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ABSTRACT

Health insurance plans increasingly pay for expenses only beyond a large annual deductible. This paper explores the implications of deductibles that reset over shorter timespans. We develop a model of insurance demand between two actuarially equivalent deductible policies, in which one deductible is larger and resets annually and the other deductible is smaller and resets biannually. Our model incorporates borrowing constraints, moral hazard, mid-year contract switching, and delayable care. Calibrations using claims data show that the liquidity benefits of resetting deductibles can generate welfare gains of 6-10% of premium costs, particularly for individuals with borrowing constraints.

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1 Introduction

Health insurance contracts in the United States increasingly include sizable annual deductibles as a form of cost-sharing against health expenditure risk. Unlike other common forms of cost-sharing, annual deductibles introduce non-linearities in the structure and timing of out-of-pocket expenditures. Unlike insurance against other risks such as automobile or homeowners insurance, in which separate deductibles apply to each loss, deductibles in health insurance apply to cumulative losses over the year. This characteristic of health insurance deductibles, coupled with the fact that most individuals have many health care encounters over the course of a year, introduces a time aggregation dimension whose implications for individual welfare are not well understood.[1] While we know that health care spending is sensitive to non-linearities in health insurance contracts (Brot-Goldberg et al., 2017; Dalton, Gowrisankaran and Town, 2019) and deductibles can reduce the value of insurance under liquidity constraints (Ericson and Sydnor, 2018), it is not obvious how these features interact under alternative time aggregations. This paper provides the first analysis of the spending and welfare impacts of this overlooked parameter of health insurance design.

The question of how to design deductibles is particularly relevant as health insurers increasingly offer high deductible plans. In 2010, only 10% of individuals with single employer-based health insurance had a plan with a deductible over $2,000, while in 2020 26% of these individuals had such a plan and 24% were offered *only* high-deductible plans (Kaiser Family Foundation, 2020). In the individual market, roughly 90% of enrollees had high deductible plans in 2015 (Dolan, 2016). These deductibles are large and can pose a significant financial burden on those exposed to health costs: for instance, the average medical deductible in the 2017 federal marketplace was $3,276 for silver plans (Kaiser Family Foundation, 2017*a*), and Rae, Claxton and Levitt (2017) show that only 47% of single households have enough liquid assets to pay this deductible.[2]

To study the effects of alternative time aggregations of deductibles in health insur-

[1] In our claims data, individuals have an average of three health care claims per month.

[2] While some individuals qualify for cost-sharing reductions (CSRs), those making over 250% of the federal poverty line are still subject to the full deductible.

ance policies on individual welfare, we build and calibrate a dynamic model of within-year health care consumption, non-health care consumption, and insurance choice under uncertainty. After choosing an insurance policy, risk-averse individuals realize health shocks over the course of the year and make decisions over health care and non-health consumption. Importantly, we introduce an alternative "resetting" deductible policy whose deductible aggregates (and thus resets) over shorter frequencies than the standard deductible that resets annually. To isolate the effect of time aggregation, we hold constant all other features of the insurance contract (e.g., the premium and actuarial value), and only vary the time over which the deductible aggregates and—to preserve actuarial equivalence—the size of the deductible.

We study two main mechanisms that highlight the trade-offs between a standard (annual) deductible and a resetting deductible. First, resetting deductibles may provide relief for liquidity constrained individuals, but at the cost of higher risk exposure. Deductibles, by nature, front-load out-of-pocket spending toward the beginning of a deductible period, which suggests that individuals who face high borrowing costs may have difficulty smoothing consumption while financing this lumpy spending. Resetting deductibles, by virtue of being smaller in size, provide built-in smoothing. On the other hand, they expose individuals to higher cumulative out-of-pocket exposure due to the fact that they reset and thus might have to be paid more frequently over the course of a year.[3] Which deductible provides more welfare gain thus depends in part on the value of liquidity versus risk protection.

Second, the frequency over which deductibles reset could interact with moral hazard. We investigate two types of moral hazard: ex-post moral hazard and timing moral hazard (i.e., claim delay). If individuals "over-consume" medical care once their health spending surpasses their deductible, all else equal a policy whose deductible resets more frequently could significantly curb ex-post moral hazard. However, again by virtue of being smaller in size, resetting deductibles are more likely to be surpassed than more aggregated, larger deductibles; this could exacerbate moral hazard. Moreover, to the ex-

[3] As we will show, actuarially-equivalent biannual deductibles will typically be greater than half the size of annual deductibles, resulting in higher annual out-of-pocket risk exposure.

tent that individuals are able to strategically delay care and shift medical costs to times with low out-of-pocket exposure, resetting deductibles might exacerbate timing moral hazard. The overall impact of resetting deductibles on moral hazard (and, as a consequence, welfare) is therefore ambiguous, and ultimately an empirical question. In sum, less-aggregated deductibles may provide welfare gains or losses, depending on the extent of liquidity constraints, risk preferences, moral hazard, and incentives to shift spending over time.

To quantify these mechanisms and others,[4] we use health care claims data from over 16 million individuals in the 2013 Truven Marketscan database and calibrate our model using benchmark figures from the federal Affordable Care Act marketplace and other standard parameters in the literature. We use the calibrated model to quantify an individual's willingness to pay to switch from an annual insurance policy with a year-long deductible to an actuarially equivalent annual policy with a deductible that resets at a shorter frequency (e.g., after six months).

Our calibration generates three main results. First, we find that borrowing costs have a first-order effect on the value of a resetting deductible policy. At one extreme in which individuals can costlessly save and borrow, individuals slightly prefer the standard (year-long) deductible policy, as it provides better insurance against right-tail events in multiple periods. At the other extreme in which individuals can neither borrow nor save, individuals strongly prefer the resetting policy: at the calibrated parameter values, they are willing to pay an extra \$270 annually, or 6.3% of their total premiums, for the resetting deductible policy instead of the standard deductible policy.[5] Second, we find that extra medical consumption generated by ex-post moral hazard is similar under the two policies for our empirical distribution. Despite this, the presence of moral hazard amplifies the liquidity benefits of resetting deductibles because moral hazard drives up deductibles; given this, liquidity constrained individuals would be willing to pay an extra \$448 annually, or 10.4% of their total premiums. Third, we find that mid-year contract switching and delayability

[4]We additionally explore the role of exogenous mid-year insurance contract switches (e.g., due to job changes).

[5]We also show that there are welfare gains to resetting deductibles for individuals who must rely on credit card interest rates and payday loan rates, which may more closely resemble loans or payment plans offered to pay medical expenses.

of care for health shocks have much smaller effects on the willingness to pay for a resetting deductible. We also show that our main results are qualitatively similar under health shock distributions with different levels of persistence, shorter period lengths, and policies that additionally have coinsurance arms. Overall, our results suggest that the value of a resetting deductible policy depends in large part on the classic trade-off between risk protection, liquidity, and moral hazard.

This paper contributes to several distinct literatures. First, our modeling approach of within-year health spending is motivated by a growing empirical literature on consumer sensitivity to the non-linearity of health insurance contracts. Much of the recent literature has found that individuals respond to "spot" prices more so than expected end-of-year prices (Brot-Goldberg et al., 2017; Dalton, Gowrisankaran and Town, 2019; Abaluck, Gruber and Swanson, 2018; Guo and Zhang, 2019), though not all have come to that conclusion (Aron-Dine et al., 2015; Einav, Finkelstein and Schrimpf, 2015). At the same time, other work shows evidence of intertemporal substitution for deferrable care (e.g., Cabral (2017) for dental care and Lin and Sacks (2019) in the RAND Health Insurance Experiment). While much of this literature has examined the effect of traditional cost-sharing levers such as coinsurance rates or the *size* of deductibles, there has not been any work to date on how the time aggregation of deductibles affects spending.

Our paper also contributes to a literature on optimal health insurance contracts. Beginning with the classic result of the optimality of a straight deductible policy in a model of insurance demand without moral hazard (Arrow, 1963), much of the literature considers the optimal level and mix of various cost-sharing vehicles, including co-insurance, co-pays, deductibles, and out-of-pocket maxima, but hold fixed the basic structure of these vehicles (e.g., Cutler and Zeckhauser, 2000; Ellis, Jiang and Manning, 2015). Closely related to the liquidity results of our paper, Ericson and Sydnor (2018) show through simulation that liquidity constraints can upend the optimality of a straight deductible policy.[6] Our paper further relaxes a particular aspect of deductibles—the timespan over which they aggregate—and shows that this relaxation can provide further welfare gains,

[6]Liu (2020) shows theoretically and empirically that adverse selection can also upend the optimality of a straight deductible policy. We abstract from adverse selection in this paper but view adverse selection in the context of choice between standard and resetting deductibles to be an interesting topic for future work.

especially for liquidity constrained individuals.

A separate optimal contracts literature examines the optimal *contract* length, holding the length of a period to be annual and thus abstracting from within-year dynamics (Ghili et al., 2020; Atal et al., 2020). This literature finds large welfare gains of longer-term health insurance contracts primarily due to adverse selection and reclassification risk. In contrast, our paper holds fixed the contract length but explores within-contract aggregation over time. Our results suggest that within-period dynamics of spending and consumption arising from the time-aggregated nature of deductibles are also important for optimal contract design.

Finally, this paper contributes to a small literature on the aggregation of continuous measures over time. Time aggregation underlies many policies and economic models, yet there has been little work understanding the consequences of these aggregation decisions. In a related paper within the context of automobile insurance, Cohen (2006) studies the trade-off between aggregate and per-loss deductibles and shows that per-loss deductibles require lower claim verification costs and induce lower ex-ante moral hazard.[7] In crop insurance in Kenya, Casaburi and Willis (2018) find that upfront lump-sum premium payments can significantly lower the value of insurance compared to periodic premium payments. In other contexts, Parsons and Van Wesep (2013) develop a model of optimal paycheck timing, and Shapiro (2005) finds evidence that more frequent Food Stamp benefit cycles produce welfare gains. Our paper suggests that the time aggregation embedded in health insurance deductible policies can also have non-trivial impacts on welfare.

While we believe this paper provides a useful starting point for studying time aggregation in health insurance and beyond, it raises several interesting questions for further research. One question is the effect of time aggregation on sorting and selection. Our analysis focuses on liquidity and moral hazard issues, and our simplifications—such as homogeneous individuals—assumes away issues related to sorting and adverse selection that may arise when consumers can select from many plans (Marone and Sabety, 2019; Liu, 2020). It would also be interesting to study other dimensions of time aggregation

[7] Per-loss deductibles are the limit of resetting deductibles, i.e., they reset after each loss event. We abstract from ex-ante moral hazard and claim verification, and instead focus on ex-post moral hazard and other mechanisms important to the health insurance context.

such as out-of-pocket maxima, which are equivalent to deductibles in our main analysis (though different in our extended model), as well as other dimensions of smoothing, such as Health Savings Accounts or payment plans, which we conceptualize as additional income and alternative interest rates, respectively. Finally, a more fundamental question is *why* deductibles at shorter frequencies are not offered. Whether this is due to historical precedent, administrative costs, or something else is not obvious, and would be an interesting avenue for further research.

Notwithstanding these caveats, our findings have policy implications for the design and effectiveness of health insurance plan offerings. This may be particularly true for plans offered through the Affordable Care Act marketplaces, where high deductible plans are common and often cater to lower income populations who may be liquidity constrained.[8] Given that deductibles are trending into the thousands of dollars, however, these issues extend far beyond low-income populations:[9] Rae, Claxton and Levitt (2017) show that less than half of single-person households have enough liquid assets to pay a $2,000 deductible. Meanwhile, policymakers continue to encourage the use of high deductible health plans on the individual market. For example, the Centers for Medicare and Medicaid Services in 2018 stated "We would like to encourage issuers to offer HDHPs [high deductible health plans]... as a cost effective option for enrollees" (Department of Health and Human Services, 2018). Designing and introducing alternative deductible structures, such as resetting deductibles, could maintain the use of high deductible policies while alleviating some of the liquidity issues that concern their critics.

The paper proceeds with a discussion of recent trends in health insurance deductibles and the parallels with short-term health insurance policies in the United States in Section 2. Section 3 develops a two-period model of health insurance choice and investigates in isolation different mechanisms that affect the value of different deductible timespans. Section 4 describes the calibration and presents results. Finally, Section 5 extends the model to alternative shock distributions, shorter time periods, and three-armed policies

[8] Our findings also have implications for short-term health insurance plans, which have similarly shorter deductible spans by definition. We leave the analysis of short-term health insurance plans to future work because this market operates in a very different policy and regulatory space, as we discuss in Section 2.

[9] Moreover, individuals with income less than 250% of the federal poverty line are eligible for cost-sharing subsidies that alleviate some of the burden of these deductibles.

with co-insurance after the deductible, and Section 6 concludes.

2 Deductibles and short-term health insurance plans

Across a range of contexts, household insurance contracts feature deductibles. For example, the median passenger automobile insurance policy includes a $500 deductible (Barseghyan, Prince and Teitelbaum, 2011), the median homeowner's insurance policy includes a $500 deductible (Sydnor, 2010), the median flood insurance policy includes a $500 deductible (Michel-Kerjan and Kousky, 2010), and the median health insurance policy contains a $1,400 deductible, sometimes in addition to other cost-sharing mechanisms (Kaiser Family Foundation, 2020). One major difference between the first three policies and the health insurance policy is that the first three deductibles are *per-event* while health insurance deductibles are *per-period*.[10] This period is almost always one year, and usually one *calendar* year. This section discusses trends in health insurance deductibles and the recent advent of short-term health insurance plans that may be an empirical analogue for understanding time aggregation in deductible design.

2.1 Trends in health insurance deductibles

Deductibles are an increasingly common form of cost-sharing in health insurance plans in the United States. In the past decade, the share of individuals covered by an employer plan with a deductible over $2,000 rose from 10% to 26% (Kaiser Family Foundation, 2020). There has also been a rapid expansion in the use of high-deductible health plans:[11] the share of employers only offering high-deductible plans increased from 7% in 2012 to 24% in 2020 (Towers Watson, 2015; Kaiser Family Foundation, 2020). In plans available

[10] One theory for this difference is that an "event" in these other policies are relatively well-defined, while in the context of health care an "event" can develop slowly over time and spill over into other "events", making it difficult to distinguish between events. Relatedly, a prominent exception to this event vs. time period distinction is Medicare hospital inpatient (Part A) deductibles, which are per-stay, where "stays" are well-defined events. Health insurance policies often also include co-pays, which are "per-event" but are typically orders of magnitude smaller than the deductibles we are concerned with in this paper.

[11] The Internal Revenue Service defines a high deductible health plan as one with a deductible of at least $1,400 for an individual or $2,800 for a family in 2020.

through federal and state health insurance exchanges, the average deductible for an individual plan is over $3,000 for silver plans (which account for 67% of plan selections), and almost $6,000 for bronze plans (which make up 22% of plan selections). To help curb this financial exposure, individuals under 250% of the federal poverty line (FPL) are eligible for cost-sharing reductions that lower their effective deductible, but those over 250% of the FPL do not receive any such subsidies.

Alongside this growth in plans with large deductibles has been increased concern in the affordability of these deductible policies. Health Savings Accounts (HSAs) provide some relief for plans with high deductibles by allowing individuals with such plans to place funds in a tax-preferred savings account to be used for medical spending or retirement, up to a contribution limit (for example, in 2018 the contribution limit was $3,450 for an individual plan). Since their introduction in 2004, the number of individuals enrolled in an HSA has grown to 22 million in 2017 with total assets of over $45 billion (Devenir Research Team, 2018), suggesting that individuals value these accounts. On the other hand, much of this growth has been concentrated among high-income households, who are less likely to need the liquidity afforded by these plans (Helmchen et al., 2015).

2.2 Short-term health insurance plans

While almost all health insurance contracts—and their corresponding deductibles—span a calendar year, one exception is short-term health insurance plans that provide coverage for a limited amount of time (i.e., less than 365 days). These plans, which were originally designed for individuals who experience a temporary gap in health coverage, typically do not comply with Affordable Care Act (ACA) standards and thus do not currently capture a large market share. However, with the repeal of the ACA's individual mandate and a recent ruling that expanded access to short-term health insurance plans (Keith, 2018), the Urban Institute estimates that 4.3 million people will enroll in the short-term policies as the plan offerings expand, while enrollment in the ACA individual market will fall by 2.2 million people in 2019 due to the availability of short-term coverage alone (Blumberg, Buettgens and Wang, 2018).

In theory, these policies have parallels with the resetting deductible policies analyzed in this paper, since the basic features of the policies – including the deductible – are defined over shorter periods of time. In practice, these policies come with many features that are beyond the scope of this paper, as they do not face as many regulatory constraints as standard health insurance policies do. First, they are not guaranteed renewable, and thus individuals who develop chronic illnesses may not be able to purchase future policies. Second, they provide fewer benefits: they can exclude coverage for pre-existing conditions, they do not have to cover essential health benefits such as maternity care, prescription drugs, mental health care, and preventive care, they can impose lifetime caps on benefits, and can have a lower actuarial value than standard plans must have (Pollitz et al., 2018). As a result, these policies are much cheaper than ACA-compliant policies but likely suffer from reclassification risk and selection problems. According to eHealth (eHealth, 2018), one of the largest online market exchange for short-term policies, the average short-term plan monthly premium was $110 in 2017, while the average individual premium in ACA-compliant plans was $427; short-term plans included an average deductible of $4,744 (covering a partial-year), while ACA-compliant plans included annual deductibles averaging $4,400.

For these reasons, we do not believe that the empirical demand for short-term health insurance plans is a useful analogue to the resetting deductible policies proposed in this paper. Instead, we next turn to a model of individual demand for health insurance to understand the value of such policies.

3 Two period model of deductible timespans

To understand the mechanisms through which the time aggregation of a deductible can affect individual welfare, we develop a two-period model of decision-making with uncertainty over medical expenditures and insurance to protect against this uncertainty. Each period, which is meant to capture a six month timespan, a risk-averse individual is subject to health expenditure risk. Individuals are ex-ante homogeneous, thus abstracting from adverse selection concerns. Prior to the realization of shocks in the first period, individuals choose whether to purchase an annual insurance policy with a "standard" deductible spanning both periods (the standard year-long deductible) or an annual policy with a "resetting" deductible that spans one period (six months) before resetting. The model incorporates four main mechanisms that may affect an individual's preference over the two deductibles: (1) borrowing costs, (2) ex-post moral hazard, (3) mid-year exogenous contract switching, and (4) strategic claim delay. We first provide a simple illustrative model with binary health shocks, and then detail the full model, including the preference structure, health risk and insurance contracts, budget constraint, and the full individual problem. Section 5 provides further extensions to the model.

3.1 Illustrative model with binary shocks

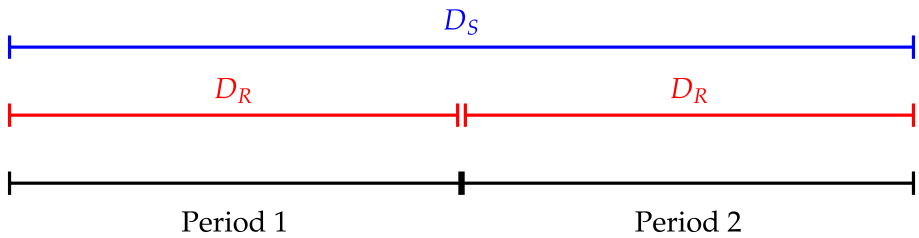
To illustrate the concept of time aggregation in health insurance deductibles, we begin with a simplified version of our model with a binary health shock and without moral hazard, mid-year contract switching, or claim delay. Assume an independent large binary health expenditure shock L that occurs with probability $\pi > 0$ in each period.[12] To protect against this risk, an individual purchases an insurance policy that spans two periods of the form (P, D_i) with per-period premiums P and a deductible $D_i < L$ where $i = S$ is a standard deductible policy in which the deductible D_S spans two periods, while $i = R$ is a resetting deductible policy in which the deductible D_R resets after each period.[13] Figure 1 depicts the length of time over which a deductible spans: the deductible that does not reset (D_S) spans both periods (blue, top line), while the deductible that resets (D_R) only spans one period (red, middle lines).

In order to isolate the effect of the resetting deductible policy on individual behavior and welfare, we hold the premium P constant and assign the same actuarial value to each policy (P, D_S) and (P, D_R). Thus, for a given standard deductible of size D_S, the size of the resetting deductible D_R must adjust to maintain the same actuarial value. Because the binary loss L is larger than both deductibles and independent over time, this means that

[12] While this binary shock process is a simplification (and we relax it later), it has also been used in many other papers on similar topics, e.g., Ericson and Sydnor (2018) and Cohen and Einav (2007).

[13] We assume that D_R is constant across the two periods; an interesting extension would be to consider increasing deductibles (see Li, Liu and Yeh (2007) for a related exercise in automobile insurance).

Figure 1: Deductible timespan schematic



Notes: Figure depicts the length of time over which a deductible applies and resets over the course of the two periods. D_R in red is the resetting deductible policy in which the deductible resets after each period, while D_S in blue is the standard deductible policy in which the deductible resets after two periods.

the expected insurance payouts over the two periods must be equivalent for both policies. Assuming no moral hazard or other modifications to the shock and payout structures (which we will incorporate in the next subsections), it must be the case that:

$$\underbrace{2\pi(L - D_R)}_{\text{Expected payout, reset policy}} = \underbrace{\pi^2(2L - D_S) + 2\pi(1-\pi)(L - D_S)}_{\text{Expected payout, standard policy}}$$

Rearranging this equation gives a relationship between the two deductibles of:

$$D_R = \frac{2-\pi}{2} D_S \tag{1}$$

There are two features of this equation of note. First, the resetting deductible is always smaller than the standard deductible. As we will show quantitatively, if individuals are liquidity constrained then they will value this smaller deductible despite its resetting nature because it corresponds to smaller immediate out-of-pocket costs.[14] Second, despite the fact that the *timespan* of the resetting deductible is half that of the standard deductible, the *size* of the resetting deductible is greater than half that of the standard deductible.[15]

[14] In fact, it can be shown analytically (through a Jensen's inequality argument) in this binary case that individuals who cannot borrow or save will strictly prefer the resetting deductible policy.

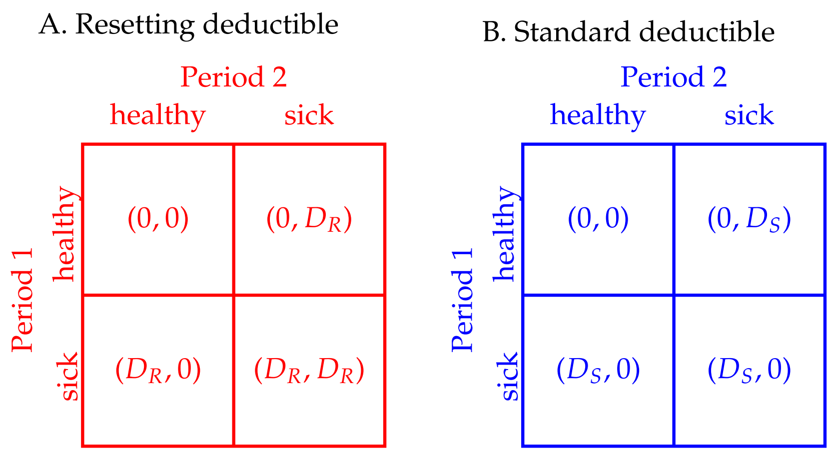
[15] To see why, rewrite the expected insurer payout as:

$$\pi^2(2L - 2D_R) + 2\pi(1-\pi)(L - D_R) = \pi^2(2L - D_S) + 2\pi(1-\pi)(L - D_S)$$

If $D_R = .5D_S$ then the insurer's losses in the $2\pi(1-\pi)$ states of the world would be too large in the resetting deductible case. If $D_R = D_S$ then the insurer's losses would be too small in the π^2 states of the world in the standard deductible case. This is analogous to the result in Cohen (2006) for aggregate versus per-loss deductibles.

As Figure 2 shows, this implies that the worst-case scenario in which an individual receives a health shock in both periods (the bottom-right corner of each schematic) results in higher total out-of-pocket costs for the resetting deductible policy (equal to $D_R + D_R$) than the standard deductible policy (equal to D_S). If individuals heavily value insurance against this worst-case scenario, then they may value the standard deductible more than the resetting deductible. These two effects – liquidity versus insurance – are further explored in the full model below, along with additional mechanisms that affect the value of different deductible timespans.

Figure 2: Out-of-pocket expenses for resetting and standard deductible policies



Notes: Figure depicts out-of-pocket expenses in the brackets for each cell under the resetting deductible policy (red) and the standard deductible policy (blue) when there is a binary health shock ("healthy" vs. "sick"). The first value in the brackets is the out-of-pocket expense in Period 1 and the second value is the out-of-pocket expense in Period 2.

3.2 Full model

We now characterize the full model, which incorporates a continuous shock distribution and allows for moral hazard, contract switching, and strategic delay.

3.2.1 Preferences

Individuals choose non-medical consumption c, medical consumption m, and savings a to solve a dynamic problem that maximizes their expected utility over two (six month) periods. Specifically, we use the utility function in Einav et al. (2013) in which non-medical consumption is the numeraire good and there are decreasing returns to medical consumption above a medical loss L, so that per-period utility is:

$$U(c, m-L) = U\left(c + m - L - \frac{1}{2w}(m-L)^2\right)$$

With this utility function, individuals will always choose $m \geq L$ because at any $m < L$, the marginal utility of an extra unit of m is greater than the marginal utility of an extra unit of c. Thus we interpret L as necessary expenditures and any $m > L$ as additional medical care that arises through moral hazard. The severity of moral hazard is dictated by the $w \geq 0$ parameter, and nests the case of no moral hazard ($w = 0$) or positive levels of moral hazard ($w > 0$). Additional medical consumption ($m > L$) arises when individuals do not have to pay the full price of medical care at the time of purchase. When individuals are fully insured such that an extra dollar of medical consumption m does not impact c, then the first order conditions imply that optimal medical consumption is $m = L + w$ (including when $L = 0$). On the other hand, if individuals must fully pay for medical consumption then they derive higher utility from spending the marginal dollar beyond L on non-medical consumption c than m due to the decreasing return to medical consumption beyond L. In that case, $m = L$. The interpretation of w, then, is the extra medical consumption due to moral hazard.

The implication of this form of moral hazard is that, *ex-post*, individuals value over-consumption of medical goods due to insurance coverage, but since the cost of this extra medical consumption feeds back into their cost of insurance (either through an increase in premium, or, as we will assume below, through an increase in the size of deductibles), *ex-ante* they do not value the over-consumption and thus prefer to minimize moral hazard. Different time aggregations of deductibles may exacerbate or hinder moral hazard, as the change in non-linearity of the contract affects if and when individuals pay full price for health care.

3.2.2 Health risk and the evolution of health spending

An individual is subject to health shocks L_1 and L_2 in the first and second period, respectively, that evolve stochastically with joint distribution $f(L_1, L_2)$. We assume all individuals have the same underlying health shock distribution.

We allow for two forces that make health *spending* endogenous insofar as it may be greater than that necessitated by the health shock and it may not occur at the same moment as the health shock. The first force, introduced above, is (ex-post) moral hazard. This type of moral hazard arises when individuals do not have to pay the full price of medical care at the time of the care. We assume that individuals only respond to spot prices, not expected end-of-year prices, and thus only over-consume once they have surpassed the deductible. While a fully rational individual would respond to expected end-of-year prices, we shut down this channel for computational tractability when we calibrate the model, and because other work shows that it is likely a more reasonable approximation to reality (Brot-Goldberg et al., 2017).

The second force, which we call "claim delay", allows individuals to delay the timing of treatment (and therefore spending and claiming) of health shocks. One prominent example of this distinction is in dental care, where procedures such as fillings can be performed many months after the advent of the cavity "shock" (Cabral, 2017), but it also applies to many other medical procedures (e.g., hip replacements). Since health insurance policies largely operate on the timing of health *care* and not the health *shock*, individuals may find it financially beneficial to delay care for certain shocks. To formalize this idea, we allow a fraction q_d of health shocks to be delayable by one period, to capture the notion that some shocks must be cared for immediately (e.g., emergencies) while others can be delayed without consequence to the next period.

3.2.3 Health insurance contracts and contract switching

We now characterize the two health insurance contracts under the full model, which includes moral hazard, strategic claim delay, and exogenous contract switching.

At the beginning of the year, individuals choose between two potential insurance contracts that have the same per-period premium, the same actuarial value, and a deductible that must be met before insurance pays for health care. The distinction between the two policies is the time over which the deductible resets: the standard deductible policy consists of a deductible that spans the full year (two periods), while a resetting deductible policy consists of a deductible that resets each period and thus spans only one period (i.e., six months) at a time. Because these two policies have the same actuarial value and same premium, the timespan over which the deductible resets means that the *size* of the deductible will also vary over the two policies.

Health insurance deductibles not only span a year, but they almost always span a *calendar* year as opposed to a year from the signing of the insurance contract.[16] This discrepancy may distort the value that individuals place on different insurance policies if mid-year job changes or other life events that are orthogonal to health cause them to abruptly change their health insurance mid-year. To formalize this idea, we assume a fraction q_m of individuals abruptly cancel their policy after the first period (i.e., mid-year) and begin a new policy in the second period, with the same deductible structure and same end-date. When this occurs, individuals must sign a new insurance contract with the same deductible end-of-calendar-year end dates, and the same deductible sizes, but without the stored health care spending from the first period that had previously gone towards meeting the deductible. Effectively, this means that individuals who have large losses in both periods would have to pay the (higher) deductible *twice* under the standard deductible policy. This feature makes insurance contracts with more time-aggregated deductibles less valuable as the risk of mid-year contract switching increases.

The insurer takes into account the extra and time-varying medical consumption brought about by moral hazard, delay, and contract switching and solves for the standard and resetting deductible sizes in order to break even. The resulting relationship between the resetting and standard deductible sizes is complex, but two features are intuitive. First, as q_d increases, D_R grows closer to D_S, because the ability to delay and thus bunch care in fewer periods means that the size of the resetting deductible must increase. Second, as

[16]Some annual health plans span a fiscal or academic year instead of a calendar year, but the discrepancy between a year at contract signing and a pre-specified year remains.

q_m increases, the size of the standard deductible decreases toward the size of the resetting deductible, because the higher the probability that one must switch contracts mid-year, the higher the probability a standard deductible "resets," which is the defining characteristic of the resetting deductible.[17] The moral hazard effect on deductible size is more nuanced, and we return to it in our quantitative results in Section 4.

3.2.4 Budget constraint

An important feature of individual welfare in a dynamic setting with risk aversion is the ability to smooth consumption over time. As we quantify in the next section, shorter time aggregation of deductibles can help smooth consumption, but the primary smoothing mechanism is through saving and borrowing. We allow for saving and borrowing to satisfy the budget constraint:

$$a_2 = \begin{cases} R_s(a_1 + Y - P - c_1 - oop_1) & \text{if} \quad a_1 + Y - P - c_1 - oop_1 \geq 0 \\ R_b(a_1 + Y - P - c_1 - oop_1) & \text{if} \quad a_1 + Y - P - c_1 - oop_1 < 0 \end{cases}$$

$$\text{subject to} \quad a_2 \geq -\left[Y - P - \max(oop_2)\right]$$

where Y and P are per-period income and premiums, c_1 is consumption in the first period, oop_t is out-of-pocket medical expenditures in each period t, and a_t are assets in each period. The budget constraint allows for borrowing up to the amount that they would be able to pay back with certainty (i.e., income net of the premium and maximum possible out-of-pocket expenditure) and allows for different interest rates for savings (R_s) and borrowing (R_b). This formulation nests costless saving and borrowing ($R_b = R_s = 1$) as well as borrowing costs ($R_b > R_s$) and an extreme form of liquidity constraints in which individuals are "hand-to-mouth" in that they neither save nor borrow ($R_b = \infty$ and $R_s = 0$).

[17] In practice, it is not obvious that health insurers appropriately adjust their cost estimates for mid-year contract switching, as Ericson, Geissler and Lubin (2018) points out for risk adjusters.

3.2.5 Individual problem

Given the above ingredients of the model, an individual solves the problem that proceeds in three steps. At time zero (before the health shock is revealed in the first period), the individual solves:

$$\max_{D_i \in \{D_R, D_S\}} V_0(a_1, Y) = E_{f(L_1,L_2)} V_1(a_1, Y, L_1 | D_i) \tag{2}$$

where V_1 is the solution to the following problem in the first period:

$$\max_{c_1, m_1, a_2} V_1(a_1, Y, L_1 | D_i) = u(c_1, m_1 - L_1) + \beta E_{f(L_2|L_1)} V_2(a_2, Y, L_1, L_2 | D_i) \tag{3}$$

and V_2 is the solution to the following problem in the second period:

$$\max_{c_2, m_2} V_2(a_2, Y, L_1, L_2 | D_i) = U(c_2, m_2 - L_2) \tag{4}$$

and each of the maximization problems are subject to the budget constraint and the law of motion of deductible spending. The state space consists of assets in each period, as well as the health shocks and insurance contract in the first and second periods. The individual first chooses an insurance contract, and then given the insurance contract, assets, and health shock in a period, decides how much to consume and thus how much to save or borrow.

3.2.6 Willingness to pay for insurance contracts

To measure the value to individuals of the standard versus resetting deductible policies, we calculate certainty equivalence between the two policies, defined as the amount of per-period income an individual would be willing to pay (in each period) for the resetting deductible to be indifferent between the standard deductible and the resetting deductible. Specifically, we calculate Z to solve:

$$E_{f(L_1,L_2)} V_0(a_1, Y | D_S) = E_{f(L_1,L_2)} V_0(a_1, Y - Z | D_R) \tag{5}$$

A positive value of Z signifies that the individual prefers the resetting deductible over the standard deductible, while a negative value of Z signifies that they prefer the standard deductible.

4 Calibrating the willingness to pay for resetting deductibles

We next calibrate the model and report our willingness-to-pay results for a resetting deductible under various scenarios. We use claims data from the Truven Marketscan database to characterize the health shock distribution, and calibrate the remaining model parameters using standard values from the literature. We then use the parameterized model to characterize the role of liquidity, moral hazard, contract switching, and claim delay in isolation before reporting overall estimates for a representative consumer for which all four mechanisms are at play. Section 5 extends the model in several ways, including alternative health shock distributions, shorter periods, and also extends the policy space to "three-armed" policies with deductibles, coinsurance, and out-of-pocket maxima.

4.1 Marketscan health care claims data

An important input into the model is the joint distribution of health care claims over time. We use claims data from the Truven Marketscan database, which contains individual health care claims from a host of large employers and private health insurers in the United States. Our sample consists of over 16 million individuals aged 26-64 who are continuously enrolled in a health plan for the entirety of 2013 and not enrolled in a capitation plan. We calculate their total health care spending in the first six months and second six months of the year, corresponding to the first and second periods of the model, respectively.[18] Total health care spending is defined as the sum of inpatient services, outpatient services, and outpatient pharmaceutical claims, and we use this spending as the health shock distribution $f(L_1, L_2)$ in the model.[19]

[18] The Marketscan database includes both service dates and paid dates; we use service dates to assign the period of spending.

[19] This is somewhat coarse, as these expenditures may reflect not only health expenditure *needs* but also moral hazard and/or timing manipulation of health expenditures.

Table 1: Summary statistics of the distribution of health care expenditures

	Health care spending ($)	
	First half of year	Second half of year
Mean	2,969	3,313
Standard deviation	12,372	13,818
Percent with zero expenditure	0.210	0.202
25th percentile	75	80
Median	550	587
75th percentile	1,992	2,179
90th percentile	5,963	6,670
Mean number of claims	20	21
Correlation of spending between periods	0.413	
Biannual mean	3,141	
Biannual standard deviation	11,016	
Number of enrollees	16,351,864	

Notes: Table reports biannual (six month) total health care expenditures (unweighted, in 2017 dollars). Data are 2013 health care claims from the Truven Marketplace database, restricted to individuals 26-64 who are not in a capitated plan and do not switch plans over the course of 2013.

Table 1 reports summary statistics of the distribution of per-period (i.e., six month) health care expenses in our sample, inflated to 2017 dollars. Average health expenditures over the first six months total $2,969, with standard deviation $12,372, though the distribution is highly skewed as shown by the median of $550. The average number of health care claims within the first six months is 20, though a significant fraction of individuals (around 20%) have zero expenditures in a given period. There is also persistence in expenditures over time: the correlation over the two periods of health care expenditures is 0.41. We incorporate this data into our model by constructing an empirical joint distribution of health expenditures over the two periods by discretizing health expenditures into 30 bins of equal probability.

4.2 Calibrated parameters

Table 2 reports our calibrated parameter values and their source. We set the interest rate for savings to 0% (or $R_s = 1.0$) and the discount factor to 1.0 (or $\beta = 1$) to isolate our main mechanisms of interest. Following much of the health literature, we use CARA preferences where $U(x) = 1 - \exp(-\alpha x)$. We set the premium for health insurance to the average benchmark silver plan in the ACA exchanges in 2017, which was $359 monthly, or $2,154 biannually (Kaiser Family Foundation, 2017*b*). We set initial assets to $0 and annual income to $30,150 (250% of the Federal Poverty Level in 2017), which was the cut-off for cost-sharing reductions (CSRs) in the health insurance marketplace (though with CARA utility, there are no income effects). We thus view our calibration as pertaining to individuals who are lower income but do not qualify for CSRs.

Table 2: Calibrated parameters

Symbol	Parameter definition	Value	Source
t	Length of a period	6 mo.	
α	CARA coefficient	0.0004	Handel (2013)
β	Discount factor	1.0	
R_s	Interest rate, saving	1.0	
R_b	Interest rate, borrowing	{1.0; 1.015; 1.095; 2.236}	Credit card 20% APR; Payday loan rates (Ericson and Sydnor, 2018)
w	Moral hazard parameter	$896	30% of average biannual health shock (Einav et al., 2013)
q_m	Prob. mid-year job change	0.08	Bjelland et al. (2011)
q_d	Prob. shock is delayable	0.40	Cabral (2017)
P	Premium	$2,154	Average second lowest-cost silver plan premium (Kaiser Family Foundation, 2017*b*)
Y	Income	$15,075	250% Federal Poverty Level in 2017
a_1	Initial assets	$0	

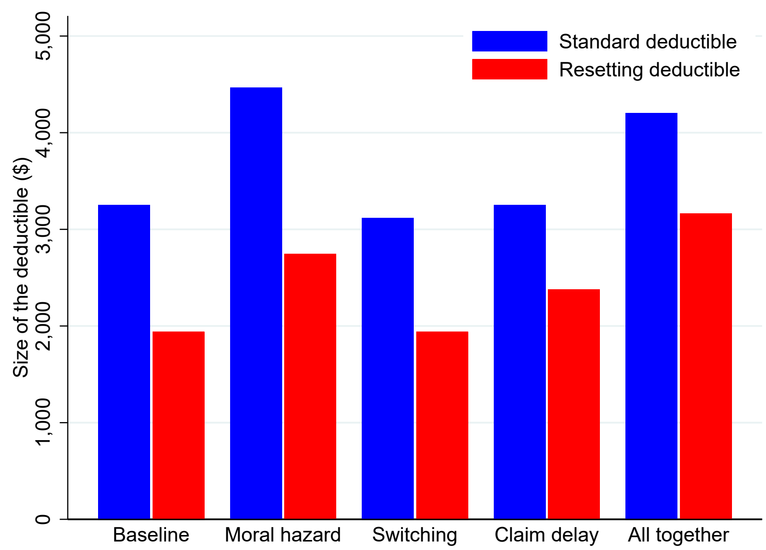
Notes: Biannual (six month) rates shown. The four values of R_b correspond to different specifications in Figure 4.

We supplement these parameters with parameters that dictate the additional forces described in Section 3. To capture the fact that borrowing can be expensive, we set different interest rates for borrowing to approximate low borrowing costs (3% annual interest rate), borrowing from a credit card at 20% APR, and payday loan rates of 400% APR (Ericson and Sydnor, 2018), and convert these annual rate to biannual rates. To capture overconsumption of medical care that arises with insurance, we convert the moral hazard parameter estimated in Einav et al. (2013) of 30% of annual health shocks into a biannual value of $896. To capture the fact that some workers switch jobs – and therefore health plans – in the middle of the year, we use the estimate of 4% quarterly employment-to-employment job flows from Bjelland et al. (2011), converted to a biannual probability of 8%. Finally, we allow a fraction of shocks to be delayable, and set the probability of delayability to 40% from Cabral (2017).

4.3 Willingness to pay: the role of liquidity

We now use the calibrated parameters in Table 2 to estimate the willingness to pay for the resetting deductible over the standard deductible, as defined in Section 3.2. We begin by analyzing the role of liquidity. To do this, we shut down moral hazard ($w = 0$), contract switching ($q_m = 0$), and care delay ($q_d = 0$), and vary R_b. The sizes of the deductibles in this case are given in the leftmost blue and red bars in Figure 3, and correspond to a standard deductible of $3,252 (which is very similar to the average deductible in a silver plan in the 2017 federal marketplace) and a resetting deductible that is 60% the size of the standard deductible.

Figure 3: Size of deductible policies under different environments

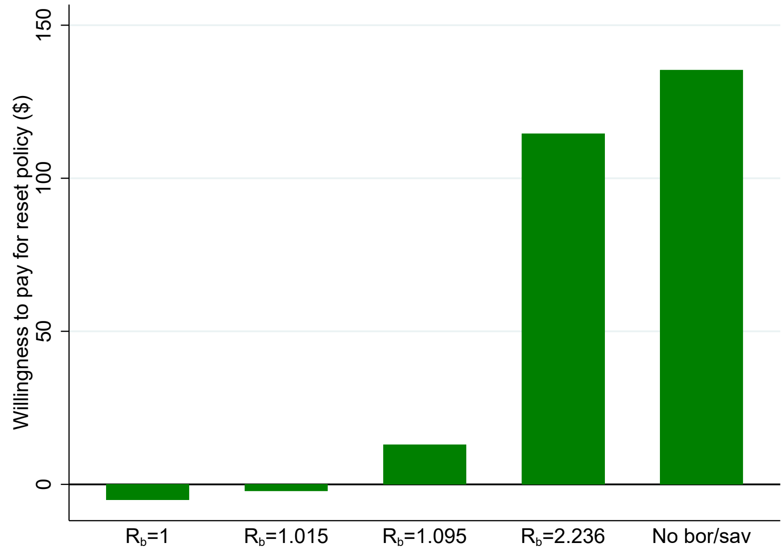


Notes: Figure presents the size of the standard (annual) deductible D_S in blue and the size of the resetting (biannual) deductible D_R in red, under four scenarios: from left to right, (1) the baseline scenario with no moral hazard ($w = 0$), no contract switching ($q_m = 0$), and no claim delay (q_d), (2) the scenario with only moral hazard, (3) the scenario with only contract switching, (3) the scenario with only claim delay, and (4) the scenario with all three of moral hazard, switching, and delay.

Using this relationship, we examine the willingness to pay for the resetting deductible under different liquidity environments. We start with the case in which individuals cannot save or borrow, which corresponds to $R_S = 0$ and $R_B = \infty$. In this case, the per-period willingness to pay for the resetting deductible is $Z = \$135$, or 6.3% of the premium, as the right-most bar in Figure 4 shows.

At the other extreme is the ability to save and borrow with no interest ($R_S = R_B =$

Figure 4: Welfare gain of a resetting deductible policy under different liquidity assumptions



Notes: Figure presents Z, the per-period willingness-to-pay for a reset policy, under five liquidity cases: from left to right, (1) benchmark saving and borrowing ($R_b = R_s = 1.0$), (2) low borrowing costs ($R_b = 1.015$), (3) credit card borrowing costs ($R_b = 1.095$), (4) payday loan borrowing costs ($R_b = 2.236$), which in practice is equivalent to saving but no borrowing, and (5) no borrowing or savings ($R_s = 0$ and $R_b = \infty$) using the other calibrated parameters in Table 2.

1.0). In this case, the opposite result emerges: individuals who can easily smooth slightly prefer the standard deductible. The left-most bar of Figure 4 shows that they value the resetting deductible at only -$5 over the standard deductible.

The reason that borrowing constrained individuals prefer the resetting deductible while unconstrained individuals prefer the standard policy relates directly to the trade-off between insurance and liquidity. The standard deductible provides better insurance against the worst-case state of the world (e.g., large shocks in both periods, where $D_S < 2D_R$). On the other hand, the resetting deductible provides an alternative form of liquidity to individuals by, in essence, breaking up the deductibles into smaller but potentially more frequent payments. Unconstrained individuals can transfer resources between states of the world on their own, and thus value the better insurance of the standard deductible, while constrained individuals rely on the insurance policy to smooth across states of the world, and thus value the less "lumpy" resetting deductible at the cost of slightly worse insurance. This is reminiscent to the result in Ericson and Sydnor (2018) that liquidity constrained individuals prefer seemingly dominated plans with lower deductibles and higher (and more frequent) premium payments.

To further understand this feature that resetting deductibles provide alternative liquidity, take the extreme case of 100% probability of a very large shock in both periods that surpasses both deductibles (note that this implies $D_R = D_S/2$). While unconstrained individuals are indifferent between the two policies (because they are actuarially equivalent and it is costless to save and borrow), constrained individuals strongly prefer the reset policy (beyond any insurance it provides, since in this case there is no uncertainty) because it provides smoothing of health costs across time periods.

We next consider the case of individuals who can save and borrow, but at higher borrowing costs. Specifically, we now allow individuals to save at rate $R_s = 1.0$ and borrow at rate $1.0 < R_b < \infty$, where $R_b > R_s$ captures that it is more costly to borrow than it is beneficial to save. The middle three specifications in Figure 4 report willingness-to-pay estimates for low borrowing costs ($R_b = 1.015$, equivalent to a 3% annual interest rate), higher borrowing costs ($R_b = 1.095$), which correspond to average credit card borrowing rates at 20% APR (Ericson and Sydnor, 2018), and very high borrowing costs ($R_b = 2.236$), which correspond to payday loan rates at 400% APR. As it becomes more expensive to borrow, the willingness to pay for a resetting deductible policy increases and becomes positive. At credit card rates, the per-period willingness to pay for the resetting deductible policy is \$13 and at payday loan rates is \$115.

In sum, this baseline model shows that preferences over the deductible timespan depends on the extent of liquidity constraints. For individuals who are not constrained, standard (more time-aggregated) deductible timespans provides better insurance, while resetting (less time-aggregated) deductibles are valuable to liquidity constrained individuals because they are smaller in size and thus provide implicit smoothing. In Section 5 we show that these results also hold for alternative shock distributions, for shorter time periods, and under three-armed policies. We next turn to the role of moral hazard and the differential ability of standard and resetting deductible policies to combat moral hazard problems.

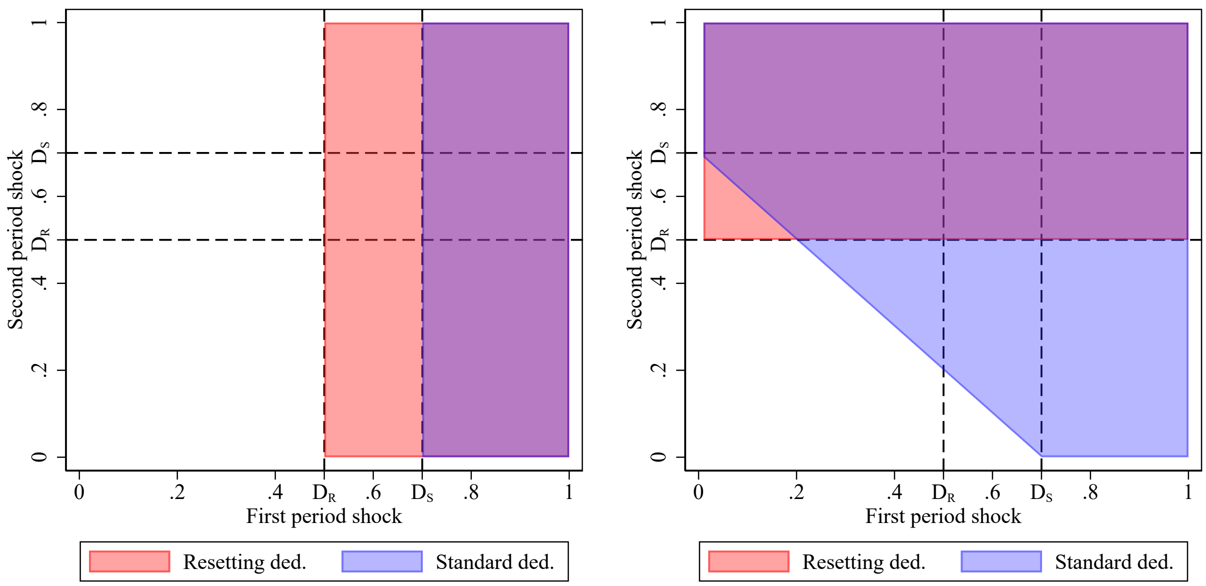
4.4 Willingness to pay: the role of moral hazard

We next explore the willingness to pay for the resetting deductible policy in an environment with moral hazard, as well as the differential effect of the two deductible policies in curbing moral hazard. As described in Section 3, moral hazard arises when individuals value medical consumption beyond the health shock L, but to a lesser degree than non-medical consumption, and thus only over-consume medical care if they are not paying the full price of medical consumption. However, the cost of this over-consumption feeds back into their *ex-ante* insurance costs in the form of higher premiums or higher deductibles (we model the latter in this paper). Because individuals do not value this over-consumption ex-ante, moral hazard is welfare decreasing.

Moral hazard manifests differently in the standard and resetting deductible policies. Figure 5 shows the region of the joint distribution of health shocks in which overconsumption occurs under the resetting and standard deductible policies. Panel (a) shows overconsumption in the first period and Panel (b) shows overconsumption in the second period. In each panel, the x-axis is the first period health shock and the y-axis is the second period health shock, both over a normalized health shock distribution from 0 to 1. D_R and D_S denote example resetting and standard deductible sizes, respectively, and red shading indicates areas in which overconsumption occurs under the resetting deductible policy and blue shading indicates areas in which overconsumption occurs under the standard deductible policy. These figures show that in the first period, there is more extra medical consumption under the resetting deductible, because both shocks that are above D_S induce overconsumption but also shocks between D_R and D_S induce overconsumption. In the second period, the same amount of overconsumption occurs under the resetting deductible policy, while overconsumption under the standard deductible policy covers a much wider area of the joint distribution. In total, which policy generates more overconsumption depends on the empirical joint distribution of health shocks.

Our empirical joint distribution of health shocks suggests that overconsumption is almost exactly the same size under the two policies: individuals consume \$351 more under the standard deductible policy and \$358 more under the resetting deductible policy (see

Figure 5: Overconsumption due to moral hazard, stylized example



(a) First period overconsumption (b) Second period overconsumption

Notes: Figure depicts regions of the first period (x-axis) by second period (y-axis) health shock space in which extra medical consumption occurs due to moral hazard for a stylized health distribution and deductible contracts. D_R and D_S are hypothetical deductible sizes. Red shading indicates areas in which overconsumption occurs under the resetting deductible policy and blue shading indicates areas in which overconsumption occurs under the standard deductible policy. Panel (a) graphs the region in which overconsumption occurs in the first period and panel (b) graphs the region in which overconsumption occurs in the second period.

Appendix Figure 1). While this is the case for our empirical distribution, Section 5 shows that the persistence of the health shock distribution can play an important role for the relative overconsumption of the two policies. In particular, lower persistence increases extra consumption under the standard deductible policy, and vice versa for higher persistence.

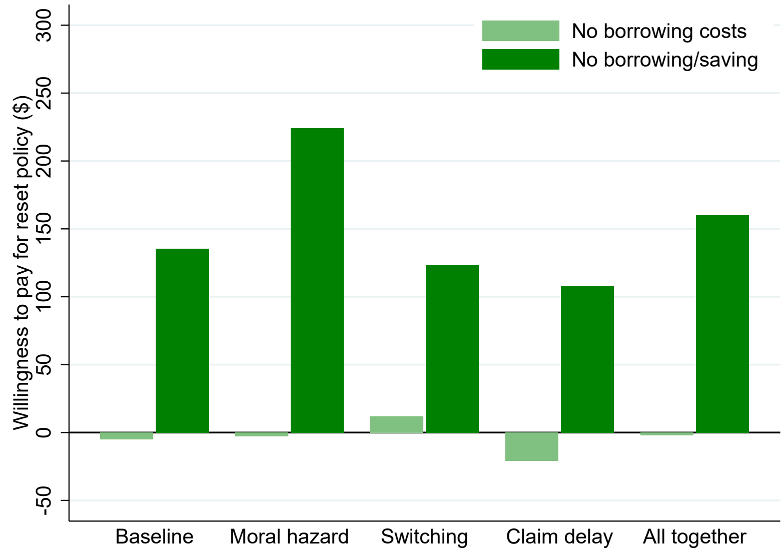
Consumers ultimately must pay for this additional medical consumption, and because we assume a constant premium P across all specifications, the deductible sizes adjust in response. The second set of bars in Figure 3 shows that the standard deductible rises from \$3,252 without moral hazard to \$4,467 with moral hazard, and the resetting deductible increases from \$1,943 without moral hazard to \$2,748 with moral hazard (both around a 40% increase).

Figure 6 reports the willingness to pay estimates for the baseline case with no moral hazard in the first set of bars (with no borrowing costs vs no borrowing or saving) on the left and with moral hazard in the second set of bars (again with no borrowing costs vs no borrowing or saving). With no borrowing costs, the addition of moral hazard changes the per-period willingness-to-pay for the resetting deductible policy from -\$5 to -\$3, and adding in the inability transfer funds across time increases it further to \$224. This corresponds to a willingness to pay of an additional 10.4% in premiums. Thus, resetting deductible policies can be even more valuable as a tool to relieve borrowing constraints under moral hazard environments.

4.5 Willingness to pay: the role of contract switching

The next environment we consider is one in which individuals change health insurance plans mid-way through the year due to events orthogonal to their health, such as job changes. As discussed in Section 3, we model this as an exogenous probability of the same contract restarting at the end of the first period. This mechanically has no effect on the resetting deductible policy, but for the standard deductible policy this effectively induces a chance that the deductible resets after the first period, but at the size of the standard deductible. The third set of bars in Figure 3 shows the sizes of the deductibles when there is an 8% chance of mid-year plan switching (as estimated in Bjelland et al.

Figure 6: Welfare gain of a resetting deductible policy, by environment



Notes: Figure presents Z, the willingness to pay for the resetting deductible policy, under five environments and within each environment, costless borrowing (light green) and no borrowing or saving (dark green). From left to right, the sets of bars are (1) baseline (i.e., no moral hazard, contract switching, or claim delay), (2) moral hazard only, (3) contract switching only, (4) claim delay only, and (5) all mechanisms in (2)-(4). Other calibrated parameters are in Table 2.

(2011)), and confirms that the resetting deductible is the same size as in the baseline case. The standard deductible is slightly smaller than the baseline standard deductible ($3,119 instead of $3,252) because contract switches makes some individuals pay the standard deductible twice, and to remain actuarially equivalent, the size must adjust downward.[20]

The third set of bars in Figure 6 shows that when borrowing is costless, the willingness to pay for the resetting deductible policy becomes positive. This is because the standard deductible policy is now more similar in nature to the resetting deductible policy since it can unexpectedly reset. In the case of no borrowing or saving, the willingness to pay for the resetting deductible policy is slightly less positive than the baseline case because the standard deductible is slightly smaller in size, which reduces the liquidity value of the resetting deductible.

There are two caveats to these results. First, our calibrated probability of contract switching is quite low at 8% biannually. If there was a 50% probability of switching contracts, individuals with no borrowing costs would more strongly prefer the resetting

[20] At the limit of 100% switching, $D_S = D_R$.

deductible at a willingness-to-pay of $32 per period. Second, it is unclear whether insurance companies account for the fact that some individuals switch plans mid-year into their pricing (Ericson, Geissler and Lubin, 2018). If insurers do not price in switching, the willingness to pay for the resetting deductible policy (with 8% switching) would increase to $45 for individuals with no borrowing costs and $166 for those who cannot borrow or save.

4.6 Willingness to pay: the role of strategic claim delay

The final environment we consider is one in which some health shocks do not necessarily require immediate medical care (e.g., dental care or some orthopedic surgeries). Since health insurance policies – and therefore deductible spending – depend on the timing of health *care*, not the health *shock*, individuals may find it financially beneficial to delay care for such shocks. For instance, in the resetting deductible case, it would be financially advantageous to bunch care into one period and only pay the deductible once. As discussed in Section 3, we model this phenomenon as a probability q_d of a shock being delayable, and we assume that individuals always delay shocks when presented with the option. In our two period model, this probability only applies to the first period, while all shocks must receive care in the second period.[21]

Because delay does not affect insurer payouts in the standard deductible policy relative to the baseline model, the standard deductible is equivalent to that of the baseline case. The resetting deductible, on the other hand, is slightly larger than that of the baseline case ($2,379 vs $1,943 in Figure 3) because the ability to shift expenditures to a later period raises the probability of only paying the resetting deductible once. To maintain actuarial equivalence, the size of the resetting deductible must therefore increase.

The willingness to pay for the resetting deductible policy for those with borrowing costs decreases in this environment compared to the baseline case, because as the size of

[21] This may not always be the optimal decision for individuals in more complex environments (e.g., with moral hazard) or for households that are not allowed to borrow or save, but we chose this assumption because (a) relaxing this assumption requires numerically solving for an equilibrium, which is computationally more taxing, (b) it is consistent with the simple nature of decision-making that we allow for with moral hazard issues, and (c) we believe the approximation is not far from reality.

the resetting deductible grows in response to delayability of care, the more the reset policy resembles the standard policy. Indeed, if all shocks are delayable then $D_R = D_S$ and the policies are almost equivalent. Thus, resetting deductibles do not curb this "timing" moral hazard, and in fact by increasing the size of the resetting deductible, the possibility of claim delay counteracts the beneficial liquidity effects of resetting deductibles.

4.7 Willingness to pay: putting it all together

The final set of main results in Figures 3 and 6 report the deductible sizes and willingness to pay for the resetting deductible policy in an environment in which all mechanisms (moral hazard, mid-year contract switching, and claim delay) are present. In this case, both deductibles are larger than the baseline case (predominantly due to moral hazard) but the standard deductible is slightly smaller than in the moral hazard case because mid-year contract switching exerts downward pressure it. On the other hand, the resetting deductible is slightly larger than in the moral hazard case because claim delay exerts upward pressure on it. Overall, the willingness to pay for the resetting deductible policy is similar to the baseline case under both costless borrowing and no borrowing or saving environments ($-2 and $160, respectively), in large part because the liquidity effect swamps other effects.

In sum, our results suggest that while resetting deductibles may have small or even negative welfare benefits under some environments (e.g., when individuals can strategically delay medical care), they may have relatively large welfare gains under other environments, such as for individuals with borrowing constraints.

5 Extensions

In this section, we explore extensions to the results in Section 4 along three main dimensions: first, allowing for different persistence in our health shock distribution; second, allowing for shorter periods for utility and health shocks; and third, allowing for a "three-armed" policy that incorporates a deductible as well as coinsurance and an out-of-pocket maximum. In all of these extensions we find similar qualitative results that liquidity constrained individuals would experience welfare gains from a resetting deductible policy.

5.1 Persistence of the health shock distribution

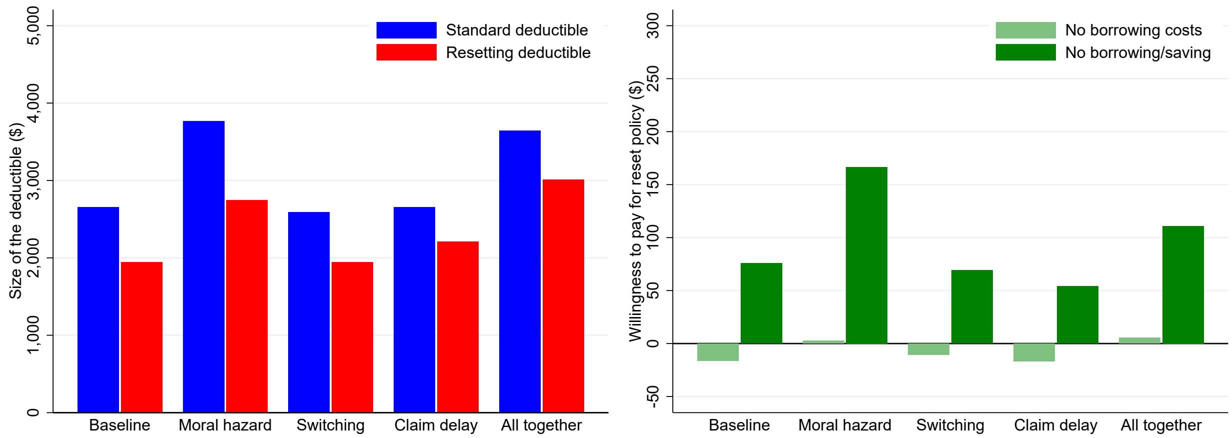
The willingness to pay for a resetting deductible policy may be particularly sensitive to the persistence of health shocks across the two periods. For example, it may impact the liquidity effects if persistence changes the relative sizes of the deductibles. It may also impact extra medical consumption from moral hazard if medical consumption is primarily concentrated among individuals who always incur large health shocks. To test how persistence affects the results, we modify our empirical health shock distribution in three ways: first, we make the empirical marginal distributions in the two periods independent; second, we make the distribution slightly less persistent but not quite independent by moving some of the mass away from the diagonals of our discretized empirical joint distribution and distribute the mass equally among all other parts of the joint distribution; third, we make the distribution slightly more persistent by adding mass to the diagonals in a similar but opposite fashion.[22]

Figure 7 shows the deductible sizes and willingness to pay for the resetting deductible policy for the case of independent health shocks. Panel (a) shows that the resetting deductible is unchanged compared to the empirical distribution, as expected, while the standard deductible is smaller in size across the specifications. This is because an independent distribution is less likely to generate large health shocks in both periods, which are more costly to the insurer because the deductible is only paid once. This lowers the deductible size in the independent distribution, and as a result the willingness to pay for the resetting deductible policy decreases across all of the environments (panel (b)). More generally, however, the same pattern exists: those with borrowing constraints prefer the resetting deductible policy, while those without borrowing costs slightly prefer the standard deductible policy.

Table 3 provides more details on the role of persistence in the case of moral hazard.

[22]Specifically, we redistribute 5% of the mass away from the diagonal in our less persistent specification and we redistribute 13% of the mass to the diagonal in our more persistent specification.

Figure 7: Deductibles and willingness to pay under independent shock distribution



(a) Deductible sizes

(b) Willingness to pay for resetting ded. policy

Notes: Left figure presents the size of the standard (annual) deductible D_S in blue and the size of the resetting (biannual) deductible D_R in red, under four scenarios: from left to right, (1) the baseline scenario with no moral hazard ($w = 0$), no contract switching ($q_m = 0$), and no claim delay (q_b), (2) the scenario with only moral hazard, (3) the scenario with only contract switching, (3) the scenario with only claim delay, and (4) the scenario with all three of moral hazard, switching, and delay. Right figure presents the willingness to pay for the resetting deductible policy for individuals who can costlessly borrow in light green and who cannot borrow in dark green for the same scenarios as in Panel (a).

Each row, which corresponds to the different levels of persistence as described above, reports the deductible sizes, extra medical consumption under the standard and resetting deductible policies, and the willingness to pay for the resetting deductible policy under the two main borrowing conditions. The standard deductible size increases with persistence, as the logic from above suggests. Overconsumption of medical care under the standard deductible policy decreases as the persistence of the health shock distribution increases. This stems from two mechanisms. First, a lower deductible is (mechanically) reached more frequently, triggering overconsumption. Second, more overconsumption will occur in the second period under an independent shock distribution than a persistent shock distribution because there are more instances in which an individual is under the deductible in the first period (and thus not overconsuming) and over the deductible in the second period.

The willingness to pay for the resetting deductible policy in an environment with moral hazard has little effect for individuals without borrowing constraints, but increases as the persistence of the health shock distribution increases for individuals with borrow-

Table 3: Sensitivity of results to health shock persistence under moral hazard

	Deductible size		Overconsumption		Willingness to pay	
Model description	D_S	D_R	Standard	Resetting	No bor. costs	No bor/sav
Independent	3769	2748	406	358	3	167
Less persistence	4385	2748	356	358	-2	217
Empirical	4467	2748	351	358	-3	224
More persistence	4673	2748	340	358	-5	244

Notes: Table presents deductible sizes, overconsumption due to moral hazard, and willingness to pay for the resetting deductible policy based on an environment with moral hazard and under different levels of persistence of the health shock distribution.

ing constraints. While overconsumption decreases in the standard deductible policy relative to the resetting deductible policy when shocks are persistent, individuals are willing to pay even more for the resetting policy because the standard deductible grows much larger in size and thus the standard deductible exhibits even worse liquidity features.

5.2 Extension to shorter periods

We next extend the model to shorter periods: instead of two six-month periods, we model period lengths of three months and two months.[23] Similar to the baseline model, utility is defined over the period and shocks occur at periodic frequencies, but the resetting deductible still spans six months and resets after six months and the standard deductible still spans 12 months (see Appendix Figure 2 for the modified schematic in the case of monthly periods). This extension may be important if health shocks are more accurately represented by shorter arrival rates or if the dynamics of utility or consumption are more appropriately captured at shorter frequencies rather than biannual frequencies (as in our baseline model) or annual frequencies (as in much of the health insurance literature and beyond).[24] We convert the premium and income level into equally divided periodic levels, and disaggregate the empirical health expenditure distribution to shorter periods. Table 4 reports willingness to pay (scaled to biannual amounts to be comparable to our

[23] Increasing the number of periods exponentially increases computational burden and hence we refrain from monthly periods. Additionally, we use a discretized grid of 10 health shocks; since our main results are very robust to this smaller health shock grid, we do not expect that this affects our results here.

[24] See Cronin (2019), who models monthly health and consumption dynamics, for an example of the exception to this.

main results) under our two main liquidity environments and without moral hazard, contract switching, or claim delay, and shows that the willingness to pay for the resetting deductible is very similar across period lengths.

Table 4: Willingness to pay for resetting deductible (biannualized), shorter periods

Model description	No bor. costs	No bor/sav
Two six-month periods	-5	140
Four three-month periods	-1	95
Six two-month periods	0	107

Notes: Table presents willingness to pay for the resetting deductible policy under no borrowing costs (first column) and no borrowing or saving (second column) for different period lengths. Premium and income are equally divided between periods to be the same annual amount as in the baseline case, and health shocks are disaggregated to the period length. The first row is slightly different from the baseline case because the health shock distribution is discretized to 10 points instead of 30 throughout the rest of the paper.

5.3 Three-armed policy

The final extension we consider is a policy that includes three cost-sharing "arms": a deductible arm, a coinsurance arm after the deductible in which the individual pays a percentage of the health care costs above the deductible, and a full insurance arm once an out-of-pocket maximum is reached, at which point the individual pays nothing.[25] In the "two-armed" policies we have considered thus far (a deductible arm and a full insurance arm), the deductible is equivalent to the out-of-pocket maximum. To investigate how the addition of a coinsurance arm affects our results, we return to the baseline two-period model and now characterize the policies as (P,D_i, c, M) with per-period premium P, deductible D_i where $i = S$ and $i = R$ are the standard deductible and resetting deductible, respectively, c is the coinsurance rate after the deductible, and M is the out-of-pocket maximum that spans the two periods.[26] We set $P = \$2,154$ as in the baseline model, $c = 0.2$,

[25] See Appendix Figure 3 for a schematic of the three-armed policy.

[26] In principle we could assume an out-of-pocket maximum for the standard policy that spans two periods and an out-of-pocket maximum for the resetting policy that spans one period to mimic the differences between the standard and resetting deductible. We chose to use a single out-of-pocket maximum for two reasons: first, distinct out-of-pocket maxima for each deductible adds an additional free parameter and it is not obvious how to pin it down, and second, using a single out-of-pocket maximum keeps the focus strictly on the time aggregation of deductibles.

and vary M. Table 5 shows the deductible sizes for the standard and resetting deductible in columns 1 and 2, respectively, and the willingness-to-pay estimates under no borrowing costs in column 3 and no borrowing or saving in column 4. Because of the additional coinsurance arm, the deductible sizes are much smaller than in this exercise, which leads to smaller willingness to pay estimates. Nevertheless, the pattern remains the same: individuals without the ability to borrow prefer shorter deductible spans, while those without borrowing costs prefer the standard deductible.

Table 5: Willingness to pay for resetting deductible, three-armed policy

			Willingness to pay	
Model description	D_S	D_R	No bor costs	No bor/sav
$M = 5,000$	2,482	1,516	-3	70
$M = 6,000$	2,211	1,312	-7	45
$M = 7,000$	2,002	1,177	-7	26

Notes: Table shows willingness to pay for a three-armed policy with a resetting deductible compared to a three-armed policy with a standard deductible, both with an annual out-of-pocket maximum as denoted in each row and a coinsurance rate of 20% after the deductible is reached.

6 Discussion and conclusions

This paper analyses the extent to which an unexplored feature of health insurance plans—the time aggregation of deductibles—affects the financial well-being of individuals. Specifically, we build and calibrate a dynamic model of within-year health care and consumption choice under uncertainty, and use it to calculate the willingness to pay for alternative deductible time aggregation policies. We show that, in lieu of an annual deductible, an actuarially-equivalent deductible that is smaller in size but resets after six months can generate welfare gains for liquidity constrained populations. On the other hand, resetting deductibles are inherently worse insurance for worst-case health shock scenarios. Thus, whether an individual prefers a resetting deductible policy depends in large part on the trade-off between risk-protection, liquidity, and to a smaller extent, moral hazard, mid-year contract switching, and the delayability of care.

Our model explores the effect of changing the timespan over which a deductible resets, but holds the timespan of the insurance contract itself fixed. A parallel literature finds large welfare gains of long-term health insurance contracts, which accrue by solving selection and reclassification risk issues (Ghili et al., 2020). While analyzing the selection issues raised by resetting deductibles would be an interesting extension, we abstract from these issues and instead focus on the higher-frequency issues of liquidity and moral hazard. Additionally, given the empirical reality of "policy churn" (Diamond et al., 2018), more work on the design of short-term health insurance would help inform policy. This study takes a first step by studying the disaggregation of a particular—and increasingly prominent—component of health insurance contracts.

Beyond health insurance, it is natural to ask how time aggregation may affect the value of other products or policies. For example, many government programs measure household income to determine eligibility, participation, benefits, and payments. Since income is often lumpy, one key component of this determination is the time span over which income is aggregated. Medicaid and SNAP programs typically assess eligibility by aggregating income over the previous month (Swartz et al., 2015), Social Security calculates retirement benefits by averaging the highest 35 years of income, and income taxes are calculated based on income over the calendar year. However, little is known about the consequences of adjusting these time windows. A fruitful next step is to investigate other contexts in which the aggregation of measures over time may matter for policy and welfare, including tax policy and income eligibility thresholds for social safety net programs.

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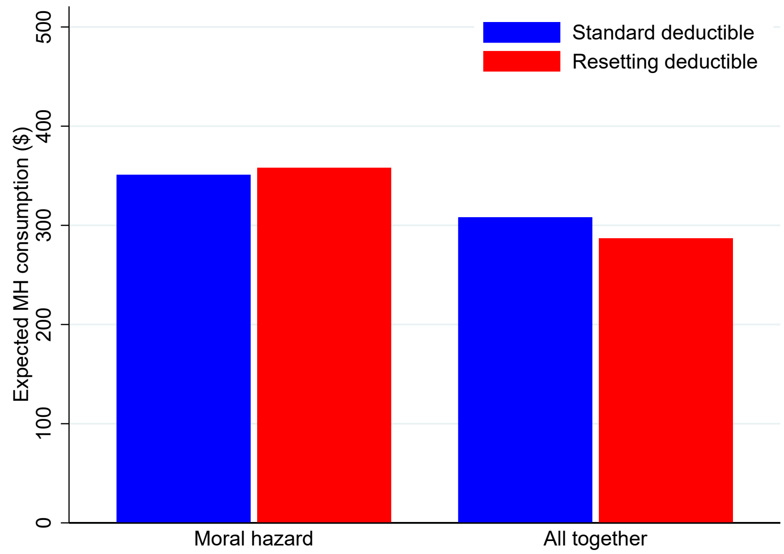
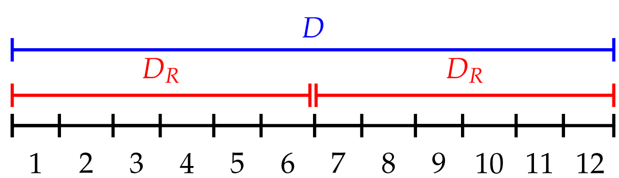
Appendix figures

Appendix Figure 1: Overconsumption due to moral hazard, by environment



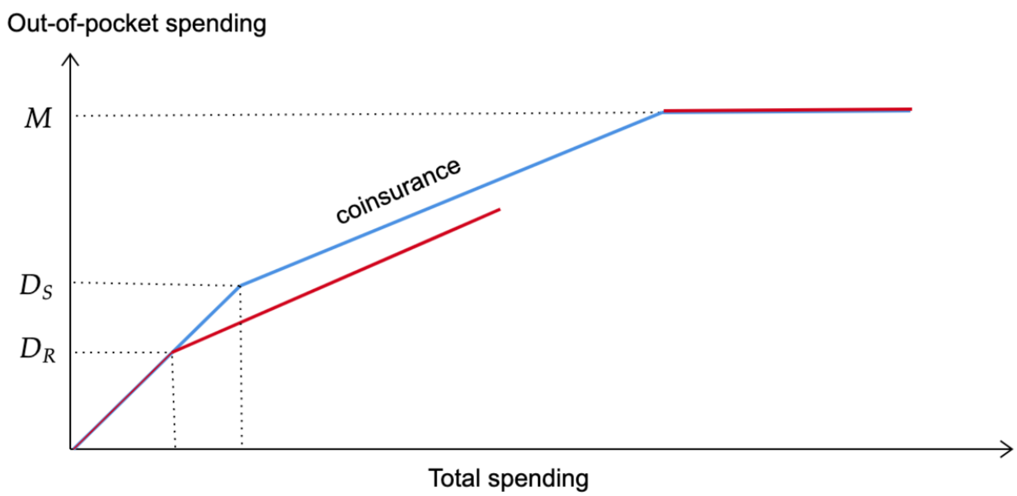
Notes: Figure presents the total extra medical consumption over the two periods due to moral hazard. The blue bars denote extra consumption under the standard deductible policy and red bars denote extra consumption under the resetting deductible policy. The bars on the left correspond to the environment with moral hazard only and the bars on the right correspond to the environment with moral hazard, contract switching, and claim delay.

Appendix Figure 2: Deductible timespan schematic, monthly periods



Notes: Figure depicts the length of time over which a deductible applies and resets. The black lines and numbers denote periods. D_R in red is the reset policy in which the deductible resets after six periods, while D_S in blue is the standard policy in which the deductible resets after twelve periods.

Appendix Figure 3: Three-armed policy schematic



Notes: Figure depicts the three-armed policy as described in Section 5.