballing (lowballing) pricing pattern means that the insurer charges a higher (lower) premium relative to the actuarial fair premium in early periods of the multi-period contractual relationship and charges a lower (higher) premium in later periods.

5 All models discussed in this paper (implicitly) assume away moral hazard. A separate stream of dynamic contracting studies investigating moral hazard includes Rubinstein and Yaari (1983), Rogerson (1985) and among many others.
a unified competitive dynamic insurance model with asymmetric learning in the spirit of de Garidel-Thoron (2005) to predict the equilibrium pricing pattern under two different commitment scenarios, i.e. one-sided commitment and no commitment. We find that with one-sided commitment, where the insurer is able to commit to the contract but the policyholder is not, the equilibrium contract exhibits a highbailing pricing pattern, i.e. the insurer charges a higher premium in the first period and a lower premium in the second period than the actuarially fair one. On the contrary, with no commitment, where both contractual parties lack commitment power to the contract, the equilibrium contracts exhibit a lowballing pricing pattern, i.e. the insurers charge a lower premium in the first period and a higher premium in the second period than the actuarially fair one. These opposite predictions form the basis of subsequent empirical tests in this paper.

Figure 1 Illustration of pricing patterns.

The existing empirical tests on the dynamic pricing pattern are performed using a single insurance product. Therefore, it is difficult to tell whether the observed pricing pattern is due to the commitment or the learning environment. To remedy this deficiency, we present a pair of two samples (group critical illness (CI) insurance and loaner’s personal accident (PA) insurance) from the same insurance company. The two products share similar learning environment but differ in the insurer’s ability to commit to the multi-period insurance relationship. This unique empirical design isolates the role of insurer’s commitment from other potential determinants (see Table 3) of the shape of the dynamic pricing pattern. We find that the CI contracts exhibit a lowballing pattern, whereas the PA contracts exhibit a highbailing pattern. These findings are consistent with the theoretical causal link between insurer’s commitment and the highballing pricing strategy, as well as the link between the lack of insurer’s commitment and the lowballing pricing strategy.

This paper contributes to the literature on competitive dynamic contracts in four aspects. First, we present a comprehensive literature review on both theoretical models (see Table 1 and Appendix A) and empirical evidence (see Table 2 and Appendix B). These two reviews structuralize the roles of commitment and information in determining the dynamic pricing patterns. Second, we use a two-period model to predict the dynamic pricing patterns under asymmetric learning and one-sided
commitment imposing no restrictions on the contract space, which is absent in the literature. By comparing our results with those in Hendel and Lizzeri (2003) and de Garidel-Thoron (2005), we are able to disentangle the impact of commitment from learning on the equilibrium contract, and identify the insurer’s commitment as the driving force of dynamic pricing pattern on the theoretical side. Third, we conduct a two-sample empirical test, eliminating heterogeneity in firm, market, time horizon, and learning environment thus to isolate the role of insurer’s commitment. Our results expand the empirical evidence on insurer learning (Hendel and Lizzeri, 2003; Cohen 2012; Kofman and Nini, 2013; Shi and Zhang, 2015) and on contractual commitment (Dionne and Doherty, 1994; Hofmann and Browne, 2013). Last but not least, our empirical test using the sample of loaner’s PA insurance fills the gap in the pricing pattern with one-sided commitment and asymmetric learning.

The remainder of the paper is structured as follows. In next section, we review the theoretical and empirical papers in dynamic insurance contracting. The section after that proposes a unified two-period model with asymmetric learning and proves associated propositions. The subsequent section describes our data and methodology for empirical tests, following by the section of empirical findings and robustness tests. The final section concludes and suggests directions for future research.

Literature review

Theories on competitive dynamic insurance contracts

The equilibrium of competitive dynamic insurance contract is characterized under various commitment and informational assumptions. There are three common assumptions on commitment: (i) no commitment, where neither the insurer nor the policyholder pre-commits to a multi-period insurance relationship; (ii) one-sided commitment, where the insurer pre-commits to a multi-period insurance relationship but the policyholder does not; and (iii) full commitment, where both the

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6 Focusing on contracts with guaranteed renewability, Pauly, Menzel, Kunreuther, and Hirth (2011) investigate the dynamic pricing pattern under the same scenario and predict that the equilibrium contract exhibits highballing. Their model rules out the possibility of experience rating. De Garidel-Thoron (2005) places no restrictions on insurers’ contract space, and predicts the widely documented bonus-malus pattern. However, the question that whether the equilibrium contract is highballing or lowballing remains unanswered.

7 The dynamic insurance contracting models are traceable to, among others, contract theories in labor (Harris and Holmstrom, 1982), procurement (Laffont and Tirole, 1990), and credit (Sharpe, 1990) markets. The development of contract theory leads modern insurance economics in three directions (D’Arcy and Doherty, 1990; Chiappori and Salanié, 2013). The first is the classic single-period contracting in competitive insurance markets (e.g., Rothschild and Stiglitz, 1976; Miyazaki, 1977; Wilson, 1977; Spence, 1978). The second direction is the multi-period contracting in a monopoly insurance market, where the role of experience rating is highlighted to solve the problem of adverse selection (e.g., Dionne, 1983; Dionne and Lasserre, 1985, 1987; Hosios and Peters, 1989). The third and most recent direction is the dynamic insurance contracting in competitive markets, on which this paper will focus on. Another stream of literature focuses on the underwriting cycles, i.e. the mid to long-term pricing dynamics of an insurance market (see e.g., Henriet, Klimenko, and Rochet, 2016).

8 In practice, the insurer’s commitment has multiple forms, e.g., long-term contracts (term life) or guaranteed renewability (health insurance). One of the common features of these commitments is the commitment to a pre-agreed premium schedule, which can either be contingent or non-contingent on claim experience. It is rarely seen in the insurance market that the insured is bound to a multi-period relationship with an insurer, while the insurer is not (Dionne and Doherty, 1994).
insurer and the policyholder commit to a multi-period insurance relationship when signing a contract (Dionne and Doherty, 1994). The typical form of no commitment is the annual contract (e.g., automobile insurance), which is renewable but without renewal guarantee from either side. The typical forms of one-sided commitment include long-term contract (e.g., ten-year term life) and annual contract with guaranteed renewability (e.g., individual health insurance with guaranteed renewal clause). Full commitment contracts are rarely observed in practice because the insurance law in most markets allows the policyholder to cancel the insurance policy at any time.

The informational assumptions in multi-period insurance contracting involve two layers: information asymmetry between (i) the policyholder and the insurer(s), and (ii) between the incumbent (current) insurer and the competing (rival) insurers. The first layer has been extensively investigated in the single-period setup, within the context of adverse selection and moral hazard. The second layer stems from the dynamic nature: the incumbent insurer may obtain information advantages over its competitors, due to its learning from the contractual experience with the policyholder. Pauly (2003) constructs three information structures concerning the policyholder’s risk type, based on the two layers of informational assumptions: (i) classic adverse selection, where the policyholder has private information that no insurers know; (ii) symmetric information, where both the policyholder and all insurers share the same information initially and learn the evolving risks symmetrically in each period; (iii) asymmetric learning, where the policyholder and the incumbent insurer learns the evolving risks symmetrically but the competing insurers do not. We further develop Pauly’s (2003) information structures to four categories based on the presence of adverse selection at the contractual stage and on the type of learning (i.e. asymmetric learning or symmetric learning).

Table 1 summarizes the theoretical literature on dynamic insurance contracting in 12 assumption sub-categories by three commitment types and four information possibilities on policyholder’s risk. Most of the models are discussed in a two-period setup, where the long-term contract lasts two periods, and the short-term contract lasts one period. Theoretical predictions regarding the types of inter-temporal pricing pattern are summarized in each category. Please see Appendix A for a detailed discussion of each paper in Table 1.

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9 However, a policyholder may partially commit to an insurance relationship with the insurer. For instance, the employment relationship partially binds the insured to the employer sponsored group health insurance; the mortgage relationship partially binds the insured to the mortgage life insurance.

10 Learning reflects the updates in part the initial (but unknown) differences in risks, and in part the signal (and real) changes in risks (Pauly, 2003).

11 There are multi-dimensions in the insured’s risk information, e.g., the risk attitude, which also have an impact on insurance contracting (Finkelstein and McGarry, 2006). However, all models discussed in this paper (implicitly) assume the risk type as the only dimension of risk information.

12 The scenario of no learning is not particularly interesting to pricing pattern of dynamic insurance contracting studies and hence is omitted. If no information update is possible over time, then the pricing strategy cannot change over time, indicating a flat pattern.
Table 1 Theories on competitive dynamic insurance contracts.

<table>
<thead>
<tr>
<th>Commitment Information</th>
<th>No commitment</th>
<th>One-sided commitment</th>
<th>Full commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymmetric learning</td>
<td>Lowballing (Kunreuther and Pauly, 1985; Nilssen, 2000)</td>
<td>Highballing for low risks and flat for high risks selecting a different contract (Cooper and Hayes, 1987; Dionne and Doherty, 1994); the pricing pattern for the high risks pooling with the low risks is indeterminate (Dionne and Doherty, 1994).</td>
<td>High risks receive a flat contract independent of experience; policies for low risks are experience rated (Cooper and Hayes, 1987).</td>
</tr>
<tr>
<td>Symmetric learning</td>
<td>Flat (Watt and Vazquez, 1997)</td>
<td>Not covered by literature</td>
<td></td>
</tr>
</tbody>
</table>

Panel A: Adverse selection is present in period 1

Panel B: Adverse selection is NOT present in period 1

Panel C: Discussions on the impact of the first period adverse selection (connecting panel A and B)

Pauly (2003)

Notes:

a. Cooper and Hayes (1987) focus on separating equilibrium. Dionne and Doherty (1994) investigate the semi-pooling equilibrium where the low risks select one contract with certainty and the high risks randomize over the two contracts; different from Cooper and Hayes (1987), contract selection made in the first period does not fully reveal policyholder’s risk type.

b. With full commitment, whether learning is symmetric or asymmetric makes no difference. To see this, notice that competition among insurers is absent in the second period when both parties are able to commit to a long-term contract in the first period.

c. De Garidel-Thoron (2005) also studies this scenario and concludes a bonus-malus experience rating system, but he does not predict the equilibrium pricing pattern.

d. Please see Palfrey and Spatt (1985), Prendergast (1992), and Cochrane (1995) on other topics under this scenario.

e. Crocker and Moran (2003) discuss this scenario, however, their model does not predict the equilibrium pricing pattern.
Three papers closely related to our theoretical framework are Hendel and Lizzeri (2003), de Garidel-Thoron (2005), and Pauly, Menzel, Kunreuther, and Hirth (2011). Assuming asymmetric learning and one-sided commitment, Pauly, Menzel, Kunreuther, and Hirth (2011) conclude that the equilibrium contract exhibits highballing by restricting attentions to contracts with guaranteed renewability. They claim that this result will not hold if “the insurer that sold GR (guaranteed renewable) coverage is able to use the information it has acquired on each insured’s risk to modify the contract quoted to that person on an individual basis, or if it can reduce service or in other ways lower the quality of the product for the high risks once those who have become higher risks are locked in.” (p. 138) We contribute to Pauly, Menzel, Kunreuther, and Hirth (2011) by showing that the equilibrium contract is indeed highballing (Proposition 2) even if the insurer is free to use the new information on risks in future periods under a mild consumer preference assumption.

Hendel and Lizzeri (2003) develop a model of life insurance assuming symmetric learning and one-sided commitment. They predict that the equilibrium pricing pattern exhibits highballing, which serves as an important device to lock in low risks. Their conclusion relies on both the assumptions of symmetric learning and one-sided commitment. We analyze the role of each assumption in our model and show that the highballing feature remains if insurer learning is asymmetric (Proposition 2).

Using a two-period asymmetric learning model of insurance, de Garidel-Thoron (2005) shows that the equilibrium contract exhibits lowballing when both parties lack commitment power; the contract displays a realistic bonus-malus pattern (i.e. experience rating) with one-sided commitment. The focus of de Garidel-Thoron (2005) is, however, the welfare analysis of enforcing information sharing. He does not predict whether the equilibrium contract exhibits a highballing, lowballing, or flat pattern in the case of one-sided commitment and asymmetric learning. Our theoretical counterpart (Proposition 2) fills in this gap.

Empirical evidence in dynamic insurance pricing pattern

Table 2 summarizes the existing empirical evidence concerning the dynamic insurance pricing pattern (see Appendix B for a detailed discussion of each paper). Table 2 reveals the relationships between the inter-temporal pricing pattern and the commitment as well as the information structure. From the commitment perspective, if the insurer offers short-term contracts without renewal guarantee (i.e. the insurer has no commitment), the inter-temporal pricing pattern is lowballing (all four pieces of evidence support this statement, Columns 1-4); if the insurer offers long-term contracts or a sequence of short-term contracts with guaranteed renewability (i.e. the insurer commits to multi-period contractual relationship), the pattern is mostly highballing (six out of seven support this statement,

13 Also related, Kunreuther and Pauly (1985) and Nilssen (2000) develop models of multi-period insurance markets with asymmetric learning and no commitment. Different from our framework, they assume the presence of adverse selection in the first period, and predict a lowballing pricing pattern as our Proposition 1. We will discuss the connections of these two papers with our results after presenting Proposition 1.
Columns 5-11). The comparison results based on extant empirical evidence strongly support Dionne and Doherty’s (1994) and Hendel and Lizzi’s (2003) theoretical assertion that the dynamic insurance pricing pattern is sensitive to the commitment type. Looking from the information structure perspective, the extant evidence does not reveal a systematic correlation between the presence of adverse selection and the pricing pattern, nor between the insurer learning environment (i.e. symmetric learning or asymmetric learning) and the pricing pattern.
**Table 2** Empirical evidence in dynamic insurance pricing pattern.

<table>
<thead>
<tr>
<th>Product</th>
<th>Market</th>
<th>Policy duration</th>
<th>Commitment type</th>
<th>Adverse selection</th>
<th>Insurer learning</th>
<th>Lowballing</th>
<th>Highballing</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
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<td>Auto</td>
<td>US</td>
<td>ST</td>
<td>No</td>
<td>Yes</td>
<td>Asym</td>
<td>/</td>
<td>/</td>
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<tr>
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<td>Israel</td>
<td>ST</td>
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<td>Yes</td>
<td>Asym</td>
<td>/</td>
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<td>Australia</td>
<td>ST</td>
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<td>Weak</td>
<td>Sym</td>
<td>/</td>
<td>/</td>
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<td>ST</td>
<td>No</td>
<td>Yes</td>
<td>Btw asym and sym</td>
<td>/</td>
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<td></td>
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<tr>
<td>Auto</td>
<td>CA, US</td>
<td>LT</td>
<td>One-sided a</td>
<td>Yes</td>
<td>Asym</td>
<td>Confirm</td>
<td>Confirm</td>
<td></td>
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<tr>
<td>Auto</td>
<td>US</td>
<td>LT or GR</td>
<td>One-sided</td>
<td>No</td>
<td>Sym</td>
<td>Confirm</td>
<td>Reject</td>
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<tr>
<td>Auto</td>
<td>US</td>
<td>GR or LT</td>
<td>One-sided</td>
<td>Not discussed</td>
<td>Sym</td>
<td>Confirm</td>
<td>Confirm</td>
<td></td>
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<tr>
<td>Auto</td>
<td>US</td>
<td>GR</td>
<td>One-sided</td>
<td>Not discussed</td>
<td>Not discussed</td>
<td>Confirm</td>
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<tr>
<td>Auto</td>
<td>US</td>
<td>LT or GR</td>
<td>One-sided</td>
<td>Yes c</td>
<td>Sym b</td>
<td>Confirm</td>
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<tr>
<td>Auto</td>
<td>Germany</td>
<td>ST</td>
<td>One-sided</td>
<td>Yes</td>
<td>Sym</td>
<td>Confirm</td>
<td>Confirm</td>
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<td>China</td>
<td>GR</td>
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<td>Asym</td>
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<td>Confirm</td>
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<tr>
<td>Auto</td>
<td>China</td>
<td>GR</td>
<td>One-sided</td>
<td>Yes</td>
<td>Asym</td>
<td>Confirm</td>
<td>Confirm</td>
<td></td>
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**No commitment** | **One-sided commitment** | **No commitment** | **One-sided commitment** |
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<tbody>
<tr>
<td>Auto Liability</td>
<td>Term Life</td>
<td>LTC</td>
<td>LTC</td>
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<tr>
<td>LT</td>
<td>LT</td>
<td>GR or LT</td>
<td>GR</td>
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<td>One-sided</td>
<td>One-sided</td>
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**Notes:**
- The definition of abbreviations are as follows. Auto stands for the automobile insurance. LTC stands for long-term care insurance. ST and LT represent short-term policy and long-term policy, respectively. Asym and Sym represent asymmetric learning and symmetric learning, respectively.
- Renegotiation is allowed at the beginning of the second period, i.e. the insurer may propose new terms but the policyholder has the right to reject new offer and stay with the original terms. Thus, in nature, the insurer is still binding with the original term for two periods, i.e. one-sided commitment.
- Pinquet, Guillen, and Ayuso (2011) notice that “the disability history allows symmetric learning, but the insurance company is committed not to use this information in its rating structure.”
- While the presence of adverse selection is confirmed empirically, their theoretical model builds on Hendel and Lizzeti (2003) and does not take adverse selection into account.
Theoretical model and propositions

Following de Garidel-Thoron (2005), we further develop a unified dynamic insurance model with asymmetric learning, which allows for the variation in insurer’s commitment types. Consider a two-period insurance market, each consumer is endowed with income $W$ and may suffer a loss of size $L$ in each period. The consumers’ utility function $u(\cdot)$ is strictly increasing in consumption, twice differentiable, and strictly concave (i.e. $u'' < 0 < u'$). Consumers and insurers share the same discount factor $\delta \in (0, 1]$.

In the first period, consumers are indexed with a probability of loss $p \in (0, 1)$ drawn from a distribution with CDF $F(\cdot)$ and PDF $f(\cdot)$. The probability of loss $p$ is assumed to be fixed across the two periods. In addition, we assume both consumers and all insurers do not learn $p$ in the first period and hence adverse selection is absent. For notational convenience, we denote the expected first period loss probability by $p_1$, which equals $\int_0^1 p \, dF(p)$. After the first period, information asymmetry between the incumbent insurer and competing insurers endogenously arises. Specifically, if an accident occurs in the first period, both the consumer and the incumbent insurer update the second period probability of loss into $p_2^A = p_2^A$. Similarly, if no accident occurs in the first period, both parties update the second period probability of loss into $p_2^N = p_2^N$. The algebra yields,

$$p_2^A = \frac{\int_0^1 p^2 \, dF(p)}{p_1} \quad \text{and} \quad p_2^N = \frac{\int_0^1 p(1-p) \, dF(p)}{1-p_1}.$$

It can be verified that $0 < p_2^N < p_1 < p_2^A < 1$, and that the martingale property $p_1 = p_1 p_2^A + (1-p_1) p_2^N$ holds. We assume that insurer learning is asymmetric in the sense that the competing insurers do not learn $p_2$. Moreover, consumers lack commitment power, i.e. they may opt out of the insurance contract at the beginning of the second period and purchase another short-term contract available on the spot market.

In each period, an insurance contract consists of a premium $Q$, and an indemnity $R > 0$ paid in the case of a loss $L$. Let $R = \bar{R} - Q$, where $\bar{R}$ is the net reimbursement paid to a consumer. Therefore, an

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14 There are two prevalent assumptions about policyholder’s risk type in the dynamic insurance literature. One assumes risk type does not change over time, e.g. in auto insurance (de Garidel-Thoron, 2005); the other assumes that risk type worsens over time, e.g., in life insurance (Hendel and Lizzeri, 2003). We adapt the first assumption because the two insurance products employed in the empirical test in this paper are both renewed on an annual basis, and hence policyholder’s risk can be considered as unchanged across the two periods. In Appendix D we show that the main results are robust if the second assumption is used.

15 The presence of adverse selection introduces the possibility of separating equilibrium. In a separating equilibrium, both the incumbent insurer and the competing insurers learn policyholders’ risk type immediately from policyholders’ contract choices. As a result, learning is of no value and there is no information asymmetry between the incumbent and its rivals in the second period. In later part, we discuss the scenarios incorporating adverse selection, which does not change our predictions.

16 We assume asymmetric learning because the information sharing system among the insurers is absent for most insurance products in most markets, including the two products employed in the subsequent empirical analyses. The modeling with symmetric learning can be found in Pauly, Kunreuther, and Hirth (1995), Hendel and Lizzeri (2003), and Hendel (2016).
insurance contract can be represented by \( C \equiv (Q, R) \), and a two-period insurance contract offered by the insurer can be indexed by \( (C_1, C_2^A, C_2^N) \equiv ((Q_1, R_1), (Q_2^A, R_2^A), (Q_2^N, R_2^N)) \), where \( C_1 \equiv (Q_1, R_1) \) is first period contract and \( C_k^k \equiv (Q_k^k, R_k^k) \) is the second period contract contingent on \( k \in \{A, N\} \). Next, we define highballing, lowballing, and flat pricing patterns as follows:

**Definition 1:** A contract \( (C_1, C_2^A, C_2^N) \) is highballing (front-loaded) if \( Q_1 > p_1/(1-p_1) R_1 \), lowballing (back-loaded) if \( Q_1 < p_1/(1-p_1) R_1 \), and flat if \( Q_1 = p_1/(1-p_1) R_1 \).

Competitive market implies zero total profit over multiple periods. If the premium in the first period is higher than the expected indemnity (i.e. positive profit) in equilibrium, then the second period premium must be lower than the expected indemnity (i.e. negative profit) for insurers to break even across the two periods. We call this pricing pattern highballing. Similarly, if the premium in the first period is lower than (equal to, respectively) the expected indemnity, we call this pricing pattern lowballing (flat, respectively). We model insurer’s commitment or lack of commitment as the possibility to renege the contract\(^{17} \) at the beginning of second period (de Garidel-Thoron, 2005).\(^{18} \)

**No commitment.** We first assume that both parties lack commitment power. Specifically, the incumbent insurers can renege\(^{19} \) the contract at the beginning of the second period, i.e. they can unilaterally modify or withdraw the contract. Similarly, policyholders are free to lapse the contract with the incumbent insurer and switch to an entrant (i.e. competing insurer) that offers a short-term contract \( C_2' \equiv (Q_2', R_2') \) without learning the first period claim history. The timeline of the dynamic insurance contracting game is the same as in de Garidel-Thoron (2005) and is shown in Figure 2.

\(^{17} \) Notice that reneging differs from Dionne and Doherty’s (1994) renegotiation. With reneging, the insurer can change or cancel the contract unilaterally in the second period; while with renegotiation, the contract can be changed if and only if this modification is mutually agreed by (implying mutually beneficial for) both the insurer and the policyholder. Therefore, reneging is a scenario of no commitment and renegotiation is considered as a weaker form of one-sided commitment.

\(^{18} \) Notice that the equilibrium two-period contract \( (C_1^\ast, C_2^A^\ast, C_2^N^\ast) \) is strategically equivalent to and can be implemented by a short-term contract \( C_1^\ast \) in the first period and a pair of short-term contracts (i.e., \( C_2^A^\ast \) and \( C_2^N^\ast \)) in the second period because consumers form correct expectations of the contracts offered in the second period.

\(^{19} \) Notice that reneging differs from Dionne and Doherty’s (1994) renegotiation. With reneging, the insurer can change or cancel the contract unilaterally in the second period; while with renegotiation, the contract can be changed if and only if this modification is mutually agreed by (implying mutually beneficial for) both the insurer and the policyholder. Therefore, reneging is a scenario of no commitment and renegotiation is considered as a weaker form of one-sided commitment.
Notice that full insurance has to be offered in each period, that is, $Q_1 + R_1 = L$, $Q_2^A + R_2^A = L$, and $Q_2^N + R_2^N = L$ must hold. Otherwise, the competing insurers can craft a contract with full insurance in each period and strictly increase consumer’s expected utility. Graphically, contracts $C_1$, $C_2^A$, $C_2^N$ must lie on the line $Q + R = L$ in the $(R, Q)$ space. Therefore, the number of variables can be reduced to three and the equilibrium contract is fully characterized by the sequence of premiums $(Q_1, Q_2^A, Q_2^N)$. It is also useful to denote consumers’ indifference curve that crosses a contract $C_2^k \equiv (Q_2^k, R_2^k)$ for type $k \in \{A, N\}$ by $R = IC_2^k(Q; C_2^k)$, which is the solution to

$$(1 - p_2^k)u(W - Q) + p_2^k u(W - L + IC_2^k(Q; C_2)) = (1 - p_2^k)u(W - Q_2) + p_2^k u(W - L + R_2).$$

In words, $(Q, IC_2^k(Q; C_2^k))$ is the contract that generates the same expected utility to a type $k$ consumer as that with contract $C_2^k \equiv (Q_2^k, R_2^k)$. As Rothschild and Stiglitz (1976) suggest, the two indifference curves $IC_2^N(Q; C_2^N)$ (the lower dashed line in Figure 3) and $IC_2^A(Q; C_2^A)$ (the upper dashed line in Figure 3) obey single-crossing condition, and $IC_2^A(Q; C_2^A)$ is steeper than $IC_2^N(Q; C_2^N)$.

The shape of the equilibrium dynamic pricing pattern is characterized in the following proposition.

**Proposition 1 (de Garidel-Thoron, 2005):** The equilibrium contract exhibits a lowballing (back-loaded) pricing pattern, under no commitment and asymmetric learning.

De Garidel-Thoron (2005) shows that the equilibrium contract satisfies: (i) type $A$ consumers receive an actuarially fair full insurance (i.e. $Q_2^A = p_2^A L$ and $R_2^A = (1 - p_2^A)L$); (ii) $IC_2^N(Q; C_2^N)$ and $IC_2^A(Q; C_2^A)$ cross on the zero-profit line for type $N$ consumers (i.e. $(1 - p_2^N)Q - p_2^N R = 0)$; (iii) $Q_1$ is obtained through zero profit condition. The equilibrium contract is illustrated in Figure 3.  

---

20 Using the notation in de Garidel-Thoron (2005), $Q^m = Q_{R_{SW}}$ is assumed for $IC_2^N(Q; C_2^N)$ and $IC_2^A(Q; C_2^A)$ to cross on the line $(1 - p_2^N)Q - p_2^N R = 0$. For the ease of exposition, we maintain this assumption in explaining Proposition 1. If this assumption is violated, $Q_2^A = p_2^A L$ holds in equilibrium, whereas $IC_2^A(Q; C_2^A)$ and $IC_2^N(Q; C_2^A)$ cross below the line $(1 - p_2^N)Q - p_2^N R = 0$. Still the contract is lowballing and Proposition 1 holds.
Figure 3 Equilibrium contract with no commitment.

The intuition of Proposition 1 is as follows. Due to insurer's lack of commitment, no loss can be made ex post on both type A and N consumers in the second period for the incumbent insurer. This is because the incumbent insurer can simply withdraw the contract at the beginning of the second period to avoid any second-period losses when the incumbent insurer learns the risk type based on the first period experience. In fact, type A consumers receive an actuarially fair premium in equilibrium in the second period. Meanwhile, because the competing insurers cannot differentiate type A and type N consumers due to asymmetric learning, the incumbent insurer is able to obtain positive information rents from type N consumers and prevent ex post entry simultaneously. Finally, competition at the beginning of the first period will force the incumbent insurer to pass the second period profits onto consumers in the form of a first period premium lower than the actuarially fair one, implying a lowballing pricing pattern.

It is worth mentioning that the above intuition applies and Proposition 1 remains valid if adverse selection is present at the beginning of the first period. Indeed, Kunreuther and Pauly (1985) and Nilssen (2000) investigate the equilibrium contracts in a similar setup except that they assume adverse selection is present in the first period. They show that the equilibrium contract is lowballing in a pooling equilibrium where all risk types are provided with the same contract in the first period. Again, insurer’s lack of commitment implies directly that the incumbent insurer will not suffer a loss on any type of policyholders in the second period because they can simply withdraw the contract to avoid
losses otherwise. Moreover, asymmetric learning endows the incumbent insurer with some market power, and earns positive profits from the low risks. As a result, Kunreuther and Pauly (1985) and Nilssen (2000) establish the same lowballing pricing pattern.

**One-sided commitment.** Now we assume that insurer pre-commits to a long-term contract at the beginning of the first period while consumers cannot commit to no lapsation. The dynamic insurance pricing game runs the same as the game under no commitment except that the incumbent insurer cannot renege the contract at the beginning of the second period. For tractability, we assume consumers' preference exhibits hyperbolic absolute risk aversion (HARA),\(^ {21} \) that is,

\[
u(c) = \frac{1 - \eta}{\eta} \left( \frac{ac}{1 - \eta} + b \right)^{\eta},
\]

where \(a, b, \) and \(\eta\) satisfy \(aW/(1 - \eta) + b > 0\) and \(a(W - L)/(1 - \eta) + b > 0\), and \(a > 0\). Following de Garidel-Thoron (2005), the equilibrium contract maximizes consumers' expected utility:

\[
\max_{\{Q_1, Q_2^A, Q_2^N\}} u(W - Q_1) + \delta[p_1u(W - Q_2^A) + (1 - p_1)u(W - Q_2^N)],
\]

subject to

\[
(Q_1 - p_1L) + \delta[p_1(Q_2^A - p_2^AL) + (1 - p_1)(Q_2^N - p_2^NL)] = 0, \quad (1)
\]

\[
Q_2^A \leq p_2^AL, \quad (2)
\]

\[
IC_2^N(Q; C_2^N) \text{ and } IC_2^A(Q; C_2^A) \text{ cross on the line } (1 - p_2^N)Q - p_2^NP = 0, \quad (3)
\]

\[
IC_2^N(Q; C_2^N) \text{ and } (1 - p_1)Q - p_1R = 0 \text{ do not intersect.} \quad (4)
\]

Constraint (1) says that insurer earns zero inter-temporal profits in a competitive insurance market. Constraint (2) guarantees that attracting type A consumers alone in the second period is not profitable for the entrant. Similarly, constraint (3) guarantees that it is not profitable to offer a separating contract to attract type N consumers. Lastly, constraint (4) guarantees that offering a pooling contract to both types is not profitable in the second period. Notice that constraint (2) states that the incumbent insurer will break even or suffer a loss on type A consumers and constraint (3) implies instantly that \(C_2^N\) must lie above the zero profit curve of type N consumers (i.e., \((1 - p_2^N)Q - p_2^NP = 0\)) and hence the incumbent insurer earns profits from type N consumers. Therefore, whether the incumbent insurer earns profits or suffer losses in the second period (i.e. whether the equilibrium contract exhibits highballing or lowballing) is non-trivial. The shape of the equilibrium dynamic pricing pattern is characterized in the following proposition.

\(^ {21} \) Almost all applied theory and empirical work use some members of HARA utility functions. The utility function exhibits constant absolute risk aversion (CARA, i.e., \(u(c) = -\exp (-ac)\)) if \(b = 1\) and \(\eta \to \infty\); the utility function exhibits constant relative risk aversion (CRRA, i.e., \(u(c) = \frac{1 - \eta}{\eta} \left( \frac{ac}{1 - \eta} \right)^{\eta}\)) if \(b = 0\). The commonly used utility functions, such as \(\ln(c)\) and \(\sqrt{c}\), are all members of HARA.
Proposition 2: If consumer’s preference exhibits HARA, the equilibrium contract exhibits a highballing (front-loaded) pricing pattern, under one-sided commitment and asymmetric learning.

Proof Please see Appendix C.

Figure 4 Equilibrium contract with one-sided commitment.

The idea of the proof is as follows, and is illustrated in Figure 4. For an equilibrium contract, denoted by \( (C_1, C_2^A, C_2^N) \), that does not exhibit highballing, we can construct a new contract that generates a strictly higher utility and satisfies Constraints (1)-(4) in two steps. Thus, the equilibrium dynamic pricing pattern must be highballing. In the first step, we slightly lower \( Q_2^A \) and \( Q_2^N \) such that \( IC_2^N(Q; C_2^N) \) and \( IC_2^A(Q; C_2^A) \) cross below the line \( (1 - p_2^N)Q - p_2^N R = 0 \) as the two dashed curves illustrate in Figure 4, and increase the first period premium \( Q_1 \) accordingly to satisfy the zero inter-temporal profit condition. The constructed new contract, denoted by \( (\hat{C}_1, \hat{C}_2^A, \hat{C}_2^N) \), satisfies all constraints except (3), which will be addressed in the second step, and generates a strictly higher expected consumer utility than that under contract \( (C_1, C_2^A, C_2^N) \). The intuition is as follows. Relative to the original contract, consumers obtain a lower expected utility in the first period and a higher expected utility in the second period. Because the original contract is not highballing, the corresponding consumption in the first period is no less than the average consumption in the second period. Therefore, the marginal cost of decreasing the first period consumption is no greater than the
average of the marginal benefits of increasing consumption in state A and N in the second period given that consumer preference exhibits HARA, indicating that the constructed contract is welfare improving.

In the second step, we keep the first period premium constructed in the first step, decrease the premium in state A, and increase the premium in state N such that the two new indifference curves cross on the line \((1 - p^N_2)Q - p^N_2 R = 0\) again as the two dotted curves illustrate in Figure 4. Now the constructed contract \((\tilde{C}_1, \tilde{C}_A, \tilde{C}_N)\) satisfies all four constraints including Constraint (3). Because consumer has incentives to insure against reclassification risk and smooth consumption across the two states in the second period, and the contract \((\tilde{C}_A, \tilde{C}_N)\) leads to smoother consumption across state A and N relative to that under the contract \((C_2^A, C_2^N)\), this modification is again welfare enhancing.

Proposition 2 contributes to the literature in three aspects. First, we show that the highballing pricing pattern predicted in Pauly, Menzel, Kunreuther, and Hirth (2011) remains if the contract space is enriched and experience rating is allowed. Second, we prove that de Garidel-Thoron’s (2005) realistic bonus-malus system exhibits highballing. Third, we complement Hendel and Lizzieri (2003) by showing that the highballing pricing pattern under one-sided commitment is robust across different learning environments. Notice that both symmetric learning and one-sided commitment play indispensable roles in shaping highballing pricing pattern in Hendel and Lizzieri (2003). Specifically, symmetric learning indicates that insurer faces fierce competition with the entrant in every state in the second period, and the incumbent insurer cannot obtain no information rents in the second period. Thus, the incumbent insurer must earn zero or negative profits in the second period. One the other hand, one-sided commitment implies that insurers have incentives to insure against the second period reclassification risk in terms of level premiums to maximize consumer’s inter-temporal expected utility. This implies directly that policyholders of low risk types will lapse the contract in the second period, yielding zero profits to the incumbent insurer, while policyholders of high risk types will stick with the contract, generating losses instead. As a result, a highballing pricing pattern emerges in Hendel and Lizzieri (2003). It is useful to point out that this result cannot be applied directly to the environment of asymmetric learning because the incumbent insurer earns profits from type N consumers and suffers losses from type A consumers as depicted in Figure 4 in equilibrium. We thus consider our Proposition 2 a new result to the literature.

22 One may notice that our model differs from Hendel and Lizzieri (2003) in the dynamics of policyholder’s risk. We assume that the risk does not change over the two periods while they assume risks deteriorate over time. In Appendix D, we show that Proposition 2 remains under the assumption of Hendel and Lizzieri (2003).

23 To see this, suppose to the contrary that the incumbent insurer offers a contract that generates positive profits for some state in the second period. Then the entrant can earn profits by providing a contract that yields less profits and a strictly higher expected utility to attract policyholders in that state.
Data and sample comparison

In this section, we test the theoretical predictions of the model using data of two products from a Chinese life and health insurer. The insurer operates nationwide, with a broad spatial range that covers over 90% of the Chinese population. It is ranked among the top ten life insurers in China over the past 15 years in terms of premium volume and assets. Its core business comes from the open market and thus is not concentrated in any particular industry or region. Its operational model, growth path, risk portfolio, and performance are typical in the Chinese insurance market. The Chinese insurance market is competitive. In 2012, 68 life and health insurers and 62 property and liability insurers operated in the Chinese insurance market, and most of them are legally eligible to issue the two products of interest.

Sample A is a portfolio of group critical illness (CI) insurance. CI insurance is a type of loss-occurrence health insurance. The claim benefit is paid in a lump sum without additional benefits, such as medical service, and equals the insurance amount. It is paid to the policyholder when an insurer-recognized hospital provides the first-time diagnosis of the covered disease during the policy period. Usually, there is a 30- to 90-day waiting period for first-time purchasers. The claim payment does not require actual medical expenditure or hospitalization. Thus CI insurance is immunized from many common problems observed in medical expense health insurance, such as moral hazard and choices between private and public hospitals. In 2007, the Insurance Association of China and the Chinese Medical Doctor Association issued guidelines that define 25 types of critical diseases and almost all insurers strictly follow the CI coverage guideline, standardizing CI insurance products and hence limiting the degree of product differentiation. In this sample, all group policies and insured individuals have the same coverage for the 25 critical diseases. There are no restrictions regarding risk classification based on age, gender, occupation, region or other possible pricing factors. The insurer has sole discretion to determine the premiums offered for both new and renewed contracts. Employee benefits constitute the majority of group CI insurance market. Usually, the employer pays the premium and the employee enjoys the coverage. The market is commercial and participation is voluntary.

The group CI insurance falls into the scenario no commitment with asymmetric learning. The insurer is free to terminate the group contract at the end of each policy period. The employer (the group) is also free to switch or to terminate the group contract at any time. The incumbent insurer is allowed to adjust the group premium based on the group’s past claim experience, which is not known by competing insurers. Using a sub-sample of the same portfolio, Eling, Jia, and Yao (2015) confirm the presence of asymmetric learning. They also show that the adverse selection in this portfolio is non-persistent and disappears after the second policy period.
Sample B is a portfolio of loaner’s personal accident (PA) insurance. The borrower (policyholder) of a bank buys the coverage from an insurer to cover his/her accidental death and disability during the loan period. The policy beneficiary is the bank and the insurance amount usually equals the outstanding loans plus interests. The bank also serves as the sales agent of the insurer, recommends this product to its borrowers, and receives sales commission as a percentage of the insurance premium from the insurer. The bank can sell the Loaner’s PA exclusively to one insurer or multiple insurers. The borrowers can buy the product from the bank or from other channels. However, after consulting with the insurer, almost all borrowers buy the product from the bank channel mainly due to the concern that products from other channels may not 100% meet the bank requirement. Villeneuve (2014) confirms this channel stickiness for a similar product of mortgage life in French market.

The loaner’s PA falls into the scenario of one-sided commitment with asymmetric learning. The loaner’s PA features one-year policy with implicit guaranteed renewability until the borrowers clear their loans. This implicit guarantee is strong, because the bank, as the beneficiary, would expect the insurer to cover all its loaners as a group and thus do not accept the insurer’s cherry picking, leaving the bank itself at risk before the loans are cleared. The bank, as the sales agent, has also the market power to enforce such implicit guarantee. The bank is free to terminate the agent agreement with the insurer at any time and switch to competing insurers, leading most individual policyholders to also switch at the time of their next renewal. In addition, the individual policyholder can terminate the coverage or significantly reduce the insurance amount at any time by early pay back (part of) his/her loans, a common phenomenon in the Chinese market. These two facts suggest individual policyholder and bank’s lack of commitment. The Loaner’s PA market also features asymmetric learning. Insurers learn borrowers’ risk gradually for a bank and adjust the group rating tariff for that bank. The parameters in the tariff include age, gender, and occupation accidental categories. Although premiums are not updated based on individual policyholder’s past claim experience (nondiscriminatory, Pauly, 2003), the group tariff is updated from time to time based on “community rating”, suggesting the presence of learning. Moreover, information sharing is not available among the insurers, indicating asymmetric learning is a plausible assumption for loaner’s PA insurance. Last, because the product has a compulsory insurance feature, i.e. almost all banks require all borrowers to present a loaner’s PA for the loans, the market presents almost no adverse selection.

Both samples include all information that the insurer uses for underwriting and pricing. Claims records are included. Sample A covers all group CI policies issued between January 2008 and June 2013 and all claims settled between January 2008 and August 2012 under the corresponding policies. Sample B covers all loaner’s PA policies issued between January 2008 and December 2011 and all

24 Borrower may prefer bank channel for other reasons. For instance, shopping products from other channels requires additional efforts and professional knowledge. Also products from other channels may be more expensive because individual borrowers may not enjoy a group discount as being pooled together with all borrowers from the bank.
claims under these policies. The two samples are selected following the same procedure. First, only policies with duration between 360 and 366 days, i.e. one-year duration, are used and thus policy age and number of renewals are aligned with each other. Second, policies, of which the renewal status cannot been identified, are deleted from the sample. Third, the premium rates are truncated at the 1st and 99th percentiles to avoid the potential bias of extreme values. The final Sample A contains 5,570 group policy-year observations purchased by 3,152 groups, representing more than 1,880,000 individual policies. Sample B contains more than 1,280,000 individual policy-year observations purchased by over 800,000 individual policyholders. Missing information is present in both samples, particularly related to missing claims and reserves.

We summarize and compare the two samples qualitatively in Tables 3 and quantitatively in Table 4. We see that the key difference between the two products is in the insurer’s commitment type as shown in Table 3. Other factors are either the same or largely similar, such that any differences in pricing and/or risk patterns likely attributable to differences in commitment type.

In practice, many other factors in addition to the type of commitment and information structure can influence insurer’s pricing decision. For example, the pricing pattern may be driven by short-term business targets or management considerations. An insurer may be under growth pressure from shareholders in some certain years. A product sample from this period may yield a lowballing pricing pattern due to the target of attracting new clients; however, in normal periods without particular growth pressure, the contract can be highballing. Another example is the insurance market cycle (Henriet, Klimenko, and Rochet, 2016), which reflects the long-term pricing pattern of an insurance market and is mingled with the temporal pricing pattern of a product. In order to isolate the impact of

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25 For Sample A, group policies with one-year duration account for 62% of all policy-years; for Sample B, policies with one-year duration account for 82% of all policy-years.

26 The original dataset A has 11,185 group-year observations from 4,516 groups. The original dataset B has 1.6 million policyholder-year observations from 1.1 million individual policyholders.

27 The original data of Sample A are at individual policy level. The individual policy entries are then organized into group policies according to the group policy number.

28 The claims information is electronically recorded in real time but only retrieved and organized by the actuarial team once per year. By the time the data for sample A was obtained, the claim information from September 2012 to June 2013 was not yet available. In the subsequent analysis, to avoid the potential truncation problem, the claim status of policies expiring after August 2012 is coded as missing values. This constitutes a major limitation of our empirical test, because we are not able to use the profit measure (e.g. loss ratio or profit ratio) to test the profit pattern of the insurer but instead observe the pricing pattern indirectly conditional on the risk classifications. We are not able to calculate the accurate profit measures for each contract because the unearned premium reserves and IBNR (incurred but not reported) reserves are not available for us.

29 It is acknowledged that risk exposures are also different for the two samples with one critical illness and the other accident. However, critical illness and accident exposures share many common features, e.g., low loss frequency, similar pricing factors, and many relatively homogeneous risks. Therefore, they are usually operated by the same A&H department in an insurance company. In addition, the pricing patterns are measured on a relative-to-actuarially-fair-premium basis and all risk classification factors have been controlled when identifying the pricing pattern.

30 The scenario of adverse selection in the two samples is the same (no adverse selection) after the second period of Sample A. Eling, Jia, and Yao (2015) suggest that the between-group adverse selection in the group CI insurance (Sample A) is non-persistent, i.e. after the initial two years, the between-group adverse selection disappears, and hence the two samples share the same information structure.
product inter-temporal pricing, the two propositions are tested with two product samples from the same insurer, the same market, and almost the same time horizon. If different pricing patterns are found in these two samples, it is more convincing to conclude that the detected differences result from differences in commitment of the two products rather than other firm-, market-, or time period-specific factors. Such an empirical design is new to the empirical literature on dynamic insurance contracting and enhances the credibility of the detected pricing pattern.

Table 3 Qualitative comparison of samples A and B.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Sample A</th>
<th>Sample B</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insurer’s commitment</td>
<td>One-year short-term policy</td>
<td>One-year short-term policy with guaranteed renewability</td>
<td>Different</td>
</tr>
<tr>
<td>Bank’s or group’s commitment</td>
<td>Employer is free to cancel or switch insurer</td>
<td>Bank is free to switch insurer</td>
<td>Same</td>
</tr>
<tr>
<td>Commitment type</td>
<td>No commitment</td>
<td>One-sided commitment</td>
<td>Different</td>
</tr>
<tr>
<td>Adverse selection</td>
<td>No after the initial two years (Eling, Jia, and Yao, 2015)</td>
<td>No</td>
<td>Similar</td>
</tr>
<tr>
<td>Incumbent insurer’s learning</td>
<td>Group level experience rating</td>
<td>Bank level experience rating</td>
<td>Same</td>
</tr>
<tr>
<td>Competing insurers’ learning</td>
<td>No information sharing system</td>
<td>No information sharing system</td>
<td>Same</td>
</tr>
<tr>
<td>Insurer’s learning type</td>
<td>Asymmetric learning</td>
<td>Asymmetric learning</td>
<td>Same</td>
</tr>
<tr>
<td>Insurer</td>
<td>Anonymous L&amp;H insurer</td>
<td>Anonymous L&amp;H insurer</td>
<td>Same</td>
</tr>
<tr>
<td>Market</td>
<td>China</td>
<td>China</td>
<td>Same</td>
</tr>
<tr>
<td>Sample period</td>
<td>2008-2013</td>
<td>2008-2011</td>
<td>Similar</td>
</tr>
</tbody>
</table>

As shown in Table 4, both samples are characterized by a low claim frequency, a relatively small insurance amount for most policies, and a mixture of ages, genders, and occupations. The loaner’s PA portfolio contains much more males than females, which we believe reflects the Chinese family tradition: male usually manages the household’s external financial relationships such as loans. It also reflects the fact that businessmen outnumber businesswomen in China. The area distributions of the two portfolios are significantly different, where the group CI concentrates more in the developed areas relative to the loaner’s PA, because firms that can afford the employee benefits tend to locate in more developed and affluent areas.
Table 4  Quantitative comparison of samples A and B.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Descriptions</th>
<th>Sample A: Group critical illness</th>
<th>Sample B: Loaner’s personal accident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Obs.</td>
<td>Mean</td>
</tr>
<tr>
<td>Premium rate</td>
<td>Annualized premium rate per policyholder</td>
<td>5,369</td>
<td>0.0028</td>
</tr>
<tr>
<td>Policy age</td>
<td>Count of renewal times</td>
<td>5,369</td>
<td>0.94</td>
</tr>
<tr>
<td>Insurance amount</td>
<td>Insurance amount per policyholder in CNY</td>
<td>5,369</td>
<td>57,229.4</td>
</tr>
<tr>
<td>Group size</td>
<td>Number of individual policyholders in the group</td>
<td>5,369</td>
<td>327.0</td>
</tr>
<tr>
<td>Policy duration</td>
<td>Policy duration in days</td>
<td>5,369</td>
<td>365.0</td>
</tr>
<tr>
<td>Sex</td>
<td>(Fraction of) women</td>
<td>5,369</td>
<td>0.41</td>
</tr>
<tr>
<td>Age</td>
<td>(Group average) age</td>
<td>5,369</td>
<td>35.9</td>
</tr>
<tr>
<td>Work&lt;sup&gt;a&lt;/sup&gt;</td>
<td>(Group average) occupation accident tendency</td>
<td>5,369</td>
<td>2.01</td>
</tr>
<tr>
<td>Area&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Indicator of relative wealth and insurance market maturity of the policy issuer location</td>
<td>5,369</td>
<td>2.05</td>
</tr>
<tr>
<td>Claim dummy</td>
<td>1 if any claim(s) under the policy</td>
<td>2,649</td>
<td>0.14</td>
</tr>
<tr>
<td>Claim frequency</td>
<td>Average number of claims per policyholder</td>
<td>2,649</td>
<td>0.00097</td>
</tr>
</tbody>
</table>

Notes:

a. The variable *work* represents the accident tendency of an occupation. 1 represents the safest occupations, and 6 represents the most dangerous ones. For example, office workers are 1, and coal mine workers are 6. The insurer accepts very few risks with occupation categories above 4.

b. The variable *area* is based on the insurer’s branch categories, which consider not only regional wealth level but also regional insurance market maturity. It is thus a better control variable than pure wealth measurement. 1 represents the most developed regions in China, and 4 represents the least developed regions.

c. The claim frequency is not applicable for Sample B because it is very close to the claim dummy. If there is any claim under a policy, almost such cases have only one accident claim in that policy.
Empirical methodology

Equation (5) is applied to Samples A and B, respectively. The actual premium rate is regressed against the complete risk classification variables. Risk classification refers to the use of observable characteristics by insurers to determine the premiums. Thus, any trend found between the actual premium rate and the policy age reflects the insurer’s inter-temporal pricing strategy controlling for the underlying risk changes. The observed trend does not necessarily indicate the increase or decrease of the nominal premium rate but a relative premium increase or decrease to the actuarily fair premium (see Kunreuther and Pauly, 1985; Pauly, Kunreuther, and Hirth, 1995). We measure the premium rate with the natural logarithm of the average annualized premium rate per person. We measure the policy age with the number of renewal counts. All policies in both samples are yearly policies, and thus the number of renewals fully captures the policy experience with the insurer. $x_{i,t}$ is a vector of control variables, including policy features (insurance amount per person and, for Sample A, group size) and the risk classification factor (age, sex, and occupation categories). $Area_i$ and $Year_t$ control for area and year fixed-effects, respectively.

$$\text{Premium rate}_{i,t} = \beta_0 + \beta_1 \text{Policy age}_{i,t} + \beta_2 x_{i,t} + \beta_3 Area_{i} + \beta_4 Year_t + \epsilon_{i,t} \quad (5)$$

Equation (5) is estimated with OLS. Random-effects and firm fixed-effects models are used as robustness tests (see Zhang and Wang, 2008; Eling, Jia, and Yao, 2015), the results of which are consistent with the OLS. Chiappori and Salanié (2000) emphasize that the use of simple, linear functional forms on insurance policy-level data should be restricted to homogeneous populations. The samples meet the homogeneous criterion because (1) the business nature is largely the same within each sample as employee benefits in Sample A and as mortgage PA in Sample B; (2) the model includes all relevant pricing factors that account for potential heterogeneity among policies; (3) robust standard errors clustered at the (group) insured level further control for the heterogeneity. The variance inflation factors of the independent variables range from 1.02 to 1.63 for Sample A and from 1.00 to 1.67 for Sample B, suggesting that multicollinearity is not a problem. The Wooldridge test for autocorrelation in panel data does not reject the null hypothesis (i.e. no first-order autocorrelation) in both samples with p-value of 0.67 for Sample A and with p-value of 0.15 for Sample B respectively.

---

31 We choose the OLS as our core model because one firm can buy two or more policies in the nth year. All of these policies have the policy age of n, however, only one of them can be incorporated in the panel regressions. Thus, 14.8% of Sample A and 7.9% of Sample B have to be dropped if using the panel regression approaches, which reduces the estimation efficiency. The use of OLS is also driven by the cross-sectional analyses with subsamples for consecutive renewals.
Empirical results

Table 5 reports the results identifying the dynamic pricing pattern based on Equation (5). The Sample A results in Panel A show significantly positive coefficients between the premium rate and the policy age, indicating a pattern of premium lowballing (back-loaded), and thus support Proposition 1. The difference between Columns 1 and 2 in Panel A is that Column 2 includes an additional independent variable, the group claim frequency at \( t-1 \), to capture the experience rating at the group level for Sample A. Its coefficient is significantly positive, as expected, meaning that last-period high claim frequency associates with a higher premium rate in the current period.

Looking at the subsample results in Panel A, the premium pattern is flat for the first two periods, and then increases with the policy age in the 2nd, 3rd, and subsequent renewals. As the theoretical model suggests, the higher profit or price is viable in later periods because the incumbent insurer can learn the policyholder’s risk type in early periods, and thus can obtain information rents from the low risks through a premium above the actuarial fair one. Due to the low frequency nature of CI insurance, the insurer’s learning process may require more than one year. The insured groups may have not yet revealed their risk types in claim experience in the first two periods. This is particularly true for small groups as they may simply be lucky for not having any claims. This explanation is consistent with Eling, Jia, and Yao’s (2015) findings, where they use a different subsample of the same portfolio and show that learning of the incumbent insurer eliminates adverse selection after the first two periods. This flat and then increasing pattern implies that insurer learning is a necessary condition for the insurer adopting a price lowballing strategy and are consistent with our theoretical prediction.

Looking at the control variables, the actual premium rates negatively associate with the insurance amount (group size), suggesting discounts for large quantity of insurance (large clients). Older people have a much higher critical illness risk than younger people.

The Sample B results in Panel B of Table 5 show significantly negative coefficients between the premium rate and the policy age, indicating a pattern of premium highballing (front-loaded) and supporting Proposition 2.\(^{32}\) Looking at the subsample results in Panel B, the premium rate decreases with the policy age. The magnitude of coefficients between policy age and premium rate becomes smaller over time, suggesting that the scale of premium reduction decreases over time. Looking at the control variables, the female is less likely to have accidents than the male and older people have a lower accident risk than younger people. The occupation types, by definition, reflect the propensity for accidents, instead of illness. Thus, as expected, people in the safer categories have a lower premium rate of accident insurance.

\(^{32}\) The practice including experience rating factor is not applicable to Sample B because the loaner’s PA is experience rated at the bank level. However, we have only the information at the individual policyholder level, which is not experience rated over periods.
Sample A and B yield contrasting inter-temporal pricing patterns, which cannot be attributed to the idiosyncrasies of insurers, markets, time horizons, or learning types by our two-sample construct, but reasonably to the differences in the insurer’s commitment type as highlighted in Table 3 and suggested by our theoretical models. The Group CI falls into the scenario of no commitment with asymmetric learning after the second contract period. The detected significant lowballing pricing pattern confirms the prediction of Proposition 1. The Loaner’s PA falls into the scenario of one-sided commitment with asymmetric learning. The detected significant highballing pricing pattern confirms the prediction of Proposition 2.

As a robustness check, we estimate Equation (5) with random-effects and firm fixed-effects models. The results in Table 6 are consistent with the OLS results and support both propositions in the sense that the signs of coefficients between premium rate and policy age remain unchanged and significant. The advantage of firm fixed-effects is that it better captures the pricing dynamics of one firm over years. However, its costs are also significant as to omit all time invariant or less variant variables, such as gender, occupation, age, insurance amount, and group size, which are important pricing factors. Moreover, fixed-effects models may significantly reduce the estimation efficiency in a short panel as with the two samples of this paper. The samples of this paper meet the assumptions of random-effects model: (1) the policyholders can be considered as a random sample of the nationwide population, and (2) the uncontrollable firm heterogeneity is random and not correlated with the error terms (Greene, 2011; Gujarati, 2010).35

33 Eling, Jia, and Yao (2015) show that adverse selection disappears in Sample A after the first two contract periods, suggesting the applicability of Proposition 1. Moreover, as we argue in Section “Theoretical model and propositions”, Proposition 1 is mainly due to the lack of insurer’s commitment and remains if adverse selection is present in the first period. The synthesized empirical evidence from Table 2 also excludes adverse selection as a determinant of shape of the inter-temporal premiums.

34 The panel is set up with the (group) insured as \( i \) and with the renewal counts as \( t \). For example, insured A and B has their first policy with the insurer in 2009 and 2010, respectively, then these two policies are \((A, 0)\) and \((B, 0)\) although they are in different years. Therefore, \( t \) varies from 0 to 5 for sample A and from 0 to 4 for sample B. The year fixed effects are then controlled by dummy variables in the regression.

35 Please see Zhang and Wang (2008) for a detailed discussion on why and how to apply random-effects models in a dynamic insurance market.
Table 5 Main results.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Panel A: Group critical illness</th>
<th>Panel B: Loaner’s personal accident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full sample</td>
<td>New--&gt;1st renewal</td>
</tr>
<tr>
<td>Variables</td>
<td>Ln(premium rate)</td>
<td>Ln(premium rate)</td>
</tr>
<tr>
<td>Policy age</td>
<td>0.0192*</td>
<td>-0.0244</td>
</tr>
<tr>
<td></td>
<td>(0.0103)</td>
<td>(0.0167)</td>
</tr>
<tr>
<td>Ln(insurance amount)</td>
<td>-0.132***</td>
<td>-0.131***</td>
</tr>
<tr>
<td></td>
<td>(0.0107)</td>
<td>(0.0105)</td>
</tr>
<tr>
<td>Ln(group size)</td>
<td>-0.0859***</td>
<td>-0.0898***</td>
</tr>
<tr>
<td></td>
<td>(0.00755)</td>
<td>(0.00706)</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.207***</td>
<td>-0.274***</td>
</tr>
<tr>
<td></td>
<td>(0.0455)</td>
<td>(0.0442)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0430***</td>
<td>0.0446***</td>
</tr>
<tr>
<td></td>
<td>(0.00174)</td>
<td>(0.00165)</td>
</tr>
<tr>
<td>Work2</td>
<td>-0.0676**</td>
<td>-0.00971</td>
</tr>
<tr>
<td></td>
<td>(0.0297)</td>
<td>(0.0294)</td>
</tr>
<tr>
<td>Work3</td>
<td>-0.212***</td>
<td>-0.210***</td>
</tr>
<tr>
<td></td>
<td>(0.0278)</td>
<td>(0.0432)</td>
</tr>
<tr>
<td>Work4</td>
<td>-0.0493</td>
<td>-0.00367</td>
</tr>
<tr>
<td></td>
<td>(0.0432)</td>
<td>(0.0482)</td>
</tr>
<tr>
<td>Work5</td>
<td>0.0766</td>
<td>0.182**</td>
</tr>
<tr>
<td></td>
<td>(0.0682)</td>
<td>(0.0852)</td>
</tr>
<tr>
<td>Prior claim frequency</td>
<td>3.697**</td>
<td>1.729</td>
</tr>
<tr>
<td>Location FE/Year FE/Constant</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R²</td>
<td>0.368</td>
<td>0.354</td>
</tr>
<tr>
<td>Observations</td>
<td>5,369</td>
<td>2,269</td>
</tr>
</tbody>
</table>

Notes:
The table reports the estimated coefficients of OLS regressions. Robust standard errors clustered at (group) insureds level are presented in parentheses. *, **, *** indicates significant differences of coefficients from 0 at the 10%, 5%, and 1% levels, respectively.
a. The coefficient becomes less significant in this subsample probably due to the small number of observations.
Table 6 Results from random- and fixed-effects models.

<table>
<thead>
<tr>
<th>Samples</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Models</td>
<td>Random-effects</td>
<td>Fixed-effects</td>
<td>Random-effects</td>
<td>Fixed-effects</td>
</tr>
<tr>
<td>Variables</td>
<td>Ln(premium rate)</td>
<td>Ln(premium rate)</td>
<td>Ln(premium rate)</td>
<td>Ln(premium rate)</td>
</tr>
<tr>
<td>Policy age</td>
<td>0.00704</td>
<td>0.0194*</td>
<td>-0.00297***</td>
<td>-0.00190***</td>
</tr>
<tr>
<td></td>
<td>(0.00673)</td>
<td>(0.0116)</td>
<td>(0.000136)</td>
<td>(0.000148)</td>
</tr>
<tr>
<td>ln(insurance amount)</td>
<td>-0.142***</td>
<td>-0.0258***</td>
<td>-0.0801***</td>
<td>-0.0801***</td>
</tr>
<tr>
<td></td>
<td>(0.00869)</td>
<td>(0.00424)</td>
<td>(0.000136)</td>
<td>(0.000136)</td>
</tr>
<tr>
<td>ln(group size)</td>
<td>0.0376***</td>
<td>-0.0135***</td>
<td>-0.0135***</td>
<td>-0.0135***</td>
</tr>
<tr>
<td></td>
<td>(0.00135)</td>
<td>(0.000225)</td>
<td>(0.000225)</td>
<td>(0.000225)</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.184***</td>
<td>-0.0135***</td>
<td>-0.0135***</td>
<td>-0.0135***</td>
</tr>
<tr>
<td></td>
<td>(0.0407)</td>
<td>(0.000952)</td>
<td>(0.000952)</td>
<td>(0.000952)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0376***</td>
<td>-2.55e-05</td>
<td>0.0376***</td>
<td>-2.55e-05</td>
</tr>
<tr>
<td></td>
<td>(3.40e-05)</td>
<td>(3.40e-05)</td>
<td>(3.40e-05)</td>
<td>(3.40e-05)</td>
</tr>
<tr>
<td>Work1</td>
<td>-0.122***</td>
<td>-0.122***</td>
<td>-0.122***</td>
<td>-0.122***</td>
</tr>
<tr>
<td></td>
<td>(0.00135)</td>
<td>(0.00135)</td>
<td>(0.00135)</td>
<td>(0.00135)</td>
</tr>
<tr>
<td>Work2</td>
<td>-0.00922</td>
<td>-0.160***</td>
<td>-0.160***</td>
<td>-0.160***</td>
</tr>
<tr>
<td></td>
<td>(0.0182)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
</tr>
<tr>
<td>Work3</td>
<td>-0.100***</td>
<td>-0.108***</td>
<td>-0.108***</td>
<td>-0.108***</td>
</tr>
<tr>
<td></td>
<td>(0.0179)</td>
<td>(0.000790)</td>
<td>(0.000790)</td>
<td>(0.000790)</td>
</tr>
<tr>
<td>Work4</td>
<td>-0.00434</td>
<td>-0.108***</td>
<td>-0.108***</td>
<td>-0.108***</td>
</tr>
<tr>
<td></td>
<td>(0.0325)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
</tr>
<tr>
<td>Work5</td>
<td>-0.0103</td>
<td>-0.108***</td>
<td>-0.108***</td>
<td>-0.108***</td>
</tr>
<tr>
<td></td>
<td>(0.0643)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
<td>(0.00115)</td>
</tr>
<tr>
<td>Location FE</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Year FE/Constant</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Overall R²</td>
<td>0.354</td>
<td>0.042</td>
<td>0.138</td>
<td>0.205</td>
</tr>
<tr>
<td>Observations</td>
<td>4,803</td>
<td>4,916</td>
<td>1,149,541</td>
<td>1,164,759</td>
</tr>
</tbody>
</table>

Notes:
The table reports the estimated coefficients of random- and fixed-effects regressions. Standard errors are presented in parentheses. *, **, *** indicate significant differences of coefficients from 0 at the 10%, 5%, and 1% levels, respectively.
Conclusion

In this paper, we identify the role of insurer’s commitment in determining the inter-temporal dynamic pricing pattern of insurance. Our theoretical model (empirical evidence) shows that the lack of insurer’s commitment to the multi-period insurance relationship leads to (is associated with) the lowballing or back-loaded pricing pattern. In contrast, the presence of insurer’s commitment predicts (is associated with) the highballing or front-loaded pricing pattern. We conclude these paired relationships between insurer’s commitment and pricing pattern by controlling for the same learning environment, the same insurer, the same market, and almost the same time horizons. The economic insight behind the dynamic insurance pricing pattern may also be useful and applied to other industries with similar dynamic features and switching possibilities. One example is the commercial banking industry, where loan applicants rejected by one bank can apply at other banks (Shaffer, 1998).

There are some interesting directions for future research. First, it would be interesting to look at other aspects of dynamic insurance contracting, for example, the risk based dynamic selection that is the policyholder’s lapsation and insurer’s risk selection behaviors based on risk types (Finkelstein, McGarry, and Sufi, 2005; Hendel, 2016). We are not able to conduct these analyses in this paper due to data limitations and we leave it for future research. Specifically, we cannot isolate the impact of risk type on risk dynamics from other unobservable factors that also impact the demand and supply of insurance. Second, in practice, two products may exhibit the same highballing (or lowballing) pattern but with one more front-loaded (or back-loaded) than the other, and it would be interesting to investigate the determinants of the degree of front-loading or back-loading in a contract both empirically and theoretically. In this regard, Meta-analysis (Kysucky and Norden, 2014) may serve an important tool to compare the magnitude of pricing strategies across different products and markets.
Appendix A

Review of theoretical literature on competitive dynamic insurance contracts

A detailed discussion of papers in Table 1 is provided below.

Panel A: Adverse selection is present in period 1.

Cooper and Hayes (1987) and Kunreuther and Pauly (1985) initiate the modelling of multi-period contracting in the insurance context, in which an important feature is the presence of adverse selection. Assuming no commitment, Kunreuther and Pauly (1985) and Nilssen (2000) model the scenario of asymmetric insurer learning; Watt and Vazquez (1997) model symmetric learning. Kunreuther and Pauly (1985) focus on the equilibrium that involves pooling in the first period. In equilibrium insurer offers the same contract to all risk types with a premium reflecting the average of low and high risks. In the second period, risks who had claim(s) in the first period (high risks), switch to competing insurers. This is because the incumbent insurer can increase the premium for the period-one claimant; however, the competing insurers cannot tell who had a claim in the first period. Risks who did not have a claim (low risks) stay with the incumbent insurer in equilibrium because the incumbent insurer shall keep their premium unchanged. Therefore, in period 2, the insurer can earn positive profits by over charging the staying (low) risks. Under the zero-profit constraint, the insurer must price lower than zero-profit in the first period to attract new customers, which is considered as the cost of acquiring knowledge about the insured’s risk type. The incumbent insurer earns an informational quasi rent in the second period, which competing insurers do not. This pricing and profit pattern for a sequence of the contracts are hence lowballing.

Nilssen (2000) relaxes two assumptions imposed in Kunreuther and Pauly (1985). The first assumption is that policyholders are completely myopic, and derives utility solely from the payoffs in the first period, when making the initial purchase decision. The second assumption is that Kunreuther and Pauly (1985) do not allow insurers to offer menu contracts to screen policyholders. Nilssen (2000) shows that: (i) a separating equilibrium is less likely to be sustained in a two-period model than in the one-period one; (ii) a lowballing pricing pattern is possible but not necessary to emerge in equilibrium.

Watt and Vazquez (1997) assume that all insurers learn the insured’s risk type at the beginning of period 2, and thus adverse selection is only present in period 1. They show that a pooling equilibrium of full coverage exists if low risks are patient enough; or a semi-pooling equilibrium exists, where a portion of impatient low risks choose a sequence of Rothschild and Stiglitz’s (1976) partial coverages and all high risks and patient low risks choose a sequence of full coverages. In equilibrium, no inter-temporal subsidization is inferred, since in the first period, the insurer undercharges high risks but overcharges low risks, generating zero profit in aggregate; in the period, full information contracts are in place and thus all risks are charged at an actuarially fair rate. Vazquez and Watt (1999) assume no
insurers can learn policyholders’ risk types over time. The model is a straightforward extension of Rothschild and Stiglitz’s (1976) to a multi-period setting. They show that with the assumption of no commitment from both parties, non-zero profits cannot be earned in any single period and hence the multi-period equilibrium is simply a periodic repetition of Rothschild and Stiglitz’s (1976) single-period separating equilibrium: the high risks are offered with a sequence of full coverages and low risks partial coverages. Therefore, the pricing pattern is flat for both risk types.

Assuming one-sided and/or full commitment, Cooper and Hayes (1987) and Dionne and Doherty (1994) model the scenario of asymmetric insurer learning; the scenario of symmetric insurer learning has not yet been covered by literature. 36

Cooper and Hayes (1987) extend Rothschild and Stiglitz’s (1976) single-period adverse selection model to multi-period and discuss both one-sided and full commitment scenarios, and focus on separating equilibrium. With one-sided commitment and asymmetric learning 37, insurer offers contracts which are independent of histories and actuarial fair in both periods to the high risks and experience rated contracts to the low risks. Specifically, in the first period, the insurer charges low risks a higher premium than they should pay in a standard Rothschild and Stiglitz’s (1976) model; in the second period, the insurer gives those low risks without any period 1 claim a heavy discount, and thus charges them a lower premium than they should pay in a standard Rothschild and Stiglitz’s (1976) model. To summarize, the pricing pattern is highballing for the low risks and flat for the high risks with one-sided commitment. Intuitively, the insurer tilts payoffs towards the future to provide an incentive for insureds to remain with the firm. With full commitment, the high risks receive the same contract as in the scenario of one-sided commitment whereas the low risks are offered an experience rated contract. However, their model does not provide predictions on the dynamic pricing pattern for the low risks in such a case.

Dionne and Doherty (1994) extend the one-sided commitment model with renegotiation, which allows the insurer initially to commit to a long-term contract and to offer a revised short-term contract in the second period. The insured may stick to the long-term contract, accept the revised second-period short-term contract, or switch insurer in the second period. They focus on the equilibrium involving semi-pooling in the first period followed by separation in the second period. Specifically, a portion of high risks choose full coverage, and the rest of high risks and all low risks choose partial coverage in the first period. In the second period, the high risks switch to full short-term coverage (either offered by the incumbent insurer as a result of renegotiation or by a competing insurer); low risks stay with the long-term partial coverage. Dionne and Doherty (1994) show that Cooper and Hayes’s (1987)

36 With full commitment, asymmetric and symmetric learning maybe indifferent, because both parties pre-commit to a long-term contract and thus competition among insurers does not exist in the second period. Thus whether the insurer learning is asymmetric or symmetric makes no difference.

37 Cooper and Hayes (1987) make an extreme assumption on learning: the competition insurers in the second period learn neither the policyholders’ histories nor their choice of contract in the first period.
result is robust to the introduction of renegotiation. In equilibrium, insurer earns positive first-period expected profits and suffers second-period expected losses from the low risks, implying a highballing pattern.

**Panel B: Adverse selection is not present in period 1.**

*Assuming symmetric learning.* Pauly, Kunreuther, and Hirth (1995), Hendel and Lizzeri (2003) develop models with one-sided commitment. Pauly, Kunreuther, and Hirth (1995) assume that the insurer pre-commits to the long-term contractual relationship and show that a guaranteed renewability insurance with a sequence of premiums can be a competitive equilibrium and is Pareto optimal. By their construction, this guaranteed renewability insurance exhibits a highballing premium pattern. Specifically, the insurer charges all risks higher than the fair premium in the first period, to cover the future reclassification risk and to lock in the low risks. Though the insured is legally allowed to cancel the contract, he/she would not in equilibrium because he/she would not be strictly better off by leaving for a spot market. Pauly, Kunreuther, and Hirth (1995) acknowledge the possibility of a level, instead of a declining, actual premium across-periods in reality, which also reflects the highballing pattern, because the health risk increases over time and thus the level premium declines relative to the risk and to the actuarially fair premium. To simplify the analysis, the coverage of the risk is assumed to be exogenously given in Pauly, Kunreuther, and Hirth (1995). As a result, insurers only engage in price competition on premiums and there exists no tension between insurance and consumption smoothing.

Hendel and Lizzeri (2003) extend Pauly, Kunreuther, and Hirth (1995) by allowing insurers to choose both the premium and the coverage of a contract. The pricing pattern is again highballing, which is an important device to lock in low risks. In equilibrium consumers with low risks tend to departure from the incumbent insurer. They show that more front-loaded contracts provide more insurance against reclassification risk, and are selected by consumers with lower income growth.

*Assuming asymmetric learning.* Pauly, Menzel, Kunreuther, and Hirth (2011) relax the assumption of symmetric learning in Pauly, Kunreuther, and Hirth (1995), and focus on contracts with guaranteed renewability. With asymmetric learning, the result of highballing in Pauly, Kunreuther, and Hirth (1995) may not hold because the fact that the competing insurers cannot identify low risks directly provides incentives to the incumbent insurer to obtain information rents in later periods and to reduce the degree of front-loading. Again they show that the highballing pricing pattern remains. They first argue that the optimal guaranteed renewable contract, which is essentially the same as Pauly, Kunreuther, and Hirth (1995), is indeed immune to the information problem due to asymmetric

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38 The guaranteed renewability does not only guarantee renewals but also guarantee to only change premium to the same extent for all in the initial rating class (community rating) or following a pre-agreed premium schedule in subsequent periods (contingent rate). The experience rating based on individual’s risk change or claim experience is not allowed.
learning. Then they argue that the attempt to alter front-loading cannot be sustained in equilibrium because otherwise the competing insurers can craft a policy to attract only low risk consumers and earn profits by the standard Rothchild-Stiglitz argument.

De Garidel-Thoron (2005) presents a two-period model where both the insured and the incumbent insurer learn about the insured’s risk type from claim histories in the first period, but competing insurers do not. He derives the equilibrium contract and shows that information sharing between insurers is detrimental to consumer’s welfare, independent of insurer’s ability to commit to a long-term contract. The intuition is as follows. Although asymmetric information between incumbent and competing insurers generates information frictions and welfare loss to policyholders, it weakens the competing insurer’s ability to exercise a cream-off strategy, and thus improves the long-term commitment of both parties on the other hand. In equilibrium, this welfare gain outweighs the welfare loss due to information asymmetry, and hence consumer welfare is higher with asymmetric learning relative to that with symmetric learning through information sharing. In terms of the dynamic pricing pattern, assuming asymmetric learning, de Garidel-Thoron (2005) shows that the equilibrium contracts exhibit lowballing when insurers lack commitment power, while the equilibrium contracts exhibit a bonus-malus pattern when insurers are able to commit. However, de Garidel-Thoron (2005) does not conclude whether the contract is highballing or lowballing in the latter case.

Recently, Hendel (2016) proposes a simple framework in the spirit of Harris and Holmstrom (1982) to survey the theory and evidence on dynamic contracting under different environments of learning and commitment. Different from our review in Appendix A and B, which focus on the dynamic pricing pattern, his survey focuses on other issues such as the relationship between dynamic selection and policyholder’s lapse behavior and the welfare consequences due to lack of commitment.

Panel C: Discussions on the impact of the first period information (a)symmetry (connecting panel A and B)

Pauly (2003) provides an informal discussion on three scenarios. First, he takes de Garidel-Thoron’s (2005) no commitment scenario and concludes a pooling equilibrium in the first period and lowballing pricing pattern. Second, he discusses the one-sided commitment scenario in Pauly, Kunreuther, and Hirth (1995) and Hendel and Lizzeri (2003). A pooled equilibrium with price highballing can be expected. Third, he attempts to build the connection between the adverse selection and no adverse selection models. He argues that the presence of adverse selection (in the first period) should not change the highballing implication embedded in the insurer’s commitment (guaranteed renewability).
Appendix B

Review of empirical literature on dynamic insurance pricing pattern

A detailed discussion of papers in Table 2 is provided below.

Testing dynamic pricing pattern in markets with no commitment

D’Arcy and Doherty (1990) pioneer the empirical investigation in multi-period insurance contracting. They present the aggregate loss ratios by policy age cohorts of automobile insurance from seven US insurers. All seven portfolios show that loss ratios decline almost monotonically with policy age, suggesting lowballing pricing pattern and supporting Proposition 1. They also look at three new market entrants, which have only new policies, but no private information. They found that these three new insurers’ loss ratios were indeed high (low profit) in the beginning but gradually converge to other matured firms, supporting the price lowballing pattern in Proposition 1.

Cohen (2012) presents the first policy-level analysis for repeated short-term insurance contracting using an Israel automobile insurance portfolio. During the entire sample period, the information-sharing platform among insurers is not available, thus the asymmetric learning best captures the nature of the market. He shows that (1) profits from repeat insureds are higher than those from new insureds (i.e. a lowballing pattern); (2) the insurer reduces the price charged to repeated insureds with good claim history by less than the reduction in expected costs associated with such insureds (i.e. premium downward stickiness). The evidence is obtained after controlling for all risk classification factors. It directly supports Proposition 1. Cohen’s (2012) sample matches Kunreuther and Pauly (1985)’s (1985) and Nilssen’s (2000) assumptions and he argues for the role of asymmetric learning in determining the lowballing pricing pattern.

Kofman and Nini (2013) examine the Australian automobile insurance market, where a claim information sharing platform is in place to support a bonus-malus rating system. They believe that the publicly available data in Australian system capture all relevant risk type information about policyholders, with the only exception of brand new policies. Thus the market matches with Watt and Vazquez’s (1997) assumptions (i.e. adverse selection in period 1, symmetric learning in later periods, and no commitment). The public nature of such system eliminates one important source of asymmetric learning. They document evidence of lowballing pattern, supporting Proposition 1. Their evidence challenges Cohen’s (2012) argument regarding the important role of asymmetric learning in determining the pricing pattern.

Shi and Zhang (2015) investigate an insurer learning scenario in between Cohen’s (2012) no information sharing market and Kofman and Nini’s (2013) complete information sharing market. The Singapore automobile insurance market has a no-claim-discount (NCD) system and a public information sharing platform. However, the platform contains only information regarding the NCD
status but neither the insureds’ claim history nor their policy choice, which implies a partial information sharing among insurers (Shi and Zhang, 2015). Their conclusions again support Proposition 1 and suggest the product pricing pattern may not depend on insurer’s learning type.

Testing dynamic pricing pattern in markets with one-sided commitment

Dionne and Doherty (1994) examine a special automobile liability insurance portfolio from California, where two types of policies are offered: a long-term policy (one-sided commitment with renegotiation) and a short-term policy (no commitment). They approximate the average policy age in a portfolio by the premium growth of that portfolio (i.e. high (low) growth indicates in average younger (older) policy age) and find a positive correlation between average policy age and loss ratio in the subsample of low risks, which is in line with the higballing prediction of one-sided commitment (with renegotiation) model (Proposition 2).

Hendel and Lizzeri (2003) present the first-piece of evidence controlling for underlying risk differences (i.e. risk classification) in multi-period insurance contracting. They look at three products of life insurance from 55 US life insurers: 20-year term life with level premium each year (TL), annual renewable term life with premiums that depend only on age (ART), and annual renewable term life with premiums that depend on age and time elapsed since last medical examination (Selection & Ultimate ART). They find that TL and ART are significant front-loaded, where the insurer pre-commits to a long-term contract (LT) or to the guaranteed renewability with a determined rating schedule (ART). The relative price to the risk almost monotonically decreases through the 20 years, supporting Proposition 2. However, for Selection & Ultimate ART, where the premiums in later periods depend on whether the insured passed the medical reexamination (a weakened commitment with re-underwriting elements), the front-loading exists only in the first year but not in following years. They approximate the risk by the present values of premiums and find negative correlation between the front-loading and the risk: more front-loaded contracts insure higher proportion of low risks. They also show that more front-loaded contract (LT) has a lower lapse rate than less front-loaded contract (ART), indicating the low-risk lock-in effects associate with the higballing pricing pattern.

Cox and Ge (2004) present a panel data from the US long-term care (LTC) insurance market with cohort-specific information. They find a positive correlation between policy age and loss ratio, but argue that it reflects the risk changes over time and thus not a higballing pricing pattern. They also find a negative coefficient for policy age square, and argue that it indicates a decreasing speed of the loss ratio increases over time and thus indicates the insurer gradually increase the price relative to actuarial fair premium (i.e. a lowballing pattern).

One way to solve this apparent theoretical (higballing, Proposition 2) and empirical (lowballing in Cox and Ge, 2004) contradictory is to use the policy level data and control for risk classification, so
that the coefficient between policy age and price/profit can directly reveal the pricing pattern. Finkelstein, McGarry, and Sufi (2005) examine the US long-term care market in such a direct way. They document pricing highballing evidence consistent with Hendel and Lizzeri (2003), thus supporting Proposition 2.

Herring and Pauly (2006) numerically develop an ideal/optimal incentive compatible premium schedule for individual health insurance with guaranteed renewability, based on Pauly, Kunreuther, and Hirth’s (1995) one-sided commitment model. In addition, they estimate the actual market premiums for individual health insurance using Medical Expenditure Panel Survey, Community Tracking Study Household Survey, and National Health Interview Survey. They find that the actual premium schedule “does appear to be surprising consistency” with the estimated ideal premium schedule, thus supporting the highballing prediction in Proposition 2. They conclude that the front-loaded premium is necessary for health insurers to provide a guaranteed renewability and to insure the reclassification risk, however, is mitigated because the low-risk’s expected expense increases with age, the likelihood of becoming a high-risk increases with age, and the high risk either recovers or dies.

Pinquet, Guillen, and Ayuso (2011) examine the dynamic lapsation behavior in a long-term package coverages of health, life, and LTC from the Spanish market. Premiums are paid annually. The experience rating on individual basis is not allowed. They find front-loaded pricing (Proposition 2) in all three coverages evidenced by the increased benefit ratios from younger to older groups.

Hofmann and Browne (2013) present evidence from the German long-term private health insurance (one-sided commitment), where the insurers commit to offer renewal at a premium rate that does not reflect revealed future information about the insured risk. They support the theoretical predictions in Hendel and Lizzeri (2003): a highballing pricing pattern generates the effect of insured lock-in. The evidence from the German private health market demonstrates the robustness of the correlation between insurer commitment and the inter-temporal pricing pattern, which are immunized from the strict regulation and from the existence and possible domination of social insurance program. This work also contributes to the debate how private health solutions can insure the reclassification risk. The empirical evidence demonstrates the viability of the front-loaded premium schedule with guaranteed renewability (Pauly, Kunreuther, and Hirth, 1995) at least in a strictly-regulated and social insurance dominated market. In such market, the accessibility of health coverage is much less a problem than that in a private market.
Appendix C

Proof of Proposition 2

It is useful to first prove a lemma. For the ease of exposition, denote \((Q_2^{A^*}, Q_2^{N^*}, Q^*)\) as the solution to the following non-linear system of equations.

\[
\begin{align*}
    p_1 Q_2^{A^*} + (1 - p_1) Q_2^{N^*} &= p_1 L, \quad \text{(C.1)} \\
    u(W - Q_2^{N^*}) &= (1 - p_2^N) u(W - Q^*) + p_2^N u \left( W - L + \frac{1-p_2^N}{p_2^N} Q^* \right), \quad \text{(C.2)} \\
    u(W - Q_2^{A^*}) &= (1 - p_2^A) u(W - Q^*) + p_2^A u \left( W - L + \frac{1-p_2^N}{p_2^N} Q^* \right), \quad \text{(C.3)}
\end{align*}
\]

with \(Q^* \in [0, p_2^N L]\). In words, \((Q_2^{A^*}, Q_2^{N^*})\) refers to the premiums that generate zero profits in the second period and satisfies constraint (3). It is clear that \(Q_2^{A^*} > Q_2^{N^*}\). Moreover, it can be verified \(Q_2^{N^*}\) and \(Q_2^{A^*}\) are both strictly decreasing in \(Q^*\) from (C.2) and (C.3) for \(Q \in [0, p_2^N L]\). Therefore, there exists a unique solution to this non-linear system of equations.

Lemma C1: Suppose consumer's preference exhibits HARA, then

\[
\frac{1}{u'(W - p_1 L)} > \frac{p_2^A}{u'(W - Q_2^{A^*})} + \frac{1 - p_2^A}{u'(W - Q_2^{N^*})}.
\]

Proof: Substituting (C.1) into the above inequality yields,

\[
p_2^A \frac{u'(W - p_1 Q_2^{A^*} - (1 - p_1) Q_2^{N^*})}{u'(W - Q_2^{A^*})} + (1 - p_2^A) \frac{u'(W - p_1 Q_2^{A^*} - (1 - p_1) Q_2^{N^*})}{u'(W - Q_2^{N^*})} < 1.
\]

With HARA utility, the marginal utility is \(u'(c) = a \left( \frac{ac}{1-\eta} + b \right)^{\eta-1}\), and the above inequality can be simplified as,

\[
p_2^A \left[ p_1 + (1 - p_1) \frac{a}{1-\eta} (W - Q_2^{A^*}) + b \right]^{\eta-1} + (1 - p_2^A) \left[ p_1 \frac{a}{1-\eta} (W - Q_2^{N^*}) + b + (1 - p_1) \right]^{\eta-1} < 1.
\]

Denote \(\frac{a e_{(W - Q_2^{N^*}) + b}}{1-\eta} (W - Q_2^{A^*} + b)\) by \(\mu\). It remains to be shown that

\[
g(\mu) := p_2^A \left[ p_1 + (1 - p_1) \mu \right]^{\eta-1} + (1 - p_2^A) \left[ p_1 \frac{p_2^A}{\mu} + (1 - p_1) \right]^{\eta-1} < 1.
\]

Carrying out the algebra, \(g'(\mu) < 0\) is equivalent to

\[
(\eta - 1) \left[ \mu^{\eta - 1} - \frac{p_1}{1-p_1} \frac{1-p_2^A}{p_2^A} \right] < 0 \iff (\eta - 1) \left[ \mu^n - \frac{p_2^N}{p_2^A} \right] < 0.
\]

Next, we consider three cases depending on the value of \(\eta\).
Case I: $0 < \eta < 1$. It is clear that $\mu > 1$ under such scenario, and hence $\mu^n > 1 > p_2^N/p_2^A$. Therefore, $g(\mu)$ is strictly decreasing in $\mu$ for $\mu > 1$, and hence $g(\mu) < g(1) = 1$.

Case II: $\eta < 0$. Again, $\mu > 1$. Moreover, $\mu \eta$ can be bounded from below by,

$$\mu \eta = \frac{e}{1-\eta} \left[ \frac{a}{1-\eta} (W - Q_2^N) + b \right]^n = \frac{u(W - Q_2^N)}{u(W - Q_2^A)}$$

$$\left( 1 - p_2^A \right) u(W - Q_2^N) + p_2^A u \left( W - L + \frac{1 - p_2^N}{p_2^N} Q_1^A \right)$$

$$\left( 1 - p_2^A \right) u(W - Q_2^N) + p_2^A u \left( W - L + \frac{1 - p_2^N}{p_2^N} Q_1^A \right) > \frac{p_2^N}{p_2^A}$$

where the second equality follows directly from the assumption of HARA utility, the third equality follows from (C.2) and (C.3), and the inequality follows from the fact that $p_2^A > p_2^N$. Therefore, $g(\mu)$ is strictly decreasing in $\mu$ for $\mu \in (1, \left( p_2^N / p_2^A \right)^{1/\eta})$, which implies $g(\mu) < g(1) = 1$.

Case III: $\eta > 1$. It is clear that $\mu < 1$. Similar to Case I, we must have $\mu^n > p_2^N/\mu^2$, which implies instantly that $\mu > \left( p_2^N / p_2^A \right)^{1/\eta}$. Therefore, $g(\mu)$ is strictly increasing in $\mu$ for $\mu \in \left( \left( p_2^N / p_2^A \right)^{1/\eta}, 1 \right)$, and hence $g(\mu) < g(1) = 1$.

Suppose to the contrary that the equilibrium contract $(Q_1^*, Q_2^A, Q_2^N)$ maximizes consumer's expected utility, and is not front-loaded (i.e. $Q_1^* \leq p_1 L$). We can construct an alternative contract that yields a strictly higher expected utility and satisfies constraint (1) to (4) by the following two steps:

**Step 1** For notational convenience, denote the solution to $IC_2^N(\bar{Q}_2^N; C_2^A^*) = IC_2^A(\bar{Q}_2^A; C_2^A^*)$ by $\bar{Q}_2^N$. For a sufficiently small $\varepsilon > 0$, let $\bar{Q}_2^A$ and $\bar{Q}_2^N$ be the solution to

$$u(W - \bar{Q}_2^N) = (1 - p_2^N) u(W - Q_1^*) + p_2^N u \left( W - L + \frac{1 - p_2^N}{p_2^N} Q_2^N + \varepsilon \right). \tag{C.5}$$

and

$$u(W - \bar{Q}_2^A) = (1 - p_2^A) u(W - Q_1^*) + p_2^A u \left( W - L + \frac{1 - p_2^N}{p_2^N} Q_2^N + \varepsilon \right). \tag{C.6}$$

Let $\bar{Q}_1$ be the solution to

$$\left( \bar{Q}_1 - p_1 L \right) + \delta \left[ p_1 (\bar{Q}_2^A - p_2^A L) + (1 - p_1) (\bar{Q}_2^N - p_2^N L) \right] = 0. \tag{C.7}$$

It is obvious that the sequence of premiums $(\bar{Q}_1, \bar{Q}_2^A, \bar{Q}_2^N)$ satisfies constraint (1), (2), and (4). Next we show that this constructed contract indeed generates a strictly higher expected utility than that under $(Q_1^*, Q_2^A^*, Q_2^N^*)$. To see this, notice that the first order approximation of equation (C.5) and (C.6) around $\varepsilon = 0$ yields,
\[ Q^N_2 - \tilde{Q}^N_2 \cong p^N_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q)}{u'(W - Q^N_2)} \varepsilon, \]

and

\[ Q^A_2 - \tilde{Q}^A_2 \cong p^A_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*)}{u'(W - Q^A_2)} \varepsilon. \]

Together with (C.7), the difference between \( \tilde{Q}_1 \) and \( Q^*_1 \) can be approximated by,

\[ \tilde{Q}_1 - Q^*_1 \cong \delta p_1 p^A_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*)}{u'(W - Q^A_2)} \varepsilon + \delta (1 - p_1) p^N_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*)}{u'(W - Q^N_2)} \varepsilon, \]

and the discounted second period expected utility increases by

\[ \delta \left( p_1 u'(W - Q^A_2) p^A_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*)}{u'(W - Q^A_2)} \varepsilon + (1 - p_1) p^N_2 \frac{u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*)}{u'(W - Q^N_2)} \varepsilon \right) = \delta p_1 u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*) \varepsilon. \]

Hence, it remains to show that

\[ \delta p_1 u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*) \varepsilon > u'(W - Q^*_1) u'(W - L + \frac{1-p^N_2}{p^N_2} Q^*) \left( \frac{\delta p_1 p^A_2}{u'(W - Q^A_2)} + \frac{\delta (1 - p_1) p^N_2}{u'(W - Q^N_2)} \right) \varepsilon, \]

which is equivalent to

\[ \frac{1}{u'(W - Q^*_1)} \geq \frac{p^A_2}{u'(W - Q^A_2)} + \frac{1 - p^A_2}{u'(W - Q^N_2)} \]

From the postulated assumption that contract \( (Q^*_1, Q^*_2, Q^N_2) \) is not front-loaded, we must have \( Q^A_2 \geq Q^A_2, Q^N_2 \geq Q^N_2, \) and \( Q^*_1 \leq p_1 L. \) Therefore,

\[ \frac{1}{u'(W - Q^*_1)} \geq \frac{1}{u'(W - p_1 L)} \geq \frac{p^A_2}{u'(W - Q^A_2)} + \frac{1 - p^A_2}{u'(W - Q^N_2)} \geq \frac{p^A_2}{u'(W - Q^A_2)} + \frac{1 - p^A_2}{u'(W - Q^N_2)}, \]

where the first and third inequality follow from the monotonicity of \( u'(\cdot) \), and the second inequality follows directly from Lemma C1. This completes the proof of Step 1.

**Step 2** Fixing \( \tilde{Q}_1 \), we increase \( \tilde{Q}^N_2 \) and decrease \( \tilde{Q}^A_2 \) to satisfy constraint (1) and (3) simultaneously. Specifically, constraint (1) is always satisfied if we increase \( \tilde{Q}^N_2 \) by \( x > 0 \) and decrease \( \tilde{Q}^A_2 \) by \( \frac{1-p_1}{p_1} x. \)

From the continuity of \( u(\cdot) \), there exists a \( \tilde{x} > 0 \) such that contract \( (\tilde{Q}_1, \tilde{Q}^A_2 - \frac{1-p_1}{p_1} \tilde{x}, \tilde{Q}^N_2 + \tilde{x}) \) satisfies constraint (3). Therefore, the constructed contract satisfies constraint (1) to (4). To complete
the proof, it suffices to show that contract \((\hat{Q}_1, \hat{Q}_2^A - \frac{1-p_1}{p_1} \bar{x}, \hat{Q}_2^N + \bar{x})\) generates strictly higher expected utility than contract \((\hat{Q}_1, \hat{Q}_2^A, \hat{Q}_2^N)\), which is equivalent to show

\[
p_1 u(W - \hat{Q}_2^A) + (1-p_1)u(W - \hat{Q}_2^N) < p_1 u\left(W - \hat{Q}_2^A + \frac{1-p_1}{p_1} \bar{x}\right) + (1-p_1)u(W - \hat{Q}_2^N - \bar{x}). \tag{C.8}
\]

Notice that

\[
W - \hat{Q}_2^A + \frac{1-p_1}{p_1} \bar{x} = \frac{1-p_1}{p_1} \hat{Q}_2^A - \frac{1-p_1}{p_1} \hat{Q}_2^N (W - \hat{Q}_2^N) + \frac{\hat{Q}_2^A - \hat{Q}_2^N - \frac{1-p_1}{p_1} \bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} (W - \hat{Q}_2^A),
\]

and

\[
W - \hat{Q}_2^N - \bar{x} = \frac{\hat{Q}_2^A - \hat{Q}_2^N - \bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} (W - \hat{Q}_2^N) + \frac{\bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} (W - \hat{Q}_2^A).
\]

The fact that \(\hat{Q}_2^N < \hat{Q}_2^A + \bar{x} < \hat{Q}_2^A - \frac{1-p_1}{p_1} \bar{x} < \hat{Q}_2^A\) together with the strict concavity of \(u()\) implies instantly that,

\[
u\left(W - \hat{Q}_2^A + \frac{1-p_1}{p_1} \bar{x}\right) > \frac{1-p_1}{p_1} \hat{Q}_2^A - \hat{Q}_2^N u(W - \hat{Q}_2^N) + \frac{\hat{Q}_2^A - \hat{Q}_2^N - \frac{1-p_1}{p_1} \bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} u(W - \hat{Q}_2^A), \tag{C.9}
\]

and

\[
u(W - \hat{Q}_2^N - \bar{x}) > \frac{\hat{Q}_2^A - \hat{Q}_2^N - \bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} u(W - \hat{Q}_2^N) + \frac{\bar{x}}{\hat{Q}_2^A - \hat{Q}_2^N} u(W - \hat{Q}_2^A). \tag{C.10}
\]

Multiplying (C.9) by \(p_1\), (C.10) by \(1 - p_1\), and adding them up yields (B.8). This completes the proof of Step 2. Q.E.D.
Appendix D

Robustness of Proposition 1-2 with a different assumption of policyholder’s risk

In this section, we assume that policyholder’s type worsens over time as in Hendel and Lizzeri (2003), and show that the equilibrium pricing patterns predicted in Proposition 1 and 2 remain. Formally, we assume that the second period loss probability is \( p_2 \in \{ p_2^A, p_2^N \} \) with \( p_2^A > p_2^N > p_1 \) and \( \text{Pr}(p_2 = p_2^A) = 1 - \text{Pr}(p_2 = p_2^N) = p \in (0,1) \). The second period loss probability \( p_2 \) is learned by the incumbent insurer and the policyholder, but not observed by the entrants. For notational convenience, denote the policyholder’s average risk in the second period by \( \bar{p}_2 \equiv p \times p_2^A + (1 - p) \times p_2^N \), and it is clear that \( \bar{p}_2 > p_1 \).

Notice that the proof of Proposition 1 is the same as that of Proposition 2 in de Garidel-Thoron (2005), which does not rely on the martingale property \( p_1 = p_1 p_2^A + (1 - p_1) p_2^N \) as well as the distribution of \( p_2 \). Therefore, the equilibrium contract still exhibits highballing with the alternative assumption \( p_2^A > p_2^N > p_1 \), and it remains to show that Proposition 2 holds. Before we proceed, it is worth mentioning that the following proof does not require consumer’s preference exhibits HARA.

The equilibrium contract solves the following problem:

\[
\max_{(Q_1, Q_2^A, Q_2^N)} u(W - Q_1) + \delta \left[ pu(W - Q_2^A) + (1 - p)u(W - Q_2^N) \right],
\]

subject to

\[
\begin{align*}
(Q_1 - p_1 L) + \delta[p(Q_2^A - p_2^AL) + (1 - p)(Q_2^N - p_2^NL)] &= 0, \quad \text{(D.1)} \\
Q_2^A &\leq p_2^AL, \quad \text{(D.2)} \\
IC_2^N(Q; C_2^N) \text{ and } IC_2^A(Q; C_2^A) \text{ cross on the line } (1 - p_2^N)Q - p_2^N R = 0, \quad \text{(D.3)} \\
IC_2^N(Q; C_2^N) \text{ and } (1 - \bar{p}_2)Q - \bar{p}_2 R &= 0 \text{ do not intersect.} \quad \text{(D.4)}
\end{align*}
\]

Suppose to the contrary that the equilibrium contract \((Q_1^{**}, Q_2^{A**}, Q_2^{N**})\) maximizes consumer’s expected utility, and is not front-loaded (i.e. \( Q_1^{**} \leq p_1 L \)). We can construct an alternative contract that yields a higher expected utility and satisfies constraint (D.1) to (D.4) by the following two steps:

**Step 1** Fix \( Q_2^{A**} \), decrease \( Q_2^{N**} \) by \( \epsilon' \), and increase \( Q_1^{**} \) by \( \delta(1 - p)\epsilon' \) for a sufficiently small \( \epsilon' > 0 \). It is clear that constraint (D.1), (D.2) and (D.4) are still satisfied but constraint (D.3) is violated. Denote policyholder’s expected utility with the equilibrium contract and the constructed contract as \( U^{**} \) and \( U(\epsilon') \) respectively. Taylor expansion around the equilibrium contract (i.e., \( \epsilon' = 0 \)) yields,

\[
U(\epsilon') - U^{**} \approx [u'(W - Q_2^{N**}) - u'(W - Q_1^{**})]\delta(1 - p)\epsilon',
\]

Therefore,
\[ U'(0) = \lim_{\varepsilon' \to 0} \frac{U(\varepsilon') - U^{**}}{\varepsilon'} = [u'(W - Q_2^{N**}) - u'(W - Q_1^{**})]\delta(1 - p). \]

From constraint (D.3) and the shape of \( IC_2^N(Q; C_2^N) \), we must have \( Q_2^{N**} \geq p_2^NL \). Together with the postulated \( Q_1^{**} \leq p_1L \), we must have
\[ Q_1^{*} \leq p_1L < p_2^NL \leq Q_2^{N**}, \]
which implies instantly that \( u'(W - Q_2^{N**}) > u'(W - Q_1^{**}) \). Therefore, \( U'(0) > 0 \). From the continuity of \( u(\cdot) \), there exists a \( \varepsilon'_1 > 0 \) such that contract with premiums \( (Q_1^{**} + \delta(1 - p)e', Q_2^{A**}, Q_2^{N**} - \varepsilon') \equiv (\hat{Q}_1, \hat{Q}_2^A, \hat{Q}_2^N) \) generates a strictly higher expected utility than the equilibrium contract with premiums \( (Q_1^{**}, Q_2^{A**}, Q_2^{N**}) \).

**Step 2** Fixing \( \hat{Q}_1 \), we increase \( \hat{Q}_2^N \) and decrease \( \hat{Q}_2^A \) to satisfy constraint (D.1) and (D.3) simultaneously. It is clear that the constructed contract satisfies constraint (D.1)-(D.4). By the same argument as Step 2 in the proof of Proposition 2, this contract generates more utility to policyholders than contract with premiums \( (\hat{Q}_1, \hat{Q}_2^A, \hat{Q}_2^N) \). This completes the proof.
References


