Insurer Commitment and Dynamic Pricing Pattern[*]

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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 and others a lowballing (back-loaded) pattern, while still others are flat. We develop a unified competitive dynamic insurance model with asymmetric learning to investigate the impact of insurer commitment on the equilibrium inter-temporal pricing pattern. The model predicts that the equilibrium contract exhibits highballing under one-sided commitment and lowballing under no commitment. We then use a unique empirical setting of two products from one insurer, eliminating heterogeneity in firm, market, time horizon, information frictions, and learning environment, to isolate the role of insurer commitment in determining the pricing pattern. Consistent with our theoretical predictions, we find that (i) the dynamic contracts exhibit a highballing pattern in loaner's personal accident insurance, a one-sided commitment scenario, and (ii) a lowballing pattern in group critical illness insurance, a no commitment scenario.

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

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Introduction

Multi-period 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[1] (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 relationships.[2]

The dynamic nature of multi-period insurance contracting, which is absent in a static setup, motivates both the 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 upon the renewals of short-term contracts. Previous studies 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). These dynamic pricing patterns result from an insurer's deliberate pricing strategy: The insurer may discriminate among cohorts of different policy ages and then charge high or low prices on average for early or late policy periods.[3]

Previous literature suggests that the equilibrium dynamic pricing pattern is sensitive to the contractual parties' commitment to the contract and to the type of information environment (see Table 1). Commitment to contract refers to the insurer's and policyholder's ability to leave or modify the contract at the end of each period. Typical forms of insurer commitment include long-term and short-term contracts with guaranteed renewability, while lack of insurer commitment is often associated with renewable short-term contracts. The information environment regarding the policyholder's risk

[1] For example, Swiss insurers usually give a premium discount to policyholders who accept three- to five-year contracts, indicating a strong preference for 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 launches, the project owner tends to continuously work with the same insurer on one project after another; hence, it is essentially a multi-period relationship.

[3] The dynamic pricing pattern is in essence an insurer's pricing strategy to charge upfront the value of its own commitment (highballing), or to pay for the opportunity of learning the risk type (lowballing). See Definition 1 in the next section for formal definitions of the highballing, lowballing, and flat pricing patterns. It is useful to point out that insurers will take into consideration the policyholder's possible action (a choice of contracts or a claim) when they make pricing decisions at the beginning. For instance, a policyholder in our theoretical model can lapse his/her contract at the beginning of the second period and select an alternative one from the competing insurers. The insurers expect such policyholder action when they offer insurance contracts. Therefore, such a pricing strategy can coexist in parallel with the actuarial pricing based on risk discrimination (e.g., a bonus-malus system) and with the policyholders' self-selection process (e.g., the design of menu contracts). See Cohen (2012) and Shi and Zhang (2016) for a detailed discussion on how the lowballing strategy works in a bonus-malus system. See also Cooper and Hayes (1987) for how the highballing strategy works when menu contracts are offered by the insurer. In our theoretical model below, the insurers can adjust their insurance prices based on policyholders' claim histories, and thus a bonus-malus system or other form of experience rating is allowed. Like de Garidel-Thoron (2005) and Hendel and Lizzeri (2003), we assume away period-1 adverse selection in our model. Therefore, the insurers have no incentive to design menu contracts to screen policyholders. See Footnotes 11 and 15 for discussions of the presence of adverse selection.

type involves two layers: information (a) symmetry between the policyholder and the insurer when signing the contract; and that between the incumbent insurer and competing insurers concerning the policyholder's risk type (i.e., whether learning is symmetric among all insurers). Different theoretical predictions based on various assumptions regarding commitment and information have fueled empirical investigations of the dynamic pricing pattern in several insurance markets (see Table 2).

Focusing on the competitive insurance market, in this paper we first comprehensively review and structuralize the extant theoretical models and empirical evidence in dynamic insurance contracting. Next, we develop a unified two-period competitive dynamic insurance model with asymmetric learning to predict the equilibrium pricing pattern under two 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 highballing pricing pattern. More formally, the insurer charges a higher premium in the first period and a lower premium in the second period than the actuarially fair one. In the case of no commitment, however, where both contractual parties lack commitment power to the contract, the equilibrium contracts exhibit a lowballing pricing pattern: the insurers charge a lower premium in the first period and a higher premium in the second than the actuarially fair one. These results are robust to different assumptions about policyholder's risk changes.

Last but not least, we empirically identify insurer commitment as an important determinant of the dynamic pricing pattern, using a unique empirical setting of two products from one insurer. The existing empirical tests on the dynamic pricing pattern are performed using a single insurance product. Therefore, it is difficult to conclude whether the observed pricing pattern is due to the commitment or the information environment. To remedy this deficiency, we present a pair of samples (group critical illness insurance and loaner's personal accident insurance) from the same insurance company. The two products share a similar information environment but differ in the insurer's ability to commit to the contract. This unique empirical setting isolates the role of insurer commitment from that of information, as well as other potential determinants (see Table 3) of the shape of the dynamic pricing pattern. We document evidence consistent with our theoretical predictions in that the group critical illness (CI) contracts exhibit a lowballing pattern, whereas the loaner's personal accident (PA) contracts exhibit a highballing pattern.

This paper contributes to the literature on competitive dynamic contracts in the following aspects. First, we develop a unified two-period model of asymmetric learning (also called private learning) based on de Garidel-Thoron (2005), to predict the dynamic pricing pattern under one-sided commitment. By comparing our results with those in the literature (Hendel and Lizzeri; 2003; de Garidel-Thoron, 2005; Pauly et al., 2011), we are able to theoretically disentangle the impact of commitment from learning on the equilibrium contract, and identify insurer commitment as the driving force behind the shape of the dynamic pricing pattern. Second, 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 equilibrium dynamic pricing patterns, and might be useful to students and researchers studying the topic on dynamic pricing. Third, we conduct a two-sample empirical test, eliminating heterogeneity in firm, market, time horizon, information frictions, and learning environment in order to isolate the role of insurer commitment. We document evidence consistent with the theoretical predictions. Our results expand the empirical evidence on insurer learning (Hendel and Lizzeri, 2003; Cohen 2012; Kofman and Nini, 2013; Shi and Zhang, 2016) and on contractual commitment (Dionne and Doherty, 1994; Hofmann and Browne, 2013). Last but not least, our empirical test using loaner's PA insurance fills the gap in the investigation of pricing pattern with one-sided commitment and asymmetric learning.

This paper also contributes to the ongoing discussion on the determinants of insurance companies' pricing strategy. For instance, Chan, Huang, and Tzeng (2016) predict that the insureds with lower loss probability and higher income level receive more premium discounts using a sequential insurance bargaining model; and document empirical evidence from Taiwanese automobile liability insurance to support their theoretical predictions. Aiming to rationalize the "underwriting cycle", Henriet, Klimenko, and Rochet (2016) develop a continuous-time general-equilibrium model and highlight the role of financial frictions in shaping firm's pricing dynamics. Our paper complements these papers by analyzing the inter-temporal pricing pattern, a new dimension of pricing strategy attaching to insurance product in addition to the pricing discount and underwriting cycles.

The remainder of the paper is structured as follows. In the next section, we review the theoretical and empirical literature on dynamic insurance contracting. The following section proposes a unified two-period model with asymmetric learning, and proves associated propositions. The subsequent section presents the empirical analyses including sample, methodology, results, and robustness tests. The final section concludes, and suggests directions for future research. All proofs are relegated to Appendix C.

Literature review

Theories on competitive dynamic insurance contracts

The equilibrium of a competitive dynamic insurance contract can be characterized under various commitments 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 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 a renewal guarantee from either side. Typical forms of one-sided commitment include a long-term contract (e.g., ten-year term life insurance) and an annual contract with guaranteed renewability (e.g., individual health insurance with a guaranteed renewal clause). One of the common features of these forms is the insurer's commitment to a pre-agreed premium schedule, which can either be contingent or non-contingent on claim experience. Contracts with full commitment are rarely observed in practice because the insurance law in most markets allows policyholders to cancel their insurance policies at any time.

The informational assumptions in multi-period insurance contracting involve two layers: information (a)symmetry between the policyholder and the insurer(s); and that between the incumbent (current) insurer and competing (rival) insurers. The first layer has been extensively studied in the single-period setup, within the context of adverse selection and moral hazard.[4] The second layer stems from the dynamic nature: the incumbent insurer may obtain information advantages over its competitors, due to its learning[5] from the contractual experience with the policyholder. Pauly (2003) proposes the following three information environments based on these two layers of informational assumptions: (i) classic adverse selection, where the policyholder has private information that no insurers know; (ii) symmetric information, where 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 learn the evolving risks symmetrically, but the competing insurers do not. In this paper, we extend Pauly's (2003) information structures to four categories based on the presence of adverse selection in period 1 and on the type of learning in period 2.

Table 1 summarizes the theoretical literature on dynamic insurance contracting into 12 assumption sub-categories by three commitment types and four information possibilities. 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. See Appendix A for a detailed discussion of each paper in Table 1.

Three papers closely related to our theoretical framework are Hendel and Lizzeri (2003), de Garidel-Thoron (2005), and Pauly et al. (2011).[6] Hendel and Lizzeri (2003) develop a model of life insurance assuming symmetric learning and one-sided commitment. They predict that the equilibrium contract is highballing. In their model, the highballing pricing strategy serves as an important device to lock in low risks. It is useful to point out that 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

[4] All models discussed in this paper (implicitly) assume away moral hazard. A separate stream of dynamic contracting studies investigates moral hazard issue (see e.g., Rubinstein and Yaari, 1983; Rogerson, 1985).

[5] Learning partly reflects the updates in the initial (but unknown) differences in risks, and partly the signal (and real) changes in risks (Pauly, 2003).

[6] Also related, Kunreuther and Pauly (1985) and Nilssen (2000) develop models of multi-period insurance markets with asymmetric learning and no commitment. Unlike our framework, they assume the presence of adverse selection in the first period and predict a lowballing pricing pattern, as in our Proposition 2. See Footnote 15 for discussions in detail on the connections of these two papers with Proposition 2 in this paper.

that the highballing feature remains if insurer learning is asymmetric (see Proposition 1 in the main text, and Proposition A1 in Appendix E).

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, and 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 1 and Remark 1) fills this gap under certain mild assumptions on the insurer learning or on consumer preference.

Assuming asymmetric learning and one-sided commitment, Pauly et al. (2011) conclude that the equilibrium contract exhibits highballing by restricting attention to contracts with guaranteed renewability (i.e., experience rating on an individual level is not allowed). 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 et al. (2011) by showing that the equilibrium contract is indeed highballing (Proposition 1) even if the insurer is free to use the new information on risks in future periods (i.e., experience rating is allowed), again under the aforementioned assumptions.

Empirical evidence on 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 sheds some light on the relationships between the dynamic pricing pattern and commitment, as well as the information environment. In terms of insurer commitment, if the insurer offers short-term contracts without a renewal guarantee (i.e., the insurer has no commitment power), the inter-temporal pricing pattern is lowballing (all four pieces of evidence support this statement, Columns 1-4). In contrast, the pattern is mostly highballing (six out of seven support this statement,[7] Columns 5-11) if the insurer offers long-term contracts or a sequence of short-term contracts with guaranteed renewability (i.e., the insurer has commitment power). In terms of the information environment, the extant evidence does not reveal a systematic relationship between the presence of adverse selection and the pricing pattern, nor one between the insurer's types of learning and the corresponding pricing pattern.

[7] This exception may be due to different interpretations of Cox and Ge's (2004) results. Their empirical model includes the *policy age* and its square term as the key explanatory variables, and the *loss ratio* of each policy as the dependent variable. They document a positive coefficient for policy age and a negative coefficient for its square term. We believe that this result should be interpreted as a highballing profit pattern with a decreasing speed of profit increase. In this sense, their empirical results also confirm the highballing strategy.

Table 1 Theories on competitive dynamic insurance contracts.

Information \ Commitment	No commitment	One-sided commitment	Full commitment
Panel A: Adverse selection is present in period 1			
Asymmetric learning	Lowballing (Kunreuther and Pauly, 1985; Nilssen, 2000)	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)[a]	High risks receive a flat contract independent of experience; policies for low risks are experience rated (Cooper and Hayes, 1987)[b]
Symmetric learning	Flat (Watt and Vazquez, 1997)	Not covered by literature	
Panel B: Adverse selection is NOT present in period 1			
Asymmetric learning	Lowballing (de Garidel-Thoron, 2005)	Highballing (Pauly et al., 2011)[c] Our contribution	Indeterminate (Hendel, 2016)[b]
Symmetric learning	Flat (Hendel, 2016)[d]	Highballing (Pauly, Kunreuther, and Hirth, 1995; Hendel and Lizzeri, 2003; Hendel, 2016)[e]	
Panel C: Discussion connecting Panels 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; unlike 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: 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 does not predict the equilibrium pricing pattern.

d. 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.

Table 2 Empirical evidence on dynamic insurance pricing pattern.

	D'Arcy and Doherty (1990)	Cohen (2012)	Kofman and Nini (2013)	Shi and Zhang (2016)	Dionne and Doherty (1994)	Hendel and Lizzeri (2003)	Cox and Ge (2004)	Finkelstein, McGarry, and Sufi (2005)	Herring and Pauly (2006)	Pinquet, Guillen, and Ayuso (2011)	Hofmann and Browne (2013)	Our paper	
	No commitment				*One-sided commitment*							*No commitment*	*One-sided commitment*
Product	Auto	Auto	Auto	Auto	Auto Liability	Term Life	LTC	LTC	Individual Health	Health, life, and LTC	Individual health	Group critical illness	Loaner's personal accident
Market	US	Israel	Australia	Singapore	CA, US	US	US	US	US	Spain	Germany	China	China
Policy duration	ST	ST	ST	ST	LT	LT or GR	GR	GR or LT	GR	GR	LT or GR	ST	GR
Commitment type	No	No	No	No	One-sided [a]	One-sided	One-sided	One-sided	One-sided	One-sided	One-sided	No	One-sided
Adverse selection	Yes	Yes	Weak	Yes	Yes	No	Yes	Not discussed	Not discussed	Yes	Yes	Yes	No
Insurer learning	Asym	Asym	Sym	Btw asym and sym	Asym	Sym	Not discussed	Sym	Not discussed	Sym [b]	Sym	Asym	Asym
Lowballing	Confirm	Confirm	Confirm	Confirm	/	/	/	/	/	/	/	Confirm	/
Highballing	/	/	/	/	Confirm	Confirm	Reject[c]	Confirm	Confirm	Confirm	Confirm	/	Confirm

Notes:

The definition of abbreviations is as follows. Auto stands for the automobile insurance. LTC stands for long-term care insurance. GR stands for guaranteed renewability. ST and LT represent short-term policy and long-term policy, respectively. Asym and Sym represent asymmetric learning and symmetric learning, respectively.

a. 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 the new offer and stay with the original terms. Thus, the insurer is still essentially bound to the original terms for two periods.

b. 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."

c. We believe that the empirical results in Cox and Ge (2004) should be interpreted as a highballing profit pattern with a decreasing speed of profit increase; hence, their empirical findings also confirm the highballing strategy. See Footnote 7 for a detailed discussion.

Theoretical model and propositions

In this section, we develop a unified dynamic insurance model with asymmetric learning to investigate the equilibrium pricing pattern for the one-sided commitment case and the no commitment case. Our baseline model builds on de Garidel-Thoron (2005), who assumes that policyholder's risk does not change over time.[8] We adopt this assumption also because the risks employed in our subsequent empirical tests can be considered as unchanged over time. De Garidel-Thoron (2005) characterizes the equilibrium contract for both the one-sided and the no commitment cases, but only predicts a lowballing pricing pattern under no-commitment. Whether the equilibrium contract for the one-sided commitment case exhibits highballing or lowballing remains unknown. In Proposition 1, we show that the equilibrium contract is indeed highballing if an insurer's learning is significant (in a sense to be made precise below), or if consumers' preference exhibits hyperbolic absolute risk aversion (HARA).

Consider a two-period insurance market in which each consumer is endowed with income W and may suffer a loss of size L in each period. The consumers' period 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 that consumer's type – the probability that the consumer suffers a loss in a period – is unknown to both consumers and all insurers, but everyone shares a common prior. Therefore, adverse selection is absent in the first period.[9] 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 period-2 probability of loss into $p_2 = p_2^A$. Similarly, if no accident occurs in the first period, both parties update the second-period probability of loss into $p_2 = p_2^N$. The algebra yields

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

It can be verified that $0 < p_2^N < p_1 < p_2^A < 1$, and that the martingale property $p_1 = p_1 p_2^A +$

[8] In Appendix E, we relax the no-risk-change assumption and again show that the results derived in Proposition 1 and Remark 1 (i.e., highballing under one-sided commitment) and Proposition 2 (i.e., lowballing under no commitment) are robust.

[9] The presence of adverse selection introduces the possibility of a 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. We discuss in Footnotes 11 and 15 the scenarios incorporating adverse selection, which do not change our predictions.

$(1-p_1)\ p_2^N$ holds. We assume that insurer learning is asymmetric in the sense that the competing insurers do not see whether a claim is filed. This assumption is made because the information-sharing system among the insurers is absent for most insurance products in most markets, including the two products in subsequent empirical analyses. Moreover, consumers lack commitment power, that is, they may opt out of the insurance contract at the beginning of the second period and purchase an alternative short-term contract available on the spot market.

In each period, an insurance contract consists of a premium Q, and an indemnity $\bar{R} > 0$ paid in the case of a loss L. Let $R = \bar{R} - Q$, where R is the net reimbursement paid to a consumer. Therefore, an insurance contract can be represented by $C \equiv (Q, R)$, and a two-period insurance contract offered by the incumbent insurer can be indexed by $\left(C_1, C_2^A, C_2^N\right) \equiv \langle (Q_1, R_1), \left(Q_2^A, R_2^A\right), (Q_2^N, R_2^N) \rangle$, where $C_1 \equiv (Q_1, R_1)$ is the first-period contract and $C_2^k \equiv \left(Q_2^k, R_2^k\right)$ 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 $\left(C_1, C_2^A, C_2^N\right)$ *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* $Q_1 = p_1/(1-p_1)\, R_1$.

A competitive market implies zero total profit over the two periods. If the period-1 premium is higher than the expected indemnity and generates a positive profit in equilibrium, then the period-2 premium must be lower than the expected indemnity 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).

One-sided commitment scenario (Proposition 1)

We first analyze the case of one-sided commitment. In the first period, insurers independently and simultaneously choose a dynamic contract, consisting of a first-period premium and coverage; and a second-period contract that is contingent on whether the consumer suffers a loss or not in the first period. An insurer pre-commits to the long-term contract that a policyholder purchases at the beginning of the first period, whereas 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 summarized in Figure 1.

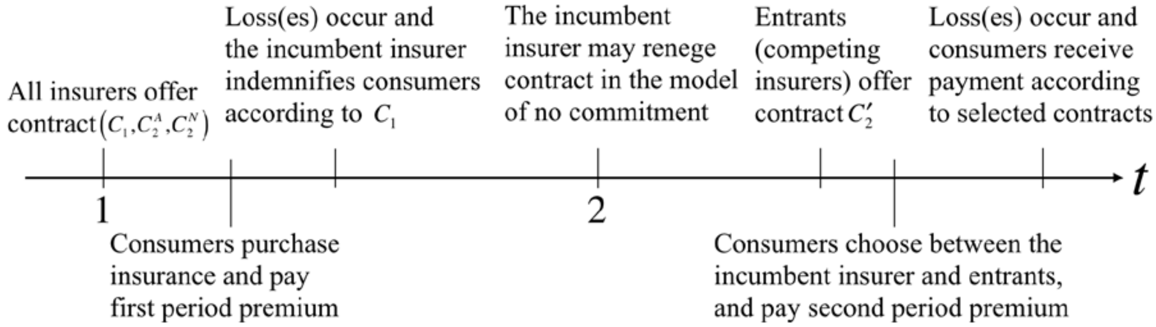

Figure 1 Timeline of dynamic insurance contracting.

Note 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, competing insurers can craft a contract with full insurance in each period and strictly increase a 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 (see Figure 2 below). Therefore, the number of variables can be reduced to three, and the equilibrium contract is fully characterized by the sequence of premiums $\left(Q_1, Q_2^A, Q_2^N\right)$. It is useful to denote consumers' indifference curve that crosses a contract $C_2^k \equiv \left(Q_2^k, R_2^k\right)$ for type $k \in \{A, N\}$ by $R = IC_2^k\left(Q; C_2^k\right)$, which is the solution to

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

In words, $\left(Q, IC_2^k\left(Q; C_2^k\right)\right)$ is the contract that generates the same expected utility to a type k consumer as that with contract $C_2^k \equiv \left(Q_2^k, R_2^k\right)$. As Rothschild and Stiglitz (1976) suggest, the two indifference curves $IC_2^N(Q; C_2^N)$ (e.g., the lower solid line in Figure 2) and $IC_2^A\left(Q; C_2^A\right)$ (e.g., the upper solid line in Figure 2) obey a single-crossing condition, and $IC_2^A\left(Q; C_2^A\right)$ is steeper than $IC_2^N(Q; C_2^N)$. Following de Garidel-Thoron (2005), Figure 2 is drawn in the (net indemnity, premium) space. The diagram redrawn in the contingent wealth space as in Rothschild and Stiglitz (1976) is presented in Appendix F.

De Garidel-Thoron (2005) shows that a pure-strategy competitive equilibrium of the specified extensive-form game can be obtained by solving the following program:

Lemma 1 The equilibrium premium profile $\left(Q_1, Q_2^A, Q_2^N\right)$ *maximizes consumers' expected utility*

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

subject to the following constraints:

$$(Q_1 - p_1 L) + \; \delta\left[p_1\left(Q_2^A - p_2^A L\right) + (1 - p_1)(Q_2^N - p_2^N L)\right] = 0, \qquad (1)$$

$$Q_2^A \leq p_2^A L, \qquad (2)$$

$$IC_2^N(Q; C_2^N) \textit{ and } IC_2^A\left(Q; C_2^A\right) \textit{ cross on the line } (1 - p_2^N)Q - p_2^N R = 0, \qquad (3)$$

$$IC_2^N(Q; C_2^N) \textit{ and } (1 - p_1)Q - p_1 R = 0 \textit{ do not intersect.} \qquad (4)$$

Proof: The proof closely follows that of Lemma 1 from de Garidel-Thoron (2005), and is omitted.

Clearly, consumer's welfare must be maximized in a perfectly competitive insurance market, as the objective function illustrates. Constraint (1) states that the 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 in equilibrium 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. Note that constraint (2) indicates that the incumbent insurer will either 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., $(1-p_2^N)Q - p_2^N R = 0$) and, hence, the incumbent insurer earns profits from type-N consumers. Therefore, whether the incumbent insurer earns profits or suffers losses in period 2, that is, whether the equilibrium contract is lowballing or highballing, is non-trivial.

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

Proposition 1: The equilibrium contract exhibits a highballing (front-loaded) pricing pattern under one-sided commitment and asymmetric learning if the insurer's learning is significant (i.e., if p_2^A/p_2^N is above a critical ratio).

Proof: See Appendix C.

Proposition 1 contributes to the literature in two ways. First, we prove that de Garidel-Thoron's (2005) realistic bonus-malus system exhibits highballing when learning is significant (i.e., when p_2^A/p_2^N is sufficiently large). Second, we show that the highballing pricing pattern predicted in Pauly et al. (2011) remains if the contract space is enriched to allow for experience rating. Thus, our Proposition 1 contributes new results to the literature.

The idea of the proof is as follows and is illustrated in Figure 2. 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 2, and increase the first-period premium Q_1 accordingly to satisfy the zero-profit condition. This 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 the 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 states A and N in the second period, given that p_2^A/p_2^N is sufficiently large, 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 $(1-p_2^N)Q-p_2^N R=0$ again, as the two dotted curves illustrate in Figure 2. It is straightforward to see that the constructed contract $(\hat{C}_1, \tilde{C}_2^A, \tilde{C}_2^N)$ satisfies all four constraints, including constraint (3). Note that the contract $(\tilde{C}_2^A, \tilde{C}_2^N)$ leads to smoother consumption across states A and N relative to that under the contract $(\hat{C}_2^A, \hat{C}_2^N)$. Because the policyholder has an incentive to insure against reclassification risk[10] and smooth consumption across the two states in period 2, this modification is, again, welfare-enhancing.[11]

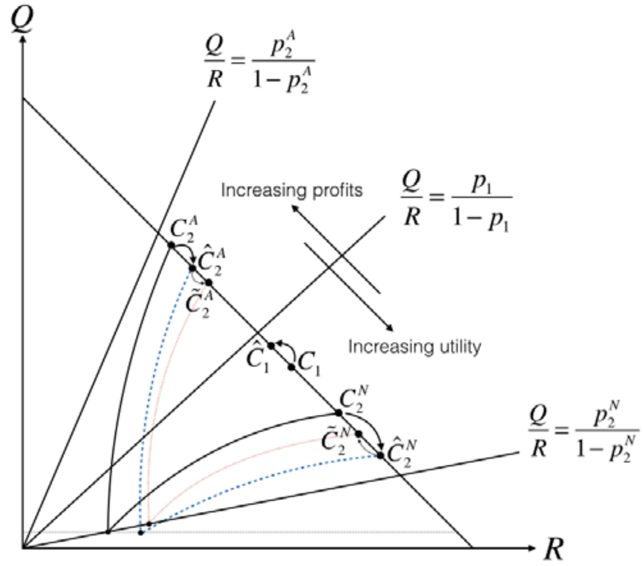

Figure 2 Graphical illustration for proof of Proposition 1.

Suppose that consumers' preference exhibits hyperbolic absolute risk aversion (HARA), that is,

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

where a, b, and η satisfy $aW/(1-\eta)+b>0$ *and* $a(W-L)/(1-\eta)+b>0$, and $a>0$.[12] The following result is then established in parallel to Proposition 1:

[10] The reclassification risk in the model refers to the period-2 risk change and the premium adjustment based on the past claim experience.

[11] Proposition 1 is robust to period-1 adverse selection. Focusing on the separating equilibrium, Cooper and Hayes (1987) extend Rothschild and Stiglitz's (1976) single-period adverse selection model to multi periods and discuss the case of one-sided commitment. They assume that the competing insurers in period 2 learn neither the policyholders' histories nor their choices of contract in period 1. They show that the incumbent insurer offers contracts that are independent of histories and are actuarially fair in both periods to the high risks, and experience-rated contracts to the low risks. Specifically, in the first period, the incumbent insurer charges the low-risk policyholder a higher premium than they would pay in a standard Rothschild and Stiglitz (1976) model; in the second period, the incumbent insurer gives those low risks without any period-1 claims a heavy discount, and thus charges them a lower premium than they would pay in a standard Rothschild and Stiglitz (1976) model. To summarize, the pricing pattern is again highballing for the low risks and flat for the high risks, with one-sided commitment.

[12] Almost all empirical work uses some members of HARA utility functions. Specifically, 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.

Remark 1: The equilibrium contract exhibits a highballing (front-loaded) pricing pattern under one-sided commitment and asymmetric learning if consumer preference exhibits HARA.

Proof: See Appendix C.

Remark 1 states that the equilibrium contract exhibits highballing regardless of the degree of insurer learning if consumers have a HARA utility function. Recall that Proposition 1 requires p_2^A/p_2^N to be above a threshold but does not assume a specific utility function. Remark 1 indicates that our result continues to hold when the learning condition is not satisfied (i.e., when p_2^A/p_2^N falls below the threshold). In addition, the simulation results in Appendix D suggest that Proposition 1 holds for a wide array of non-HARA utility functions and for all values of $p_2^A/p_2^N > 1$.[13] Therefore, we believe that the significant insurer learning and the functional form of utility are not crucial to the highballing prediction although we have not been able to provide a formal proof.

No commitment scenario (Proposition 2)

Next, we consider the case where both parties lack commitment power. Specifically, the incumbent insurers can renege on the contract at the beginning of the second period, that is, they can unilaterally modify or withdraw the contract.[14] The dynamic insurance pricing game runs the same as that under one-sided commitment, except that the incumbent insurer is free to tear up the second-period component of the contract. The equilibrium pricing pattern in the absence of insurer commitment is shown to exhibit lowballing in de Garidel-Thoron (2005). This result is restated in the following proposition for completeness.

Proposition 2 (de Garidel-Thoron, 2005): The equilibrium contract exhibits a lowballing (back-loaded) pricing pattern under no commitment and asymmetric learning.

It is useful to point out that the equilibrium two-period contract $\left(C_1^*, C_2^{A*}, C_2^{N*}\right)$ in the absence of insurer commitment is strategically equivalent to, and can be implemented by, a short-term contract C_1^* in the first period and a pair of short-term contracts (i.e., C_2^{A*} and C_2^{N*}) in the second period because consumers form correct expectations of the contracts offered in the second period in equilibrium.

The intuition of Proposition 2 is as follows. Due to lack of insurer commitment, no loss can be made ex-post on both type-A and type-N consumers in the second period for the incumbent insurer. This is

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[13] Specifically, the condition of a sufficiently large ratio of p_2^A/p_2^N is used to establish the inequality (A.4) in the proof of Proposition 1. Our numerical results in Appendix D indicate that (A.4) holds for all values of $p_2^A/p_2^N > 1$, under the expo-power (EP) utility functions (Saha, 1993), the power risk aversion (PRA) utility functions (Xie, 2000), and the flexible three parameter (FTP) utility functions (Conniffe, 2007).

[14] Note that reneging differs from Dionne and Doherty's (1994) renegotiation. When reneging, the insurer can change or cancel the contract unilaterally in the second period; whereas with renegotiation, the contract can be changed if - and only if - this modification is mutually agreed by both the insurer and the policyholder. Therefore, reneging is a scenario of no commitment, and renegotiation can be considered as a weaker form of one-sided commitment.

because the incumbent insurer can simply withdraw the contract at the beginning of the second period to avoid any period-2 losses when the incumbent insurer learns the risk type from the first-period experience. In fact, type-A consumers receive an actuarially fair premium in equilibrium in the second period. Meanwhile, because competing insurers cannot differentiate between 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 simultaneously prevent ex-post entry. Finally, competition at the beginning of the first period will force the incumbent insurer to pass the second-period profits on to consumers in the form of a first-period premium that is lower than the actuarially fair one, implying a lowballing pricing pattern.[15]

Before we proceed to the empirical analysis, it is worth noting that our theoretical results, together with those in de Garidel-Thoron (2005) and Hendel and Lizzeri (2003), suggest that the type of insurer commitment is more important than the type of learning environment in determining the inter-temporal pricing pattern. Specifically, Hendel and Lizzeri (2003) show that the equilibrium contract exhibits highballing under one-sided commitment and symmetric learning. Making the same assumption on the insurer commitment, our Proposition 1 (see also Proposition A1 in Appendix E) again predicts a highballing pricing pattern under asymmetric learning. This implies that the learning environment does not determine equilibrium pricing pattern. In contrast, holding fixed the learning environment (i.e., asymmetric learning), our Proposition 2 (as well as de Garidel Thoron (2005)) predicts a lowballing pricing pattern under no commitment, whereas our Proposition 1 predicts a highballing pattern under one-sided commitment, indicating the importance of the type of insurer commitment in shaping the pricing pattern.

Empirical analysis

Data and samples

We explore data concerning two products from a Chinese life and health insurer to test Propositions 1 and 2. The two products are group critical illness insurance (Sample A) and loaner's personal accident insurance (Sample B). The insurer operates nationwide, with a broad spatial range that covers over 90% of the Chinese population. It has ranked among the top ten life insurers in China over the past 15 years in terms of premium volume and total assets. Its core business comes from the open market and is thus not concentrated in any particular industry or region. Its operational model, growth path, risk

[15] The above intuition applies, and Proposition 2 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, lack of insurer commitment implies directly that the incumbent insurer will not suffer a loss on any type of policyholder in the second period because it can simply withdraw the contract to avoid losses. Moreover, asymmetric learning endows the incumbent insurer with some market power from which positive profits can be earned on low risks. As a result, Kunreuther and Pauly (1985) and Nilssen (2000) establish the same lowballing pricing pattern.

portfolio, and performance are typical in the competitive Chinese insurance market.[16]

The group critical illness (CI) insurance in Sample A is a type of loss-occurrence health insurance. It is the most popular health insurance product in the Chinese market due to its simple claim payment feature.[17] The claim benefit is paid in a lump sum without additional benefits, such as medical service, and equals the insurance amount.[18] 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. 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. 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 the new and the renewed contracts. Employee benefits constitute the majority of group CI insurance market. Usually, the employer pays the premium, the employees enjoy the coverage, and participation is voluntary.

The loaner's personal accident (PA) insurance in Sample B operates as follows. The borrower (policyholder) of a bank purchases 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 serves as the sales agent of the insurer, who recommends the product to its borrowers and receives sales commission as a percentage of the insurance premium from the insurer. The bank may sell the loaner's PA exclusively for one insurer or for multiple insurers. Although the borrowers can buy the product either from the bank or from other channels, almost all borrowers buy the product the bank recommends, mainly due to the concern that

[16] Our theoretical model assumes a competitive market. We maintain the hypothesis of competition in the empirical analyses. The A&H lines, including the two products concerned, are the most open product markets in China in the sense that all L&H and P&C insurers are allowed to sell these products. The spatial segmentation in the Chinese market may reduce the degree of competition. Some insurers are only licensed to operate in one or a few provinces (e.g., AIG) but not nationwide. Although we are not able to empirically conclude for a fully competitive market, we cautiously maintain the competition hypothesis following the extant literature (Chan, 2009; Lu, Wang, and Kweh, 2014).

[17] We note that many other insurance products feature no-commitment and asymmetric learning, for example, automobile insurance used by D'Arcy and Doherty (1990), Cohen (2012), Kofman and Nini (2013), and Shi and Zhang (2016). This paper first-time presents a non-automobile short-term health insurance portfolio to show the lowballing premium pattern.

[18] In critical illness insurance, the insurance compensation paid after the occurrence of the insurance event is always equal to the insurance amount (i.e., the sum insured). In loaner's personal accident insurance, the insurance compensation paid is less than the insurance amount (i.e., the sum insured) when partial disability occurs or equal to the insurance amount when death or complete disability occurs.

products from other channels may not 100% meet the bank's requirements.[19] Villeneuve (2014) confirms this channel stickiness for a similar mortgage life product on the French market.

Both samples include all the information used by the insurer for underwriting and pricing, as well as the claim records. 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.[20] Sample B covers all loaner's PA policies issued between January 2008 and December 2011, and all claims under these policies. The two samples are selected based on the same procedure as follows. First, we only use policies with a duration between 360 and 366 days (i.e., 1-year policy), and thus policy age and number of renewals are aligned with each other.[21] Second, policies whose renewal status cannot be identified are dropped from the sample. Third, the premium rates are truncated at the 1st and 99th percentiles to avoid the potential bias of extreme values. Sample A thus contains 5,570 group policy-year observations purchased by 3,152 groups, representing more than 1,880,000 individual–years. Sample B contains more than 1,280,000 individual policy-year observations purchased by over 800,000 individual policyholders.[22]

Qualitative sample comparison

The purpose of the two-sample empirical setting is to establish the contrast of insurer commitment and thus to isolate its role in determining the inter-temporal pricing pattern. Table 3 summarizes and compares the two sampled products qualitatively. The key difference between the two products is in the insurer commitment type and other factors are the same, except a shorter period of Sample B.

Table 3 Qualitative comparison of Samples A and B.

	Sample A: Group CI	*Sample B: Loaner's PA*	*Comparison*
Commitment type	No commitment	One-sided commitment	Different
Insurer commitment	One-year short-term policy	One-year short-term policy with guaranteed renewability	Different
Insured commitment	Employer is free to cancel or switch insurer	Bank is free to switch insurer as well as the individual policyholder	Same
Insurer's learning type	Asymmetric learning	Asymmetric learning	Same
Incumbent insurer's learning	Group level experience rating[a]	Bank level experience rating[a]	Same
Competing insurers' learning	No information-sharing system	No information-sharing system	Same

[19] Borrowers may prefer bank channels for other reasons. For instance, shopping for products from other channels requires additional effort and professional knowledge. In addition, products from other channels may be more expensive because individual borrowers may not enjoy a group discount from being pooled together with all borrowers from the bank.

[20] The claim information is electronically recorded in real time but only retrieved and organized by the actuarial team once per year. At the time the data for sample A were obtained, the claim information from September 2012 to June 2013 was not yet available. In the subsequent analysis, in order to avoid the potential truncation problem, the claim status of polices expiring after August 2012 is coded as missing values.

[21] For Sample A, group policies with a one-year duration account for 62% of all policy-year observations; for Sample B, individual policies with a one-year duration account for 82% of all policy-year observations.

[22] 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.

Information environment	Free of adverse selection after the initial two years	Free of adverse selection	Same[b]
Operating team	A&H	A&H	Same
Insurer	Anonymous L&H insurer	Anonymous L&H insurer	Same
Market	China	China	Same
Sample period	2008-2013	2008-2011	Similar

Notes:

a. In this paper, we consider two scenarios of premium adjustments (reclassification) based on past claim experience: (i) the experience rating on the group policy level for Sample A; and (ii) the experience rating on the bank's past experience for Sample B, although the policy is on the individual level. In this sense, both products have the community rating. Reclassification and experience rating have different meanings in different products, e.g., health insurance vs. worker compensation. We, however, use these terms only to refer to the premium adjustments based on past claims.

b. The scenario of adverse selection in the two samples becomes the same (no adverse selection) after the second period of Sample A. Eling, Jia, and Yao (2017) show that the between-group adverse selection in the group CI insurance (Sample A) is non-persistent and disappears after the initial two years.

The group CI insurance (Sample A) falls into the scenario of 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 insured) is also free to switch to other insurers or to terminate the current group contract at any time. The lack of insurer commitment in the group CI insurance is primarily driven by the nature of group insurance. The composition of a group can change from year to year because people join and leave the employer. Thus, it is very difficult for the insurer to offer a long-term contract or guarantee the renewability of any group insurance. On the contrary, individual CI insurance is almost always offered through long-term contracts as the dreadful deceases usually occur at very advanced ages. 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 (2017) 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.

The loaner's PA insurance (Sample B) falls into the scenario of one-sided commitment. The loaner's PA features a one-year policy with implicit guaranteed renewability until the borrowers clear their loans, indicating the insurer's commitment to the contract. This implicit guarantee is strong because the bank, as the beneficiary, would expect the insurer to cover all its loaners and thus does not accept the insurer's cherry picking, leaving the bank itself at risk before the loans are cleared. The bank, as the sales agent, also has the market power to enforce this implicit guarantee.[23] Specifically, 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 paying back (part of) his/her loans early, a common phenomenon in the Chinese market.

[23] The individual insureds buy this product at the request of their bank and thus they do not care very much about whether the insurer commits to multiple periods or not. In practice, when we discuss with the insurance company, it acknowledged that the renewal process is rather automatic; the insurer essentially delegates the underwriting authority to the bank; and thus hardly declines any renewal requests from the bank's clients.

These facts indicate the lack of commitment by individual policyholders and the bank. The loaner's PA market also features asymmetric learning. The incumbent insurer learns borrowers' risk over time and adjusts the rating tariff for a bank. The parameters used in setting tariffs include age, gender, and occupation accidental categories. Although premiums are not updated based on an individual policyholder's past claim experience (non-discriminatory (Pauly, 2003)), the tariff at the bank level is updated from time to time based on the "community rating", suggesting the presence of learning. Information-sharing is not available among the insurers, indicating that the learning is asymmetric. Lastly, because the product has a compulsory insurance feature, that is, almost all banks require all borrowers to present a loaner's PA for the loans, the market presents little adverse selection.

Among all the similarities summarized in Table 3, we discuss the information environment in greater detail. The two products have the same information environment, i.e., they are free of adverse selection, during the periods when the pricing patterns are significant (i.e., from the second renewal onward in Sample A, and for all periods in Sample B). In Sample B, the loaner's PA insurance is free of adverse selection because the insurance demand is not driven by risk but by demand for the loans. The loaner's PA insurance can be considered as compulsory insurance for any loaner. In Sample A, the individual level (within-group) adverse selection is eliminated by the group insurance setup. The between-group adverse selection does exist in the initial two periods of group CI insurance but disappears in later periods due to the insurer's learning (Eling, Jia, and Yao, 2017). Successful risk discrimination (i.e., learning) yields two simultaneous effects: the disappearance of adverse selection as shown by Eling, Jia, and Yao (2017), and the significant lowballing (back-loaded) pattern as we will show in Table 5. In this sense, at the periods when we observe the significant lowballing/highballing patterns, adverse selection is absent from both samples.

The risk exposures and product types also differ in the two products, with one being critical illness risk and group insurance, and the other accident risk and individual insurance through underwriting via a bank. Despite the difference, they are quite similar in terms of pricing. First, both products have the same individual pricing factors: age, gender, and occupation. Second, individual pricing results are further adjusted based on the group/bank characteristics. For instance, those insured by CI insurance can negotiate with the insurer to obtain discounts based on either group size or insurance amount for each individual insured. So can the bank. The bank can ask for a group discount for the PA insurance when it sells many policies or policies with greater coverage, which brings the insurer more premiums. Third, both products are subject to the experience rating at the group/bank level based on past claims (i.e., community rating). Last but not least, both products feature low loss frequency and numerous homogeneous risks. Thus, the difference between group and individual policies should be considered non-material in terms of the insurer pricing practice. In addition, the pricing patterns are measured on a relative-to-actuarially-fair-premium basis, and we control all risk classification factors when identifying the pricing pattern.

In practice, the insurer strategic considerations, the market environment, and the underwriting cycle may also influence an insurer's pricing decision. For example, an insurer may be under growth pressure from shareholders in 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 such a growth pressure, the contract can be a highballing one. Another example is the insurance underwriting 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. Propositions 1 and 2 are tested with two product samples from the same A&H team of the same insurer[24], the same market, and almost the same time horizon. Therefore, if different pricing patterns are found in these two samples, it is less likely driven by these firm-, market-, or time period-specific factors. Such an empirical setting is new to the empirical literature on dynamic insurance contracting and enhances the credibility of the detected pricing pattern.

The group CI insurance corresponds to the case of no commitment, and the loaner's PA insurance corresponds to the case of one-sided commitment. As stated previously, insurer's commitment can be in the form of either guaranteed renewability (GR) or long-term (LT) contract. We use a sample of accident insurance with guaranteed renewability in the empirical analyses, and we expect the same conclusions if we use a sample of long-term policy, for example, the life insurance.

Quantitative sample comparison

Table 4 quantitatively compares the two samples. 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 far more males than females, which we believe reflects the Chinese family tradition whereby the man usually manages the household's external financial relationships, such as loans. It also reflects the fact that businessmen outnumber businesswomen in China. The average occupational category in Sample B (2.72) is slightly more dangerous than that in Sample A (2.01), possibly because Sample A consists mostly of group insurance in the form of employee benefits and thus more white-collar employers are able to afford and willing to offer such benefits than blue-collar employers, yielding occupational categories that are safer overall. We note that basing the occupational categories on accident tendency may not fit perfectly for the assessment of illness risk. However, doing so is the current market practice and these occupational categories are standard in the insurance market of China. The area distributions of the two portfolios are significantly different, with group CI concentrated more in the developed areas

[24] These two products are managed by a single A&H team. The size of the two product portfolios is similar and large to that team. The sales teams for these two products approach the groups (CI) or the banks (PA) to compete for business with other insurers. On the individual-risk level, the group (or the bank) usually enrolls most of its employees (borrowers) in the insurance coverage. We are not aware that the insurer or the A&H team has different commercial or marketing considerations to weigh the importance of these two products differently.

relative to the loaner's PA due to the fact that firms that can afford employee benefits tend to be located in more developed and affluent areas.

Table 5 presents the distribution of the policy ages in both samples, from which a sufficiently high lapse rate in both samples is observed. We observe a higher portion of old policies in Sample A than in Sample B, because the period of Sample A (2008-2013) is two years longer than that of Sample B (2008-2011). Interestingly, although Sample B is much larger than Sample A due to the fact that Sample A is group policies and Sample B is individual policies, the total number of individual-years in Sample A (1.88 million) is greater than that in Sample B (1.28 million).

The risk changes are insignificant and are not major concerns for these two products. The risk changes of group health insurance are less a problem than that of individual health insurance. The health condition deteriorates as age increases, and thus the individual health risk usually deteriorates at each renewal. However, group average risk does not necessarily follow this trend as young employees continuously join firms. This is true in our Sample A, for group policies renewed at least three and at least four times, the mean differences of groups' average ages over policy years are insignificant at 95% confidence levels, subject to the mean difference F tests. The personal accident risk is stable for mid-aged individuals over a 3-5 year period. All risk classification factors were controlled when we identify the pricing pattern.

Table 4 Quantitative comparison of Samples A and B.

Variables	Descriptions	*Sample A: Group critical illness insurance*						*Sample B: Loaner's personal accident insurance*					
		Obs.[c]	Mean	S.D.	P5	Median	P95	Obs.[c]	Mean	S.D.	P5	Median	P95
Premium rate	Annualized premium rate per policyholder	5,369	0.0028	0.0020	0.00070	0.0024	0.0066	1,242,577	0.0027	0.00083	0.0013	0.0028	0.0040
Policy age	Count of renewal times	5,369	0.94	1.16	0	1	3	1,242,577	0.31	0.63	0	0	2
Insurance amount	Insurance amount per policyholder in CNY	5,369	57,229.4	59,753.2	3,000	5,0000	173,729	1,242,577	37,041.6	21,469.1	10,000	30,000	90,000
Group size	Number of individual policyholders in the group	5,369	327.0	1370.3	6	65	1,237	N.A.					
Policy duration	Policy duration in days	5,369	365.0	0.86	364	365	366	1,242,577	364.1	1.02	362	364	365
Sex	(Fraction of) women	5,369	0.41	0.21	0.083	0.39	0.80	1,242,577	0.12	0.33	0	0	1
Age	(Group average) age	5,369	35.9	6.87	25.0	35.9	47.0	1,242,577	40.4	9.00	26	40	56
Work[a]	(Group average) occupation accident tendency	5,369	2.01	1.03	1	2	4	1,242,577	2.72	1.22	1	3	4
Area[b]	Indicator of relative wealth and insurance market maturity of the policy issuance location	5,369	2.05	0.86	1	2	3	1,242,577	3.12	0.68	2	3	4
Claim dummy	1 if any claim(s) under the policy	2,649	0.14	0.35	0	0	1	988,527	0.00075	0.027	0	0	0
Claim frequency	Average number of claims per policyholder	2,649	0.00097	0.0051	0	0	0.0049	N.A.[d]					

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. Both samples are on the policy level. Sample A is a group insurance, one-group (employer) policy, covering in average 327 individuals under each policy. Sample B is an individual insurance, with one person one policy. The bank, as an agent, has some general conditions and a tariff applicable for all loaners buying this coverage from that bank. The difference in policy type yields different sample size, however, which does not relate to the type of commitment by the contracting parties.

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

Table 5 Distribution of policy age.

Policy age	*Sample A* No. of Policies	Portion	Lapse Rate[a]	*Sample B* No. of Policies	Portion	Lapse Rate[a]
0	2,516	46.9%	36.7%	955,752	76.9%	79.5%
1	1,593	29.7%	58.8%	195,538	15.7%	57.4%
2	657	12.2%	44.7%	83,355	6.7%	93.6%
3	363	6.8%	53.7%	5,327	0.4%	51.1%
4	168	3.1%	57.1%	2,605	0.2%	N.A.
5	72	1.3%		0	0.0%	
Total	5,369	100.0%		1,242,577	100.0%	

Notes:

[a] Lapse rate captures the percentage of policyholders left the incumbent insurer in the next policy period. The lapse rates in both samples suggest that the dynamics from period to period are large enough to identify the inter-temporal pricing pattern. The high lapse rates in Sample B might be driven by the short sampling period, which truncates the policies with longer policy ages.

Methodology

Equation (5) below is applied to Samples A and B, respectively. The actual *premium rate* is regressed on the complete risk classification variables. Risk classification refers to the use of observable characteristics by insurers to determine the premiums (Dionne and Rothschild, 2014). It is important to control for the complete risk classification factors used by the insurer for pricing. Thus, any trend found between the actual *premium rate* and the *policy age* captures the residual effect net of the insurer's understanding of the underlying risk and the risk changes (Eling, Jia, and Yao, 2017). Such residual effect is thus an insurer's inter-temporal pricing strategy. The observed trend does not necessarily indicate the change in the nominal premium rate but a change relative to the actuarially fair premium (Kunreuther and Pauly, 1985; Pauly, Kunreuther, and Hirth, 1995). This setting is commonly used in the previous empirical studies (see Table 2 and Appendix B for a review). We acknowledge that ideally, we should use the actuarially fair premium as the dependent variable, which is however not available to us, so as to previous empirical studies.

$$premium\ rate_{i,t} = \beta_0 + \beta_1 policy\ age_{i,t} + \beta_2 X_{i,t} + \beta_3 area_i + \beta_4 year_t + \varepsilon_{i,t} \quad (5)$$

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 the number of renewals thus 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.

Equation (5) is estimated with OLS. Random-effects and firm fixed-effects models are used as robustness tests (Zhang and Wang, 2008; Eling, Jia, and Yao, 2017), and the results are consistent with that in the OLS (see Table 7).[25] 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.

Chiappori and Salanié (2000) emphasize that the use of simple, linear functional forms on insurance policy-level data should be restricted to homogeneous populations. Both samples meet the homogeneous criterion because (i) the business nature is largely the same within each sample as employee benefits in Sample A and as mortgage PA in Sample B; (ii) the model includes all relevant pricing factors that account for potential heterogeneity among policies; and (iii) robust standard errors clustered at the insured level (i.e., the group insured for Sample A and individual insured for Sample B) further control for heterogeneity. As the relationship between *premium rate* and *policy age* may be nonlinear (Cox and Ge, 2004), we conduct two additional tests. First, we use subsamples including policies having two adjacent ages, i.e., new and first-time renewed policies, first- and second-time renewed policies, etc (see Table 5).[26] Second, as a robustness test, we include the square term of *policy age* and alternatively take the natural log of *policy age*. The results of these tests are consistent with our conclusions (see Table 7).

Our selected two products also minimize the endogeneity problem with the standard coverages. For the loaner's PA portfolio, the insurance coverage is the same for all loaners; the insurance amount is determined by the amount of the loans rather than the individual's choice; and the renewal decision is not driven by the price but the clearance of the loans. For the group CI insurance, the insurance coverage strictly follows a nationwide guideline issued by the Chinese Insurance Industry Association, covering the same 25 diseases for all insureds. As a group insurance, the renewal and insurance amount decisions are more driven by the corporate budget and the risk types of the group rather than by a competitive market price (Eling, Jia, and Yao, 2017). Thus, the reverse causality from premium rate to policy features is remote.[27]

[25] We choose the OLS as our core model because one insured may buy two or more policies in the n^{th} year. All these policies have the same 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 regressions, reducing the estimation efficiency.

[26] Consistent with the full sample analysis, OLS regressions are used for subsample analyses with consecutive renewal policies. Alternatively, we conduct the Bayesian information updating regressions for the subsample analyses, with the prior assumption that the coefficient of *policy age* follows $N(\mu, \sigma^2)$, where μ and σ^2 are estimated based on the OLS coefficient of a prior period. For example, in the subsample regression with first- and second-time renewed policies, the prior coefficient distribution is assumed to follow the corresponding coefficient in the subsample of the new and first-time renewed policies. The results of Bayesian regressions are consistent with the OLS results and are available from the authors upon request.

[27] Additionally, we conduct the 2SLS regressions to address the endogeneity concern. The results are consistent with those of the OLS and are available from the authors upon request.

Empirical results

Table 6 reports the main results, identifying the dynamic pricing pattern based on Equation (5). The Sample A results in Panel A show significantly positive coefficients of *policy age*, indicating a lowballing (back-loaded) pricing pattern, and thus support Proposition 2. In Column 2, Panel A, we include an additional independent variable, the group *claim frequency* at $t-1$, to capture the experience rating at the group level for Sample A. The positive coefficient of *claim frequency* indicates that a last-period high claim frequency is associated with a high premium rate in the current period. The subsample results in Columns 3-6 suggest that the premium pattern is flat for the first two periods (i.e., from new to 1st renewal, and from 1st renewal to 2nd renewal) and then increases with the policy age in the second, third, and subsequent renewals.[28] These results also confirm Proposition 2. Looking at the control variables, the actual premium rates are negatively associated with the insurance amount (group size), suggesting discounts for large quantities of insurance (large clients). Older people have a much higher CI risk than younger people.

The flat premium pattern for the first two periods is mainly due to insufficient insurer learning. As our theoretical model predicts, higher profits or prices are viable in later periods because the incumbent insurer is able to learn the policyholder's risk type in the early periods and thus to 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 in not having any claims. Since effective learning is a necessary condition to implement a lowballing pricing strategy, the pricing pattern is expected to be flat in the first two periods. This flat-then-lowballing pattern is expected because the back loading only becomes viable and materializes when the incumbent insurer privately learns the risk types of insureds, so that it can discriminate the low risks by "over-charging" them. This explanation is consistent with Eling, Jia, and Yao's (2017) findings, where they use a different subsample of the same portfolio and show that the learning of the incumbent insurer eliminates adverse selection only after the first two periods.

The Sample B results in Panel B of Table 6 show significantly negative coefficients of the *policy age*, indicating a highballing (front-loaded) pricing pattern and supporting Proposition 1.[29] The subsample results in Columns 8-10 show that 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 as time passes. Looking at the control variables, the female is

[28] As shown in Tables 5 and 6, we note that in each subsample in Table 6, the variation of *policy age* is large enough to yield significant results. For instance, the ratio of new policies to first-time renewed policies is 3:2 in Sample A and 5:1 in Sample B.

[29] The practice including experience rating factor is not applicable to Sample B because the loaner's PA is experience-rated at the bank level instead of at the individual policyholder level.

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, rather than illness. Thus, as expected, people in the safer categories have a lower premium rate of accident insurance.

Samples A and B yield contrasting inter-temporal pricing patterns, which cannot be attributed to the idiosyncrasies of insurers, markets, time horizons, information frictions, or the learning types in our two-sample setting, but, reasonably, to the differences in the insurer's commitment type, as highlighted in Table 3 and suggested by our theoretical models.

Robustness tests

To test the robustness of our empirical results, we conduct the following three tests. First, we estimate Equation (5) with random-effects and firm fixed-effects models.[30] The benefit of introducing firm fixed-effects is that they better capture the pricing dynamics of one firm over the years. However, the cost is also significant as it omits 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 used in this paper. The results in Columns 1-4, Table 7 are consistent with our main results, and support the theoretical predictions in the sense that the signs of *policy age* coefficients remain unchanged and significant. The price decrease in the highballing pricing pattern becomes milder in Sample B.

Second, to address the concern on the unbalanced panel, i.e., smaller number of policies with older policy age, we restrict our sample to contracts observed at least the 3rd renewals. If a contract renews with the insurer for at least three times, we then include all contracts of this policyholder into the subsample. The results in Columns 5-7, Table 7 show that the signs of all coefficients remain consistent with our main results. The significance level in Sample B (3rd+) reduces to a p-value of 0.185, due to reduced sample size. However, if we incorporate policyholders having at least the 2nd renewal in Sample B, the coefficient becomes significant.

Third, we test the potential non-linear impact of policy age on pricing.[31] Intuitively, the insurer collects more and more information regarding the policyholder's risk as the learning process continues, and it might be able to organically apply the learned information to better implement the pricing strategies. Therefore, the degree of frontloading or backloading may depend on the insurer's learning, and thus may differ across cohorts of policy ages. Formally, we investigate the potential

[30] The panel is set up with the (group) insured as i and with the renewal counts as t. For example, suppose that insured X and Y have their first policy with the insurer in 2009 and 2010, respectively. Then these two policies are (X, 0) and (Y, 0) although they are in different years. Therefore, t varies from 0 to 5 in Sample A and from 0 to 4 in Sample B. The year fixed effects are then controlled by year dummies in the regressions. See Zhang and Wang (2008) for a detailed discussion on why and how to apply random-effects models to dynamic insurance markets.

[31] We thank one reviewer for suggesting this robustness check.

non-linear impact of policy age by (i) adding the square term of policy age; and (ii) replacing policy age by its natural log in Equation (5). The results in Columns 8 and 10 of Table 7 suggest that the price increase in the lowballing pricing pattern is accelerating in Sample A. In contrast, the results in Columns 9 and 11 of Table 7 indicate that the price decrease in the highballing pattern is slowing down in Sample B. These contrasting results imply a subtle interaction between the pricing pattern and the insurer's learning: Although the direction of the pricing pattern is determined by insurer commitment as predicted in our theoretical model, the insurer's learning has a second-order impact on the curvature of the pricing pattern, which again turns out to hinge on the type of insurer commitment. The insurance and economics theory has so far provided little guidance in predicting how the dynamic pricing pattern depends on the insurer's learning over time and how the pricing pattern applies to the policy age cohorts under different types of insurer commitment. To answer these questions, a model of three or more periods is required. It would be interesting to generalize our theoretical framework to rationalize the above findings. We leave the exploration of this possibility for future research.

Table 6 Main results.

	Panel (Sample) A: Group critical illness insurance						*Panel (Sample) B: Loaner's personal accident insurance*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Samples	Full Sample A		New-->1st renewal	1st --> 2nd renewal	2nd-->3rd renewal	3rd and subsequent renewals	Full Sample B	New-->1st renewal	1st --> 2nd renewal	2nd and subsequent renewals
Policy age	0.0192*	0.0690***	-0.0244	0.0200	0.105***	0.0876***	-0.0790***	-0.100***	-0.00421***	-0.00149
	(0.0103)	(0.0158)	(0.0167)	(0.0210)	(0.0298)	(0.0303)	(0.000528)	(0.000638)	(0.000923)	(0.00301)
Ln(insurance amount)	-0.132***	-0.138***	-0.131***	-0.146***	-0.138***	-0.0519	-0.0342***	-0.0331***	-0.0586***	-0.0620***
	(0.0107)	(0.0163)	(0.0105)	(0.0152)	(0.0245)	(0.0380)	(0.000443)	(0.000417)	(0.00118)	(0.00228)
Ln(group size)	-0.0859***	-0.0597***	-0.0898***	-0.0711***	-0.0667***	-0.0172				
	(0.00755)	(0.0109)	(0.00706)	(0.00963)	(0.0155)	(0.0211)				
Sex	-0.207***	-0.00203	-0.274***	-0.000411	0.169	0.216	-0.0145***	-0.0145***	-0.0289***	0.0154***
	(0.0455)	(0.0745)	(0.0442)	(0.0716)	(0.125)	(0.167)	(0.00117)	(0.00111)	(0.00211)	(0.00327)
Age	0.0430***	0.0404***	0.0446***	0.0438***	0.0393***	0.0507***	-0.000486***	-0.000338***	-0.00114***	-0.00123***
	(0.00174)	(0.00262)	(0.00165)	(0.00230)	(0.00337)	(0.00428)	(3.88e-05)	(3.63e-05)	(7.80e-05)	(0.000120)
Work1 [a]							-0.106***	-0.0948***	-0.299***	-0.343***
							(0.000793)	(0.000752)	(0.00186)	(0.00388)
Work2 [a]	-0.0676**	-0.0946**	-0.000971	-0.0715*	-0.265***	-0.347***	-0.119***	-0.115***	-0.158***	-0.157***
	(0.0297)	(0.0464)	(0.0294)	(0.0383)	(0.0610)	(0.0762)	(0.00154)	(0.00146)	(0.00299)	(0.00488)
Work3 [a]	-0.212***	-0.147***	-0.210***	-0.179***	-0.242***	-0.380***	-0.0636***	-0.0753***	-0.148***	-0.143***
	(0.0278)	(0.0432)	(0.0270)	(0.0369)	(0.0608)	(0.0881)	(0.000975)	(0.000925)	(0.00219)	(0.00437)
Work4 [a]	-0.0493	-0.00367	-0.0683	-0.0357	-0.0154	-0.128				
	(0.0432)	(0.0482)	(0.0473)	(0.0501)	(0.0664)	(0.104)				
Work5 [a]	0.0766	0.182**	-0.00149	0.206	0.0267	0.0119				
	(0.0682)	(0.0852)	(0.0768)	(0.132)	(0.190)	(0.158)				
Prior claim frequency		3.697**								
		(1.729)								
Location FE/Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.368	0.354	0.399	0.377	0.322	0.393	0.161	0.114	0.391	0.514
Observations	5,369	2,269	4,109	2,250	1,020	603	1,242,577	1,151,290	278,893	91,287

Notes: The table reports the estimated coefficients of OLS regressions. Robust standard errors clustered at (group) insureds level are presented in parentheses. *, **, ***, indicate significant differences of coefficients from 0 at the 10%, 5%, and 1% levels, respectively. Constant is included but not reported.

a. *Work1* to *Work5* are occupational categories capturing the tendency of occupational accidents. *Work1* is the safest category including, for example, office workers; and *Work5* includes relatively dangerous occupations, such as police officers. Samples A and B follow the same occupational classifications.

Table 7 Robustness tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Samples	A	B	A	B	A(3rd+)	B(3rd+)	B(2nd+)	A	B	A	B
Models	RE	RE	FE	FE	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Policy age	0.00704	-0.00297***	0.0194*	-0.00190***	0.103***	-0.00136[b]	-0.0108***	0.0177*	-0.0789***		
	(0.00673)	(0.000136)	(0.0116)	(0.000148)	(0.0255)	(0.00102)	(0.000440)	(0.0102)	(0.000517)		
Policy age^{2} [a]								0.0184***	0.0229***		
								(0.00455)	(0.000519)		
ln(policyage)										0.0253	-0.141***
										(0.0218)	(0.000865)
ln(insurance amount)	-0.142***	-0.0258***			-0.116***	-0.0477***	-0.0440***	-0.129***	-0.0348***	-0.139***	-0.0346***
	(0.00869)	(0.000424)			(0.0358)	(0.00560)	(0.00195)	(0.0107)	(0.000444)	(0.0108)	(0.000443)
ln(group size)	-0.0801***				-0.0744***			-0.0836***		-0.0873***	
	(0.00557)				(0.0196)			(0.00753)		(0.00770)	
Sex	-0.184***	-0.0135***			0.0499	0.0216**	0.00772***	-0.207***	-0.0133***	-0.223***	-0.0136***
	(0.0407)	(0.000952)			(0.140)	(0.0102)	(0.00286)	(0.0454)	(0.00117)	(0.0460)	(0.00117)
Age	0.0376***	-2.55e-05			0.0391***	-0.00144***	-0.00105***	0.0431***	-0.000500***		
	(0.00135)	(3.40e-05)			(0.00424)	(0.000394)	(0.000104)	(0.00173)	(3.87e-05)		
ln(age)										1.377***	-0.0232***
										(0.0753)	(0.00150)
Work1		-0.122***				-0.343***	-0.343***		-0.105***		-0.105***
		(0.000729)				(0.0105)	(0.00360)		(0.000792)		(0.000792)
Work2	-0.00922	-0.160***			-0.245***	-0.174***	-0.131***	-0.0685**	-0.117***	-0.0766**	-0.117***
	(0.0182)	(0.00115)			(0.0710)	(0.0162)	(0.00443)	(0.0296)	(0.00153)	(0.0305)	(0.00153)
Work3	-0.100***	-0.108***			-0.371***	0.0206	-0.0974***	-0.212***	-0.0615***	-0.231***	-0.0620***
	(0.0179)	(0.000790)			(0.0764)	(0.0128)	(0.00392)	(0.0278)	(0.000972)	(0.0279)	(0.000972)
Work4	-0.00434				0.0411			-0.0498		-0.0732*	
	(0.0325)				(0.0899)			(0.0426)		(0.0431)	
Work5	-0.0103				0.220*			0.0603		0.0475	
	(0.0643)				(0.126)			(0.0670)		(0.0678)	
Location FE	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.354	0.138	0.042	0.205	0.311	0.452	0.569	0.370	0.162	0.363	0.162
Observations	4,803	1,149,541	4,916	1,164,759	1,484	26,032	255,959	5,369	1,242,577	5,369	1,242,577

Notes: Standard errors are presented in parentheses. *, **, *** indicate significant differences of coefficients from 0 at the 10%, 5%, and 1% levels, respectively. Constant is included but not reported

a. Centered to avoid multicollinearity.

b. P-value equals 0.185.

Conclusion

In this paper, we investigate the role of insurer commitment in determining the inter-temporal dynamic pricing pattern in competitive insurance markets by (i) comprehensively reviewing the extant theoretical and empirical literature in dynamic insurance contracting; (ii) predicting the equilibrium pricing patterns under one-sided and no commitment assumptions using a two-period competitive insurance model with asymmetric learning; (iii) empirically identifying the highballing pricing pattern in a sample of loaner's personal accident insurance, a one-sided commitment scenario, and the lowballing pricing pattern in a sample of group critical illness insurance, a no commitment scenario.

Our theoretical results indicate that the type of insurer commitment is more important than the type of information friction or the type of learning environment in determining the inter-temporal pricing pattern. Our theoretical model (empirical evidence) suggests that the presence of insurer commitment predicts (is associated with) the highballing or front-loaded pricing pattern (Proposition 1). In contrast, the lack of insurer commitment to a multi-period insurance relationship leads to (is associated with) the lowballing or back-loaded pricing pattern (Proposition 2). Our theoretical model proves that these two opposite predictions are robust to the first-period adverse selection (see Footnotes 11 and 15), to the learning environment (see the last paragraph in the "Theoretical model and propositions" section), and to the risk dynamics (see Appendix E). Our empirical results are also consistent with these theoretical predictions.

The economic insight that links the insurer's commitment to its pricing strategy may be applicable to and can be tested in other industries, where the information problem and the commitment problem coexist. One potential application is the commercial banking industry, where loan applicants rejected by one bank can apply again at other banks (Shaffer, 1998) and loan applicants may switch banks from time to time. Commercial banks mostly offer renewable short-term loans (lack of commitment). Ioannidou and Ongena (2010) show that loans granted by a new (outside) bank carry loan rates that are significantly lower than the rates on comparable loans from the firm's current (inside) banks, i.e., the banks apply a lowballing strategy. They attribute this interest rate pattern to both informational lock-in and hold-up costs (i.e., commitment problem). It would be interesting to theoretically and empirically disentangle the contribution of informational lock-in and the commitment problem in the banking industry. The approaches found in this paper may provide a potential identification path.

There are several additional interesting directions for future research. First, it would be interesting to develop a theoretical framework to better understand the interaction between insurers' learning and their pricing decisions, and then empirically investigate the impact of learning on the dynamic pricing pattern. Second, it is important to examine the risk-based dynamic selection, i.e., the policyholder's lapsation and insurer's selection behaviors based on risk types (Finkelstein, McGarry, and Sufi, 2005; Hendel, 2016). We are not able to conduct these analyses due to data limitations. Specifically, we cannot isolate the impact of risk type on risk dynamics from other unobservable factors that also influence the demand and supply of insurance. Third, in practice, two products may exhibit the same highballing (or lowballing) pattern but with one being 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 as an important tool to compare the magnitude of pricing strategies across different products and markets. Last but not least, the recent development of digitalization enables insurers to understand the risk type earlier and more accurately than via the conventional learning process. How technological progress will change the dynamic equilibrium as well as the pricing pattern remains a green field to explore.

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APPENDICES

In Appendix A, we review the theoretical literature on competitive dynamic insurance contracts. In Appendix B, we provide a review of empirical literature on dynamic insurance pricing pattern. In Appendix C, we present the detailed proof of Proposition 1 and Remark 1. In Appendix D, we provide the simulation results and show that Proposition 1 holds for a wide array of non-canonical utility functions and for all values of $p_2^A/p_2^N > 1$. In Appendix E, we assume policyholder's risk type deteriorates over time and show that our theoretical results in the main text are robust. In Appendix F, we redraw Figure 2 in the contingent wealth space as in Rothschild and Stiglitz (1976).

A Review of theoretical literature on competitive dynamic insurance contracts

The dynamic insurance contracting models can be 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 monopolistic insurance market, where the role of experience rating is highlighted to solve the adverse selection problem (e.g., Dionne, 1983; Dionne and Lasserre, 1985, 1987; Hosios and Peters, 1989). The third direction is the dynamic insurance contracting in competitive markets, on which this paper will focus. Recently, a growing literature has focused on the underwriting cycles, i.e., the mid- to long-term pricing dynamics in the insurance market (see, e.g., Henriet, Klimenko, and Rochet, 2016). 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 modeling 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, the insurer offers the same contract to both 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-1 claimant; however, the competing insurers cannot differentiate who had a claim in period 1. Risks who did not have a claim (low risks) stay with the incumbent insurer in equilibrium because the incumbent insurer will keep their premium unchanged. Therefore, in period 2, the insurer can earn positive profits by overcharging the staying (low) risks. Under the zero-profit constraint, the insurer must suffer a loss 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 period 2 while the competing insurers do not. This pricing pattern for a sequence of the contracts is hence lowballing.

Kunreuther and Pauly (1985) assume that policyholders are completely myopic when making the initial purchase decision, and that insurers are not allowed to offer menu contracts to screen policyholders. Nilssen (2000) relaxes these two assumptions and shows that: (i) a separating equilibrium is less likely to be sustained in a two-period model than in a one-period one; and (ii) a lowballing pricing pattern is possible but not necessary to emerge in equilibrium.

Watt and Vazquez (1997) consider a multi-period model with the presence of period-1 adverse selection. They assume that all insurers learn the insured's risk type over time, and that learning is thus symmetric. They show that a pooling equilibrium with 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. In period 1, the insurer undercharges high risks and overcharges low risks, generating zero profits in aggregate. In future periods, full information contracts are in place and thus all risks are charged at an actuarially fair rate. Therefore, the equilibrium pricing pattern is flat.

Assuming one-sided and/or full commitment, Cooper and Hayes (1987) and Dionne and Doherty (1994) model the scenario of asymmetric learning. The scenario of symmetric learning has not yet been covered by the literature. Focusing on the separating equilibrium, Cooper and Hayes (1987) extend Rothschild and Stiglitz's (1976) single-period adverse selection model to multi periods and discuss both the cases of one-sided and full commitment. They make an extreme assumption on insurers' learning: the competing insurers in period 2 learn neither the policyholders' histories nor their choices of contract in period 1. With one-sided commitment, the incumbent insurer offers contracts that are independent of histories and actuarially fair in both periods to the high risks, and experience-rated contracts to the low risks. Specifically, in the first period, the incumbent insurer charges the low-risk policyholder a higher premium than they would pay in a standard Rothschild and Stiglitz (1976) model; in the second period, the incumbent insurer gives those low risks without any period-1 claims a heavy discount, and thus charges them a lower premium than they would pay in a standard Rothschild and Stiglitz (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 the insureds to remain with the incumbent insurer. With full commitment, it shows that the high-risk policyholder receives the same contract as s/he does in the case of one-sided commitment, whereas the low-risk policyholder is offered an experience-rated contract. Their model does not provide predictions on the dynamic pricing pattern for low risks in the case of full commitment.

Dionne and Doherty (1994) introduce the possibility of renegotiation into the one-sided commitment model by allowing the insurer to commit to a long-term contract in period 1 and to offer a revised short-term contract in period 2. The insured may stick to the long-term contract, accept the revised period-2 short-term contract, or switch to competing insurers in period 2. They characterize the equilibrium involving semi-pooling in period 1 followed by separation in period 2. In such an equilibrium, a fraction of the high-risk policyholders chooses full coverage and the rest of the high risks and all the low risks receive partial coverage in period 1. In period 2, the high risks switch to a short-term contract with full coverage, either offered by the incumbent insurer as a result of renegotiation or by a competing insurer, and the low risks stay with the long-term partial coverage. Dionne and Doherty (1994) show that Cooper and Hayes's (1987) result is robust to the introduction of renegotiation. In equilibrium, the insurer earns positive period-1 expected profits and suffers period-2 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) and 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 contract. To simplify the analysis, the coverage of the risk in their model is assumed to be exogenous. Therefore, insurers only engage in price competition on premiums. They construct a guaranteed renewability[32] insurance with a sequence of premiums that survives in a competitive equilibrium and show that such a contract is Pareto optimal. By their construction, this guaranteed renewability insurance exhibits a highballing premium pattern. Specifically, the insurer charges all risks a premium that is higher than the actuarially fair one in period 1 so as to upfront charge for its commitment and to lock in the low risks. Although the insured is allowed to cancel the contract, s/he would not do so in equilibrium because leaving for a spot market would not make him/her strictly better off.

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 depart from the incumbent insurer. They show that more front-loaded contracts provide more insurance against reclassification risk and are selected by consumers with a lower income growth.

Assuming asymmetric learning, Pauly et al. (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

[32] Guaranteed renewability not only guarantees renewals but also guarantees to only change a premium to the same extent for all in the initial rating class or following a pre-agreed premium schedule in subsequent periods. Experience rating based on an individual's risk change or claim experience is not allowed.

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 will not be overturned. They first argue that the optimal guaranteed renewable contract, which is essentially the same as in Pauly, Kunreuther, and Hirth (1995), is indeed immune to the information problem due to asymmetric learning. They then 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 the low-risk consumers and earn profits by the standard Rothchild-Stiglitz argument.

De Garidel-Thoron (2005) presents a two-period model in which both the insured and the incumbent insurer learn the policyholder's risk type from her/his period-1 claim history, but competing insurers do not. He derives the equilibrium contract and shows that information-sharing between insurers is detrimental to consumer welfare, independent of an 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 the policyholders, it also weakens the competing insurer's ability to exercise a cream-off strategy and thus improves the long-term commitment of both parties. In equilibrium, this welfare gain outweighs the welfare loss due to information asymmetry. As a result, consumer welfare is higher when information-sharing is prevented than when information-sharing is allowed. 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 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) has proposed 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. Unlike our review in Appendix A and B that focuses on the dynamic pricing pattern, his survey focuses on other issues, such as the relationship between dynamic selection and policyholder's lapsation behavior and the welfare consequences due to lack of insurer commitment.

Panel C: Discussions connecting Panels 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 period 1 and lowballing pricing pattern. Second, he discusses the one-sided commitment scenario in Pauly, Kunreuther, and Hirth (1995) and Hendel and Lizzeri (2003). A pooling equilibrium with a highballing pricing pattern is expected. Third, he attempts to build the connection between models with the adverse selection and those without. He argues that the period-1 adverse selection should not change the highballing implication embedded in insurer commitment (guaranteed renewability).

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) pioneered empirical investigation of multi-period insurance contracting. They presented the aggregate loss ratios by policy age cohorts of automobile insurance from seven US insurers. All seven portfolios showed that loss ratios decline almost monotonically with policy age, suggesting a lowballing pricing pattern that supports Proposition 2 in this paper. They also looked at three new market entrants, who 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 and gradually converged with those of other matured firms, supporting the lowballing pricing pattern predicted in Proposition 2.

Cohen (2012) presented the first policy-level analysis of repeated short-term insurance contracts using an Israeli automobile insurance portfolio. During the entire sample period, no information-sharing platform among insurers was available and asymmetric learning thus best captured the nature of the market. He showed that (i) profits from the repeat insureds were higher than those from the new insureds (i.e., a lowballing pattern); and (ii) the insurer reduced the price charged to repeated insureds with a good claim history by less than the reduction in expected costs associated with such insureds (i.e., premium downward stickiness). The evidence was obtained after controlling for all risk classification factors and hence directly supports Proposition 2. Cohen's (2012) sample matches Kunreuther and Pauly's (1985) and Nilssen's (2000) assumptions, and he points out the role of asymmetric learning in determining the lowballing pricing pattern accordingly.

Kofman and Nini (2013) examined 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 the Australian system captures all relevant information regarding the policyholders' risk types, with the only exception being brand-new policies. Thus, the market matches Watt and Vazquez's (1997) assumptions (i.e., adverse selection in period 1, symmetric learning in later periods, and no insurer commitment). They documented evidence of lowballing pricing patterns and support our Proposition 2. Their evidence challenges Cohen's (2012) argument regarding the important role of asymmetric learning in determining pricing pattern.

Shi and Zhang (2016) investigated an intermediate learning scenario in between the no information-sharing market in Cohen (2012) and the complete information-sharing market in Kofman and Nini (2013). 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 and contains no information regarding either the insureds' claim history or policy choice. This implies a partial information-sharing system among insurers (Shi and Zhang, 2016). Their conclusions again support Proposition 2 and suggest that pricing pattern may not depend on insurer's learning type.

Testing dynamic pricing pattern in markets with one-sided commitment

Dionne and Doherty (1994) examined 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 approximated the average policy age in a portfolio by the premium growth of that portfolio (i.e., a high/low premium growth indicates an average younger/older policy age) and found a positive correlation between average policy age and loss ratio in the subsample of the low risks, which is in line with the highballing prediction of the one-sided commitment model (Proposition 1).

Hendel and Lizzeri (2003) presented the first piece of evidence controlling for underlying risk differences (i.e., risk classification) in multi-period insurance contracting. They looked at three products of life insurance from 55 US life insurers: 20-year term life insurance with level premium each year (TL), annual renewable term life insurance with premiums that depend only on age (ART), and annual renewable term life insurance with premiums that depend on age and time elapsed since last medical examination (Selection & Ultimate ART). They found that TL and ART are significantly 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 decreased through the 20 years, supporting Proposition 1. However, for Selection & Ultimate ART, where the premiums in later periods depended on whether the insured passed the medical re-examination (a weakened commitment with re-underwriting elements), front-loading existed only in the first year but not in the following years. They approximated the risk by the current values of premiums and found a negative correlation between the degree of front-loading and the policyholder's risk: more front-loaded contracts insured a higher fraction of low-risk policyholders. They also showed that a more front-loaded contract (LT) has a lower lapse rate than a less front-loaded contract (ART), indicating that the low-risk lock-in effects are associated with the highballing pricing pattern.

Cox and Ge (2004) presented a panel data from the US long-term care (LTC) insurance market with cohort-specific information. They found a positive correlation between policy age and loss ratio but argued that this reflected the risk changes over time and was thus not a highballing pricing pattern. They found a negative coefficient for *policy age*^{2}, indicating that the loss ratio increases became slower and slower over time. As previously mentioned, we, as well as other empirical works, have interpreted the above findings differently to Cox and Ge (2004). The positive coefficient of *policy age* is a direct indicator of a highballing pattern and the negative coefficient of *policy age*^{2} suggests that the price decrease in the highballing pattern becomes milder over time. This result is consistent with our Sample B results.

One way to solve this apparent theoretical (highballing, Proposition 1) and empirical (lowballing in Cox and Ge, 2004) contradiction 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 LTC market in just such a direct way. They documented pricing highballing evidence consistent with Hendel and Lizzeri (2003), thus supporting Proposition 1.

Herring and Pauly (2006) numerically developed 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 estimated the actual market premiums for individual health insurance using a Medical Expenditure Panel Survey, Community Tracking Study Household Survey, and National Health Interview Survey. They found that the actual premium schedule and the estimated ideal premium schedule do "appear to be surprisingly consistent", thus supporting the highballing prediction in Proposition 1. They concluded that the front-loaded premium is necessary for health insurers to provide guaranteed renewability and to insure the reclassification risk.

Pinquet, Guillen, and Ayuso (2011) examine the dynamic lapsation behavior in a long-term package of coverages of health, life, and LTC from the Spanish market. Premiums were paid annually and experience rating on an individual basis was not allowed. They found a highballing pricing pattern (Proposition 1) in all three coverages, evidenced by the increased benefit ratios from younger to older groups.

Hofmann and Browne (2013) presented evidence from the German long-term private health insurance (one-sided commitment), where insurers commit to offer renewal at a premium rate that does not reflect the revealed future information about the insured's 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 is immunized from strict regulation and from the existence and possible domination of social insurance programs. Their work also contributes to the debate on 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 a market, the accessibility of health coverage is much less a problem than in a private market.

C Proof of Proposition 1 and Remark 1

It is useful to first prove a lemma. Denote $\left(Q_2^{A\dagger}, Q_2^{N\dagger}, Q^{\dagger}\right)$ as the solution to the following non-linear system of equations:

$$p_1 Q_2^{A\dagger} + (1-p_1) Q_2^{N\dagger} = p_1 L, \tag{A.1}$$

$$u\left(W - Q_2^{N\dagger}\right) = (1-p_2^N) u\left(W - Q^{\dagger}\right) + p_2^N u\left(W - L + \frac{1-p_2^N}{p_2^N} Q^{\dagger}\right), \tag{A.2}$$

$$u\left(W - Q_2^{A\dagger}\right) = \left(1-p_2^A\right) u\left(W - Q^{\dagger}\right) + p_2^A u\left(W - L + \frac{1-p_2^N}{p_2^N} Q^{\dagger}\right), \tag{A.3}$$

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

Lemma A1: Suppose that (i) p_2^A / p_2^N is large enough; or (ii) consumer's preference exhibits HARA. Then the following inequality holds:

$$\frac{1}{u'(W - p_1 L)} > \frac{p_2^A}{u'\left(W - Q_2^{A\dagger}\right)} + \frac{1 - p_2^A}{u'\left(W - Q_2^{N\dagger}\right)}. \tag{A.4}$$

Proof: We first prove part (i) of the lemma. Holding fixed (W, L, p_1), consider p_2^N and $\left(Q_2^{A\dagger}, Q_2^{N\dagger}, Q^{\dagger}\right)$ as functions of p_2^A. By the martingale property, we have that $p_2^N = \frac{p_1}{1-p_1} \times \left(1 - p_2^A\right)$, which is strictly decreasing in p_2^A. Therefore, it suffices to show that (A.4) holds as p_2^A becomes sufficiently large.

Equations (A.1)-(A.3) imply that

$$\lim_{p_2^A \to 1} Q_2^{A\dagger}\left(p_2^A\right) = L \ \ and \ \lim_{p_2^A \to 1} Q_2^{N\dagger}\left(p_2^A\right) = 0.$$

Therefore, we have that

$$\lim_{p_2^A \to 1} \left[\frac{p_2^A}{u'\left(W - Q_2^{A\dagger}\right)} + \frac{1 - p_2^A}{u'\left(W - Q_2^{N\dagger}\right)}\right] = \frac{1}{u'(W - L)} < \frac{1}{u'(W - p_1 L)} = \lim_{p_2^A \to 1} \frac{1}{u'(W - p_1 L)},$$

which indicates immediately that (A.4) holds if p_2^A / p_2^N is large enough.

Next, we show that (A.4) holds under HARA preferences. Substituting (A.1) into (A.4) yields

$$p_2^A \frac{u'\left(W - p_1 Q_2^{A\dagger} - (1-p_1) Q_2^{N\dagger}\right)}{u'\left(W - Q_2^{A\dagger}\right)} + \left(1 - p_2^A\right) \frac{u'\left(W - p_1 Q_2^{A\dagger} - (1-p_1) Q_2^{N\dagger}\right)}{u'\left(W - Q_2^{N\dagger}\right)} < 1.$$

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

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

Denote $\left[\frac{a}{1-\eta}\left(W-Q_2^{N\dagger}\right)+b\right]/\left[\frac{a}{1-\eta}\left(W-Q_2^{A\dagger}\right)+b\right]$ by μ. It remains to show that

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

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

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

We consider the following three cases depending on the value of η.

Case I: $0<\eta<1$. It is clear that $\mu>1$ under such a scenario, and hence $\mu^\eta>1>p_2^N/p_2^A$. Therefore, $g(\mu)$ is strictly decreasing in μ for $\mu>1$, and hence $g(\mu)<g(1)=1$.

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

$$\mu^\eta=\left[\frac{\frac{a}{1-\eta}\left(W-Q_2^{N\dagger}\right)+b}{\frac{a}{1-\eta}\left(W-Q_2^{A\dagger}\right)+b}\right]^\eta=\frac{u\left(W-Q_2^{N\dagger}\right)}{u\left(W-Q_2^{A\dagger}\right)}=\frac{(1-p_2^N)u\left(W-Q^\dagger\right)+p_2^N u\left(W-L+\frac{1-p_2^N}{p_2^N}Q^\dagger\right)}{(1-p_2^A)u(W-Q^\dagger)+p_2^A u\left(W-L+\frac{1-p_2^N}{p_2^N}Q^\dagger\right)}$$

$$>\frac{p_2^N}{p_2^A},$$

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

Case III: $\eta>1$. It is clear that $\mu<1$. As with Case II, we must have that $\mu^\eta>p_2^N/p_2^A$, which in turn implies immediately that $\mu>\left(p_2^N/p_2^A\right)^{1/\eta}$. Therefore, $g(\mu)$ is strictly increasing in μ for $\mu\in\left(\left(p_2^N/p_2^A\right)^{1/\eta},1\right)$, and hence $g(\mu)<g(1)=1$.

This completes the proof of Lemma A1.■

Now we can prove Proposition 1 and Remark 1. Suppose, to the contrary, that the equilibrium contract $\left(Q_1^*,Q_2^{A*},Q_2^{N*}\right)$ maximizes a consumer's expected utility and is not front-loaded (i.e., $Q_1^*\le p_1L$), then we can construct an alternative contract that yields a strictly higher expected utility and satisfies constraints (1) to (4) by the following two steps:

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

$$u(W - \hat{Q}_2^N) = (1 - p_2^N)u(W - Q^*) + p_2^N u\left(W - L + \tfrac{1-p_2^N}{p_2^N}Q^* + \varepsilon\right), \quad \text{(A.5)}$$

and

$$u(W - \hat{Q}_2^A) = (1 - p_2^A)u(W - Q^*) + p_2^A u\left(W - L + \tfrac{1-p_2^N}{p_2^N}Q^* + \varepsilon\right). \quad \text{(A.6)}$$

Let $\hat{Q}_1(\varepsilon)$ be the solution to

$$(\hat{Q}_1 - p_1 L) + \delta[p_1(\hat{Q}_2^A - p_2^A L) + (1 - p_1)(\hat{Q}_2^N - p_2^N L)] = 0. \quad \text{(A.7)}$$

It is obvious that the sequence of premiums $\left(\hat{Q}_1(\varepsilon), \hat{Q}_2^A(\varepsilon), \hat{Q}_2^N(\varepsilon)\right)$ satisfies constraints (1), (2), and (4). Next, we show that the constructed contract generates a strictly higher expected utility than that under contract $(Q_1^*, Q_2^{A*}, Q_2^{N*})$. Note that $\left(\hat{Q}_1(0), \hat{Q}_2^A(0), \hat{Q}_2^N(0)\right) = (Q_1^*, Q_2^{A*}, Q_2^{N*})$. Differentiating Equations (A.5) and (A.6) with respect to ε and evaluating at $\varepsilon = 0$, we can obtain

$$\left.\frac{d\hat{Q}_2^N(\varepsilon)}{d\varepsilon}\right|_{\varepsilon=0} = -p_2^N \frac{u'\left(W - L + \frac{1-p_2^N}{p_2^N}Q^*\right)}{u'(W - Q_2^{N*})},$$

and

$$\left.\frac{d\hat{Q}_2^A(\varepsilon)}{d\varepsilon}\right|_{\varepsilon=0} = -p_2^A \frac{u'\left(W - L + \frac{1-p_2^N}{p_2^N}Q^*\right)}{u'(W - Q_2^{A*})}.$$

Together with (A.7), we have that

$$\left.\frac{d\hat{Q}_1(\varepsilon)}{d\varepsilon}\right|_{\varepsilon=0} = \delta p_1 p_2^A \frac{u'\left(W - L + \frac{1-p_2^N}{p_2^N}Q^*\right)}{u'(W - Q_2^{A*})} + \delta(1 - p_1)p_2^N \frac{u'\left(W - L + \frac{1-p_2^N}{p_2^N}Q^*\right)}{u'(W - Q_2^{N*})}.$$

Denote consumer's expected utility under the premium profile $\left(\hat{Q}_1(\varepsilon), \hat{Q}_2^A(\varepsilon), \hat{Q}_2^N(\varepsilon)\right)$ by $\hat{U}(\varepsilon)$. It is straightforward to verify that

$$\begin{aligned}\left.\frac{d\hat{U}(\varepsilon)}{d\varepsilon}\right|_{\varepsilon=0} &= -u'(W - Q_1^*)\left.\frac{d\hat{Q}_1}{d\varepsilon}\right|_{\varepsilon=0} - \delta p_1 u'(W - Q_2^{A*})\left.\frac{d\hat{Q}_2^A}{d\varepsilon}\right|_{\varepsilon=0} - \delta(1 - p_1)u'(W - Q_2^{N*})\left.\frac{d\hat{Q}_2^N}{d\varepsilon}\right|_{\varepsilon=0} \\ &= \delta p_1 u'\left(W - L + \tfrac{1-p_2^N}{p_2^N}Q^*\right) \times \left[1 - p_2^A \times \frac{u'(W - Q_1^*)}{u'(W - Q_2^{A*})} - (1 - p_2^A) \times \frac{u'(W - Q_1^*)}{u'(W - Q_2^{N*})}\right].\end{aligned}$$

It remains to show that $\left.\frac{d\hat{U}(\varepsilon)}{d\varepsilon}\right|_{\varepsilon=0} > 0$, which is equivalent to

$$\frac{1}{u'(W - Q_1^*)} > \frac{p_2^A}{u'(W - Q_2^{A*})} + \frac{1 - p_2^A}{u'(W - Q_2^{N*})}.$$

From the postulated assumption that the equilibrium contract $(Q_1^*, Q_2^{A*}, Q_2^{N*})$ is not front-loaded, we must have $Q_2^{A*} \geq Q_2^{A\dagger}$, $Q_2^{N*} \geq Q_2^{N\dagger}$, and $Q_1^* \leq p_1 L$. Therefore, we have that

$$\frac{1}{u'(W-Q_1^*)} \geq \frac{1}{u'(W-p_1L)} > \frac{p_2^A}{u'\left(W-Q_2^{A\dagger}\right)} + \frac{1-p_2^A}{u'\left(W-Q_2^{N\dagger}\right)} \geq \frac{p_2^A}{u'(W-Q_2^{A*})} + \frac{1-p_2^A}{u'(W-Q_2^{N*})},$$

where the first and third inequalities follow from the monotonicity of $u'(\cdot)$, and the second inequality follows directly from Lemma A1. This completes the proof of Step 1.

Step 2 Fixing $\hat{Q}_1$, we increase $\hat{Q}_2^N$ and decrease $\hat{Q}_2^A$ to satisfy constraints (1) and (3) simultaneously. Specifically, constraint (1) is always satisfied if we increase $\hat{Q}_2^N$ by $x > 0$ and decrease $\hat{Q}_2^A$ by $\frac{1-p_1}{p_1}x$. From the continuity of $u(\cdot)$, there exists $\tilde{x} > 0$ such that the contract $\left(\hat{Q}_1, \hat{Q}_2^A - \frac{1-p_1}{p_1}\tilde{x}, \hat{Q}_2^N + \tilde{x}\right)$ satisfies constraint (3). Therefore, the constructed contract satisfies constraint (1) to (4). To complete the proof, it suffices to show that the contract $\left(\hat{Q}_1, \hat{Q}_2^A - \frac{1-p_1}{p_1}\tilde{x}, \hat{Q}_2^N + \tilde{x}\right)$ generates a strictly higher expected utility than does the contract $\left(\hat{Q}_1, \hat{Q}_2^A, \hat{Q}_2^N\right)$, which is equivalent to show

$$p_1 u\left(W-\hat{Q}_2^A\right) + (1-p_1)u\left(W-\hat{Q}_2^N\right) < p_1 u\left(W-\hat{Q}_2^A + \frac{1-p_1}{p_1}\tilde{x}\right) + (1-p_1)u\left(W-\hat{Q}_2^N-\tilde{x}\right). \quad \text{(A.8)}$$

Note that

$$W-\hat{Q}_2^A + \frac{1-p_1}{p_1}\tilde{x} = \frac{\frac{1-p_1}{p_1}\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}\left(W-\hat{Q}_2^N\right) + \frac{\hat{Q}_2^A-\hat{Q}_2^N-\frac{1-p_1}{p_1}\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}\left(W-\hat{Q}_2^A\right),$$

and

$$W-\hat{Q}_2^N-\tilde{x} = \frac{\hat{Q}_2^A-\hat{Q}_2^N-\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}\left(W-\hat{Q}_2^N\right) + \frac{\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}\left(W-\hat{Q}_2^A\right).$$

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

$$u\left(W-\hat{Q}_2^A + \frac{1-p_1}{p_1}\tilde{x}\right) > \frac{\frac{1-p_1}{p_1}\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}u\left(W-\hat{Q}_2^N\right) + \frac{\hat{Q}_2^A-\hat{Q}_2^N-\frac{1-p_1}{p_1}\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}u\left(W-\hat{Q}_2^A\right), \quad \text{(A.9)}$$

and

$$u\left(W-\hat{Q}_2^N-\tilde{x}\right) > \frac{\hat{Q}_2^A-\hat{Q}_2^N-\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}u\left(W-\hat{Q}_2^N\right) + \frac{\tilde{x}}{\hat{Q}_2^A-\hat{Q}_2^N}u\left(W-\hat{Q}_2^A\right). \quad \text{(A.10)}$$

Multiplying (A.9) by p_1, (A.10) by $1-p_1$, and summing them yields (A.8). This completes the proof of Step 2. Therefore, the equilibrium contract must be highballing under one-sided commitment and asymmetric learning. Q.E.D.

D Simulation results

In this part, we provide some numerical results, which suggest that the requirement of a sufficiently large ratio between p_2^A and p_2^N in Proposition 1 is not crucial to drive the highballing pricing pattern.

Fixing (W, L, p_1), consider p_2^A and $\left(Q_2^{A\dagger}, Q_2^{N\dagger}, Q^{\dagger}\right)$ as functions of $p_2^N \in (0, p_1)$. From the martingale property, we have that

$$p_2^A = 1 - \frac{1 - p_1}{p_1} \times p_2^N.$$

Moreover, $\left(Q_2^{A\dagger}, Q_2^{N\dagger}, Q^{\dagger}\right)$ solves Equations (A.1)-(A.3). For Proposition 1 to hold, it suffices to show that condition (A.4) is satisfied for all $p_2^N \in (0, p_1)$, which is equivalent to

$$\psi(p_2^N) \coloneqq \left(1 - \frac{1 - p_1}{p_1} \times p_2^N\right) \times \frac{u'(W - p_1 L)}{u'\left(W - Q_2^{A\dagger}(p_2^N)\right)} + \left(\frac{1 - p_1}{p_1} \times p_2^N\right) \times \frac{u'(W - p_1 L)}{u'\left(W - Q_2^{N\dagger}(p_2^N)\right)} < 1.$$

To proceed, we set $(W, L) = (1, 0.5)$, and consider the following families of utility functions:

a) The expo-power (EP) utility functions (Saha, 1993):

$$u(c) = -\exp(-\beta \cdot c^{\alpha}), \text{with } \alpha \neq 0, \beta \neq 0, \text{and } \alpha\beta > 0.$$

b) The power risk aversion (PRA) utility functions (Xie, 2000):

$$u(c) = \frac{1}{\gamma}\left\{1 - \exp\left[-\gamma\left(\frac{c^{1-\sigma} - 1}{1 - \sigma}\right)\right]\right\}, \text{with } \sigma \geq 0, \text{and } \gamma \geq 0.$$

c) The flexible three parameter (FTP) utility functions (Conniffe, 2007):

$$u(c) = \frac{1}{\theta}\left\{1 - \left[1 - \lambda\theta\left(\frac{c^{1-\tau} - 1}{1 - \tau}\right)\right]^{\frac{1}{\lambda}}\right\}, \text{with } \tau > 0, \theta > 0, \text{and } \lambda \leq 1.$$

Note that the EP and the PRA forms are equivalent. To translate parameters, let $\sigma = 1 - \alpha$ and $\gamma = \alpha\beta$. Figures A1(a) and A1(b) below plot $\psi(p_2^N)$ with different parameters of the above utility functions, assuming the first-period loss probability is small ($p_1 = 0.2$) and large ($p_1 = 0.8$), respectively. It is clear that $\psi(p_2^N) < 1$ is satisfied for all $p_2^N \in (0, p_1)$, suggesting that Proposition 1 holds regardless of the size of the ratio p_2^A / p_2^N.

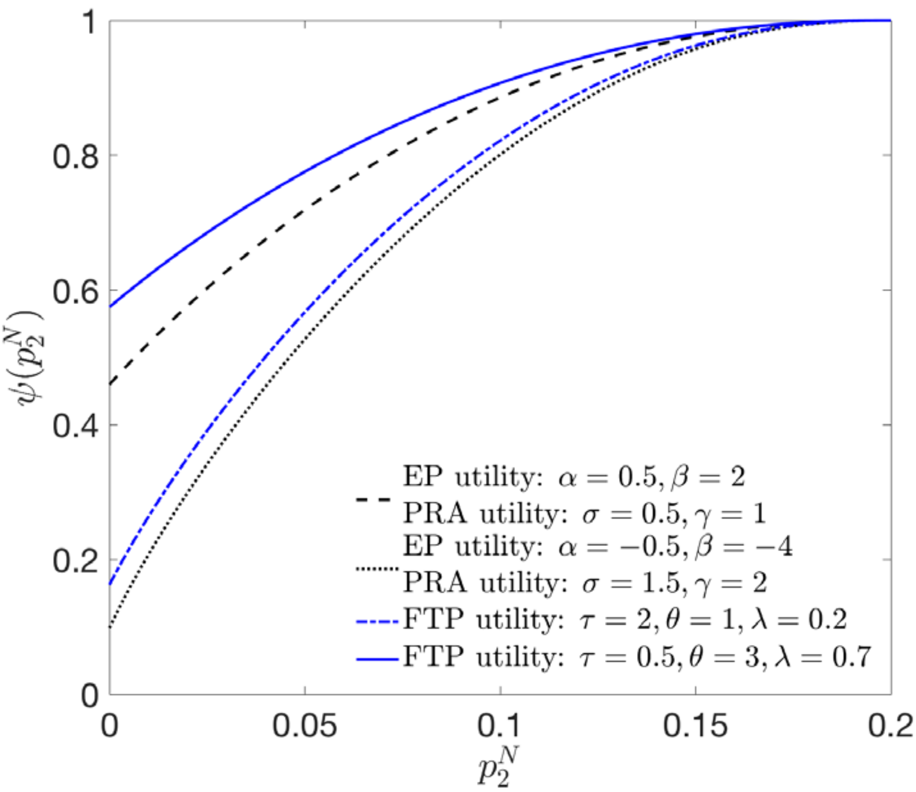

Figure A1(a) $(W, L, p_1) = (1, 0.5, 0.2)$.

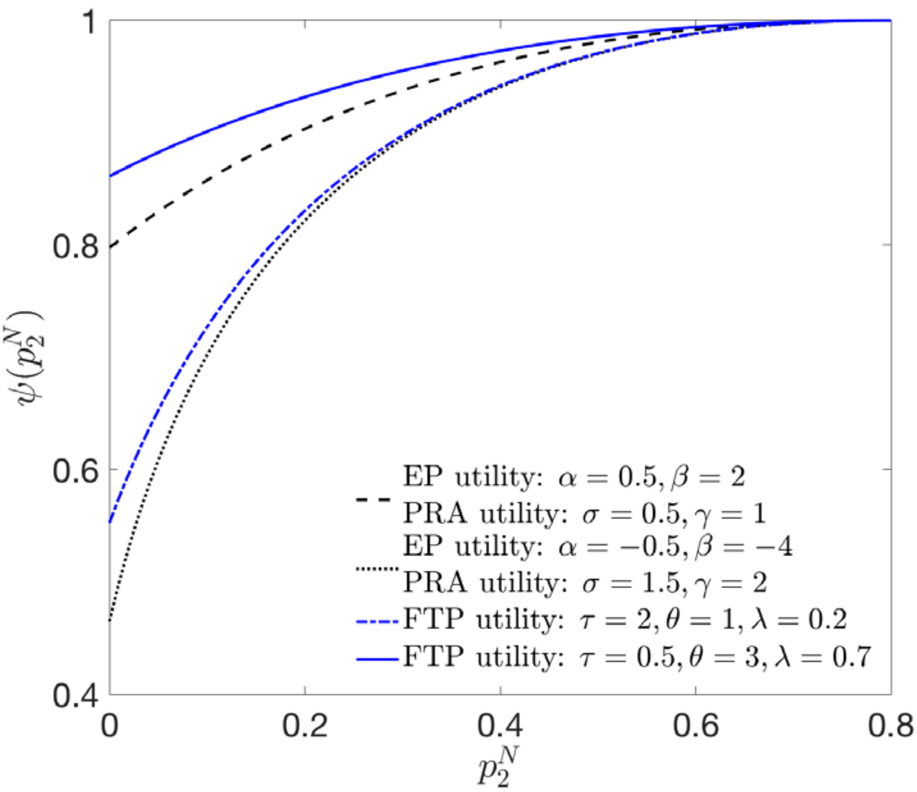

Figure A1(b) $(W, L, p_1) = (1, 0.5, 0.8)$.

E Robustness of Propositions 1-2 under an alternative assumption of risk dynamics

In the main text, we assume that policyholder's risk type does not change (e.g., accident insurance). In this part, we relax this assumption and assume that policyholder's type worsens over time (e.g., life insurance) as in Hendel and Lizzeri (2003). Again, we can show that the equilibrium pricing patterns predicted in Propositions 1 and 2 hold under this alternative assumption of risk changes.

More 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 $\Pr(p_2 = p_2^A) = 1 - \Pr(p_2 = p_2^N) = \tilde{p} \in (0,1)$. The second-period loss probability p_2 is learned by the incumbent insurer and the policyholder, but not observed by the entrants.

Proposition A1: Suppose that policyholder's risk type worsens over time and learning is asymmetric. Then the equilibrium contract exhibits:

(i) highballing (front-loaded) pricing pattern under one-sided commitment;

(ii) lowballing (back-loaded) pattern under no commitment.

Proof: Denote $\tilde{p} \times p_2^A + (1-\tilde{p}) \times p_2^N$ by $\overline{p}_2$ It is clear that $\overline{p}_2 \equiv \tilde{p} \times p_2^A + (1-\tilde{p}) \times p_2^N > \tilde{p} \times p_1 + (1-\tilde{p}) \times p_1 = p_1$. Note that the proof of our Proposition 2 is exactly the same as that of Proposition 2 in de Garidel-Thoron (2005), which does not rely on the martingale property $p_1 = p_1 p_2^A + (1-p_1)\, p_2^N$ and the distribution of p_2. Therefore, the equilibrium contract still exhibits lowballing with the alternative assumption $p_2^A > p_2^N > p_1$; and it remains to prove part (i) of the proposition. The equilibrium contract solves the following maximization problem:

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

subject to

$$(Q_1 - p_1 L) + \; \delta\left[\tilde{p}\left(Q_2^A - p_2^A L\right) + (1-\tilde{p})(Q_2^N - p_2^N L)\right] = 0, \qquad (A.11)$$

$$Q_2^A \leq p_2^A L, \qquad (A.12)$$

$$IC_2^N(Q; C_2^N) \text{ and } IC_2^A\left(Q; C_2^A\right) \text{ cross on the line } (1-p_2^N)Q - p_2^N R = 0, \qquad (A.13)$$

$$IC_2^N(Q; C_2^N) \text{ and } \left(1-\overline{p}_2\right)Q - \overline{p}_2 R = 0 \text{ do not intersect.} \qquad (A.14)$$

Suppose, to the contrary, that the equilibrium contract, denoted by $\left(Q_1^{**}, Q_2^{A**}, Q_2^{N**}\right)$, maximizes consumer's expected utility and is not front-loaded (i.e., $Q_1^{**} \leq p_1 L$). Then we can construct an alternative contract that yields a higher expected utility and satisfies constraints (A.11) to (A.14) by the following two steps:

Step 1 Fix Q_2^{A**}, decrease Q_2^{N**} by ε', and increase Q_1^{**} by $\delta(1-\tilde{p})\varepsilon'$ for a sufficiently small $\varepsilon' > 0$. It is clear that constraints (A.11), (A.12) and (A.14) are still satisfied but constraint (A.13) is violated. Denote consumer's expected utility with contract $\left(Q_1^{**} + \delta(1-\tilde{p})\varepsilon', Q_2^{A**}, Q_2^{N**} - \varepsilon'\right)$ by $U(\varepsilon')$. It can be verified that

$$\left.\frac{dU(\varepsilon')}{d\varepsilon'}\right|_{\varepsilon'=0} = \delta(1-\tilde{p}) \times [u'(W - Q_2^{N**}) - u'(W - Q_1^{**})].$$

From constraint (A.13) and the shape of $IC_2^N(Q; C_2^N)$, we have $Q_2^{N**} \geq p_2^N L$. Together with the postulated $Q_1^{**} \leq p_1 L$, we must have that

$$Q_1^{**} \leq p_1 L < p_2^N L \leq Q_2^{N**},$$

which in turn implies that $u'(W - Q_2^{N**}) > u'(W - Q_1^{**})$ and $\left.\frac{dU(\varepsilon')}{d\varepsilon'}\right|_{\varepsilon'=0} > 0$. By the continuity of the utility function $u(\cdot)$, there exists $\varepsilon_1' > 0$ such that the contract with the premium profile $\left(Q_1^{**} + \delta(1-\tilde{p})\varepsilon_1', Q_2^{A**}, Q_2^{N**} - \varepsilon_1'\right) \equiv \left(\hat{\hat{Q}}_1, \hat{\hat{Q}}_2^A, \hat{\hat{Q}}_2^N\right)$ generates a strictly higher expected utility than does the equilibrium premium profile $\left(Q_1^{**}, Q_2^{A**}, Q_2^{N**}\right)$.

Step 2 Fixing $\hat{\hat{Q}}_1$, we increase $\hat{\hat{Q}}_2^N$ and decrease $\hat{\hat{Q}}_2^A$ to satisfy constraints (A.11) and (A.13) simultaneously. It is clear that the constructed contract satisfies constraints (A.11)-(A.14). By the same argument as in Step 2 in the proof of Proposition 1, this contract generates strictly higher utility to the policyholders than does the contract with the premium profile $\left(\hat{\hat{Q}}_1, \hat{\hat{Q}}_2^A, \hat{\hat{Q}}_2^N\right)$. Q.E.D.

Proposition A1 complements Hendel and Lizzeri (2003) by showing that the highballing pricing pattern under one-sided commitment is robust across different learning environments. It should be noted that both symmetric learning and one-sided commitment play indispensable roles in shaping the highballing pricing pattern in Hendel and Lizzeri (2003). On the one hand, symmetric learning indicates that an insurer faces fierce competition with the entrant in every state in the second period, and, hence, the incumbent insurer cannot obtain information rents in the second period. To see this more clearly, suppose to the contrary that the incumbent insurer offers a contract that generates positive profits for some state in the second period. The entrant can then earn profits by providing a contract that yields less profit and a strictly higher expected utility to attract policyholders in that state. Therefore, the incumbent insurer must earn zero or negative profits in the second period. On the other hand, one-sided commitment implies that insurers have incentives to insure against the period-2 reclassification risk in terms of level premiums to maximize consumers' 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 the competitive equilibrium in Hendel and Lizzeri (2003). Note that their result cannot be directly generalized to the environment of asymmetric learning as is assumed in this paper because the incumbent insurer earns profits from type-N consumers [see constraint (A.3)] and suffers losses from type-A consumers [see constraint (A.2)].

F Figure 2 in the contingent wealth space

In this section, we redraw Figure 2 in the contingent wealth space as in Rothschild and Stiglitz (1976). Before we proceed, it is useful to first introduce several notations. In each period, an insurance contract can be represented by $c \equiv (\overline{x}, \underline{x})$, where $\overline{x}$ specifies the consumption level when no accident occurs, and $\underline{x}$ refers to the consumption level when an accident occurs. Therefore, a two-period insurance contract can be indexed by $(c_1, c_2^A, c_2^N) \equiv \langle(\overline{x}_1, \underline{x}_1), (\overline{x}_2^A, \underline{x}_2^A), (\overline{x}_2^N, \underline{x}_2^N)\rangle$, where $c_1 \equiv (\overline{x}_1, \underline{x}_1)$ is the first-period contract and $c_2^k \equiv (\overline{x}_2^k, \underline{x}_2^k)$ is the second-period contract contingent on $k \in \{A, N\}$. Fixing (R, Q) as specified in the main text of the paper, it is clear that $(\overline{x}, \underline{x})$ can be derived as the following:

$$\overline{x} = W - Q, \text{and } \underline{x} = W - L + R.$$

Moreover, consumers' indifference curve that crosses a contract $c_2^k \equiv (\overline{x}_2^k, \underline{x}_2^k)$ for type $k \in \{A, N\}$, which we denote by $\underline{x} = IC_2^k(\overline{x}; c_2^k)$, is the solution to

$$(1 - p_2^k)u(\overline{x}) + p_2^k u\left(IC_2^k(\overline{x}; c_2^k)\right) = (1 - p_2^k)u\left(\overline{x}_2^k\right) + p_2^k u(\underline{x}_2^k).$$

Then Figure 2 can be redrawn as Figure A2 in the $(\overline{x}, \underline{x})$ space as follows.

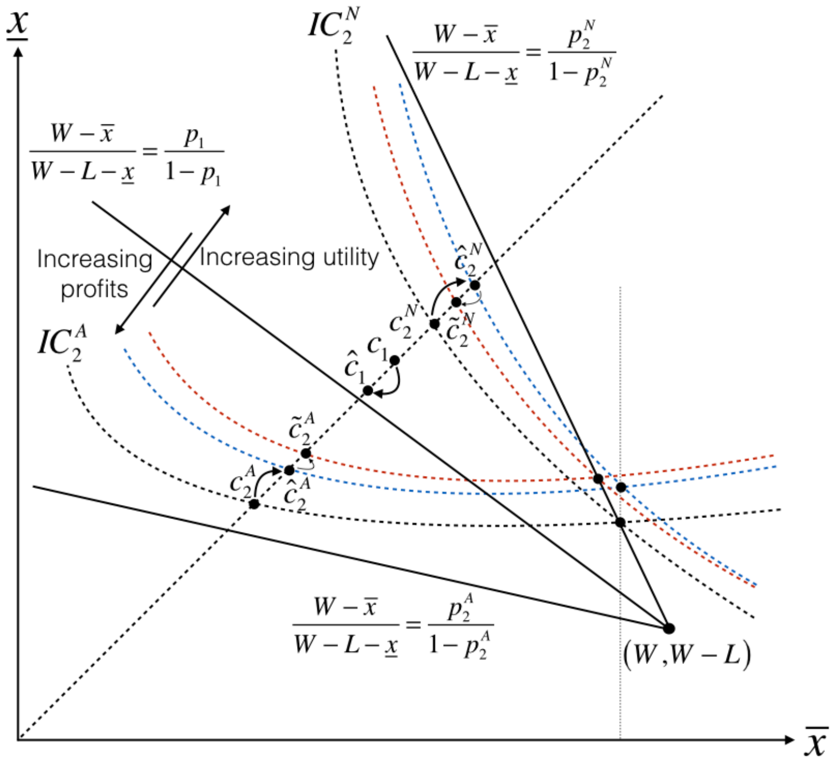

Figure A2 Graphical illustration for proof of Proposition 1 in the contingent wealth space.