Moral Hazard under Liquidity Constraints
PRELIMINARY DRAFT- DO NOT CIRCULATE *

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Abstract

Ex-post moral hazard has almost definitionally been interpreted as inefficient and undermining the value of insurance. We reexamine moral hazard under liquidity constraints by adapting standard models to incorporate hand-to-mouth individuals. For the liquidity constrained, insurance provides both a standard risk-protection benefit but also a financing benefit by spreading costs over time via premiums. We show that because of this liquidity effect, a component of insurance-induced spending is *efficient* moral hazard. Although price distortions from insurance will also lead to some inefficient moral hazard, the net welfare impact of moral hazard can be positive for the hand-to-mouth. We show how the efficient and inefficient components of moral hazard can be identified and quantified in intuitive graphical frameworks. In simulations we find that the positive welfare benefits of moral hazard can be economically significant. We use our framework to revisit prior estimates of the value of Medicaid from the Oregon Health Insurance Experiment. If Medicaid recipients live hand-to-mouth, and medical spending shocks are concentrated in time, the observed moral hazard from full health insurance is welfare enhancing and the transfer value of Medicaid is more than twice as high as prior estimates. In addition to our results for the liquidity constrained, our framework also provides a new way of quantifying and visualizing how the "income effect" of health insurance highlighted by Nyman (1999b) can lead to efficient moral hazard even for those without liquidity constraints when the likelihood of health shocks are low. The benefits of moral hazard are higher for hand-to-mouth individuals due to the liquidity effect regardless of the likelihood of the health shocks.

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1 Introduction

The change in spending resulting from insurance coverage is typically referred to as moral hazard. This empirical definition—a change in spending—is often paired with a welfare interpretation: moral hazard is considered "excess" spending that individuals value less than its full cost due to a distortion in incentives (Pauly, 1968).

We show instead that moral hazard can be efficient and welfare increasing for liquidity constrained individuals. This is because insurance provides both a risk-protection benefit and access to financing: while insured expenses are often concentrated in a particular consumption period, the cost of insurance via premiums is typically spread across multiple consumption periods. Recent work has shown that important feature of insurance is that it often smooths expenditures across time, not merely across states (e.g. Ericson and Sydnor (2018); Gross et al. (2022)), and that this can quantitatively and qualitatively change patterns of insurance demand.

Accounting for liquidity constraints is important, most clearly for evaluating expansions insurance to low-income individuals. Many individuals face liquidity constraints (either the inability to borrow or high interest rates) and have high marginal-propensities to consume out of shocks Parker et al. (2013). As a result, important macroeconomic models treat a large share of individuals as living essentially hand-to-mouth, consuming all liquid resources in a given period (Kaplan et al., 2014; Lee and Maxted, 2023; Aguiar et al., 2024). Moreover, because of holdings in illiquid assets, hand-to-mouth behavior can describe even wealthy, optimizing individuals (Kaplan et al., 2014) and the role of behavioral biases can also lead individuals to act "as-if" they were hand-to-mouth even if they have access to liquid assets or credit (Olafsson and Pagel, 2018; Lee and Maxted, 2023). As a result, liquidity constraints can be broadly applicable.

In this paper we revisit the welfare implications of ex-post moral hazard in light of liquidity constraints. Our setting is health insurance, which has been the focus of a substantial body of literature on moral hazard (Einav and Finkelstein, 2018), but the model is broadly applicable to various types of insurance. Standard models of ex-post moral hazard in (health) insurance are one-period models in which premiums, cost-sharing, and consumption all occur in the same consumption period. Our innovation, which closely follows the approach in Ericson and Sydnor (2018) is to introduce multiple underlying consumption periods within the insurance period. The cost of insurance via premiums is spread equally across all N consumption periods within the insurance policy term. Uninsured medical expenses, however, are spread across K periods. In this way we introduce a portable extension of the standard model, in which $K = N$ embeds the standard model that implicitly assumes perfect liquidity, while $K = 1$ is the full hand-to-mouth case, in which all uninsured expenses are born in a single consumption period. This framework was previously used by Ericson and Sydnor (2018) to examine the value of insurance under liquidity constraints in the absence of moral hazard. The current paper explicitly focuses on moral hazard and the endogenous decision of medical spending.

We define the efficient level of medical spending for a given level of insurance coverage as the medical spending the individual would choose if they maximized ex-ante utility fully internalizing

that their decision about medical spending when sick will affect the equilibrium cost of insurance. We also examine the level of medical spending the individual would choose when uninsured as well as the chosen level of medical spending the individual will select under insurance taking the premiums for insurance as given (i.e., sunk). The chosen level of spending under insurance does not incorporate the full cost because it ignores the impact on premiums. This allows us to present simple definitions decomposing moral hazard into a a potential inefficient and *efficient* component.

Our theory first develops intuition by considering the case in which the loss is certain to happen. In this case, we show that the standard static model of insurance, as well as unconstrained individuals in our model, produces the standard intuition for moral hazard's inefficient: adding insurance increases expenditure, and this expenditure is not valued by individuals at its full cost. Specifically, the level of spending that individual would contract on is invariant to the insurance level, meaning the privately chosen uninsured spending level was optimal. As a result, increasing insurance lowers welfare.

The results are quite different for liquidity constrained individuals. The level of spending that an individual and insurer would jointly contract on does now depend on the level of insurance, since insured spending (ultimately borne via premiums) is smooth but cost-sharing is lumpy. The efficient level of spending increases with the level of insurance. As a result, when spending increases with an expansion of insurance, this can increase rather than reduce welfare.

We show in numerical simulations that the welfare impacts of moral hazard can be significantly positive for individuals living hand-to-mouth. This updated welfare interpretation of moral hazard is relevant for setting the optimal level of cost-sharing. In standard theory, when demand is more responsive to price– when there is more moral hazard– optimal cost-sharing should be higher (Zeckhauser, 1970; Pauly and Blavin, 2008). Moreover, when evaluating an insurance expansion, the cost of that expansion has to be weighed against the benefits of that expansion. A key insight of Pauly (1968) is that the costs of moral hazard may make individuals worse off with insurance.

We use our framework to revisit Finkelstein et al. (2019)'s estimate of the value of Medicaid that made use of the Oregon Health Insurance Experiment. Finkelstein et al. (2019) develop a framework for welfare analysis and use the experiment to conclude that the willingness to pay for the expansion to insured individual is well below the cost to the government. A key part of that analysis is a quantification of the value of the increased medical spending resulting from gaining insurance– the value of moral hazard.

We adapt the Finkelstein et al. (2019) framework to account for the fact that for a hand-to-mouth individual, out-of-pocket medical spending is borne in particular consumption periods, while premiums are spread smoothly across periods. For those living hand-to-mouth, uninsured medical spending occurs in periods that have higher marginal utilities than premium spending. In contrast, in Finkelstein et al. (2019)'s analysis, medical spending and premiums all are resolved in the same (implicitly annual) consumption period. We show that the formula for the value of the transfer resulting from Medicaid needs to be adjusted to account for the fact that premiums are paid, on average, in periods with lower marginal utility of consumption than medical spending. The updated

formula for hand-to-mouth agents involves a multiplier on the transfer value of insurance that has an intuitive interpretation as the ratio of the expected marginal utility of consumption in periods when uninsured medical expenses are paid to the average expected marginal utility of consumption across all consumption periods. This ratio also affects the calculation of what Finkelstein et al. (2019) refer to as the "pure insurance" value of insurance. We provide estimates of the value of Medicaid if recipients live hand-to-mouth and incur medical expenses in a single monthly consumption period using the distribution of medical expenes from the paper by Finkelstein et al. (2019). We estimate that the value of the transfer from Medicaid is more than double as high if recipients live hand-to-mouth. The welfare impact of Medicaid for the hand-to-mouth is etimates to be significantly positive and the net value of Medicaid to recipients would be much higher than the cost of providing Medicaid.

1.1 Related Literature

Our work is closely related to a pair of papers by John Nyman. In Nyman (1999a), he revisits Pauly (1968) analysis of moral hazard, noting that Pauly assumes that there is no income effect on health care consumption. The welfare loss of moral hazard from an insurance expansion, argues Nyman (1999a), should only be the moral hazard that results from price effects, not income effects.

Nyman (1999b) argues that health insurance contains an "access motive": the ability to access treatments when the costs of those treatments exceed their ability resources. This relates to the income effect: health insurance would not have this access motive if contracts contained lump-sum payments when getting ill. Indeed, Nyman et al. (2018) conduct empirical decomposition of moral hazard, showing the part moral hazard that is efficient is the part that results from a lump sum payment that would be received when becoming ill.

Estimates of the welfare loss from moral hazard often do not explicitly account for the results in these papers, perhaps because the income effects have been presumed to be small with marginal changes in health insurance (e.g. Blomqvist (2001)). We show how our framework in addition to quantifying liquidity effects provides a new way of visualizing and quantifying these income effects.

The channel through which liquidity constraints deliver a positive value for moral hazard is different. This can be seen by examining the case in which the claim is certain to happen. In this case, there is no income effect nor access motive and the standard Pauly (1968) analysis applies. However, moral hazard can still be welfare increasing due to the financing effect.

2 Model

2.1 Layout

In our model, individuals live N periods.[1] They receive total income y, paid in equal installments each period. Individuals have flow consumption utility in each period t given by $u(c_t)$. The consumption utility function $u(\cdot)$ is continuous with $u' > 0$ and $u'' < 0$ and follows the standard Inada conditions.

In addition to consumption utility, the individual has separable utility from health that is given by $h(m, \theta)$, where θ indexes the individual's health state and m indexes the total level of medical spending.[2] In our baseline model for simplicity we assume there are two health states: sick, which occurs with probability π, and healthy, with probability $1 - \pi$. For simplicity we assume that the realization of the health state occurs at the beginning of the first period.[3] In the healthy state, health is unaffected by medical spending and can be normalized at zero. In the sick state, medical spending initially generates a positive but decreasing marginal benefit, such that $h'(m) > 0$ and $h''(m) < 0$ for all values of m smaller than $\bar{m}$. The function thus mimics the benefits of medical spending up to a point. Once $\bar{m}$ is reached, more medical spending has a negative effect of health such that $h'(m) < 0$ and $h''(m) < 0$. This is in line with the models of Einav et al. (2013) and Marone and Sabety (2022) and captures the idea that after reaching a certain health state additional medical spending is either useless (but still leads to detriments due the associated hassle costs) or actively harmful.

With these assumptions, the total utility over the lifetime is denoted by $U = \sum_{t=1}^{N} \delta^{t-1} u(c_t) + h(m, \theta)$, where δ is the exponential discount factor. We assume $\delta = 1$ throughout to highlight the role of liquidity constraints apart from time preference; moreover, with horizons less than a year, δ should be near 1 (Ericson and Laibson, 2019).

The individual chooses the consumption vector c and the level of medical spending m after observing the realization of the health state subject to budget constraints. This choice process is described in more detail below as we describe two types of individuals varying in their liquidity constraints.

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[1] This model and exposition builds on Ericson and Sydnor (2018), adding the possibility of choosing medical spending as in Finkelstein et al. (2019). In contrast to the Finkelstein et al. (2019) model, we assume N consumption periods in a given year rather than just one.

[2] Note that $h(\cdot)$ is not indexed by t. This could be interpreted in a few ways. First, one can imagine that there is an overall health state that affects the entire lifetime and is impacted by a total level of medical spending. Second, one can concretely think of this as sickness when it arises occurring in a single period and being affected by a decision about medical spending in that period alone. In this way of thinking, the assumption is that treatment cannot be delayed to later periods and the impact of sickness on health lasts for only the period when the sickness arises regardless of the medical spending decision.

[3] Note that this simplifying assumption eliminates the need to consider more complicated dynamics related to the potential timing of when a sick state might arise during the N periods that would affect consumption decisions for individuals that can borrow and save across consumption periods. For individuals that are fully constrained to live hand-to-mouth and can neither borrow nor save, this assumption can be relaxed without complicating the model.

Before period 1, the individual enters into an insurance plan $Z = (p, \alpha)$ characterized by a total insurance premium p and proportional insurance level α. That is fraction α of medical spending is covered by insurance, leaving the individual with out-of-pocket costs $(1-\alpha)m$. Note that the level of insurance α will affect the level of medical spending optimally chosen by the individual– this allows for the possibility of moral hazard. We assume in our baseline analysis that premiums are actuarially fair such that $p = \pi\alpha m$ and reflect the endogenously chosen level of medical spending in the sick state.[4] Importantly, as in most models incorporating the possibility of moral hazard, the individual will endogenously choose medical spending taking the level of premium as fixed and not inernalizing the impact of medical spending on premiums.

2.2 Types of individuals

We consider two types of individuals $i \in \{PL, HTM\}$. The first, denoted PL, has "perfect liquidity", which means they can allocate their total income toward consumption, premium payments and medical spending across periods in the contract term in any way they desire.[5] Given the assumptions above – specifically that the realization of the health state occurs at the start of first period, that there are no other sources of risk, and the individual has concave consumption utility each period – the optimal decision under "perfect liquidity" will be to perfectly smooth consumption across all periods. As such, the ex-ante expected utility for individuals with perfect liquidity is given by:

$$EU_{PL} = \pi \left[Nu\left(\frac{y - (1-\alpha)m(\alpha) - p}{N} \right) + h(m(\alpha)) \right] + (1-\pi) Nu\left(\frac{y-p}{N} \right). \tag{1}$$

Note that in this equation, the coverage level α and premium are taken as given and the medical spending $m(\alpha)$ will be endogenously chosen by the individual to maximize utility in the event that the sick state arises. This utility function is equivalent to the static utility model in prior work on health insurance and moral hazard, including Finkelstein et al. (2019).

The second type of individual, denoted HTM, has liquidity constraints and lives hand-to-mouth – they cannot move resources between periods. They consume all available resources each period.[6] They have to pay any medical spending in $K < N$ consumption periods. We assume that premium

[4] This assumption that premiums reflect the chosen level of medical spending could imply either that they are set with correct expectations of how individuals will respond to their insured incentives or could be thought of as a longer-run equilibrium result where premiums and spending decisions adjust to be mutually consistent.

[5] Note we are assuming here that it is both costless to borrow from future income and that savings earn no rate of return.

[6] The stark hand-to-mouth case facilitates developing theoretical results. As shown in Ericson and Sydnor (2018), the same insights translates to a more computationally difficult model in which individuals can borrow at high interest rates.

payments are made smoothly over time, such that they pay a $1/N^{\text{th}}$ of the premium in each period.[7] For these individuals the ex-ante expected utility is given by:

$$EU_{HTM} = \pi \left[(N-K)u\left(\frac{y-p}{N}\right) + Ku\left(\frac{y-p}{N} - \frac{(1-\alpha)m(\alpha)}{K}\right) + h(m(\alpha)) \right] + (1-\pi)Nu\left(\frac{y-p}{N}\right). \tag{2}$$

As in the case for perfect liquidity above, the individual will choose the level of medical spending $m(\alpha)$ in the event of the sick state endogenously taking premiums and insurance coverage as given. The key difference from the perfect-liquidity case is that the cost of uninsured medical expenses $(1-\alpha)m(\alpha)$ is born in only K periods instead of being spread across all N periods. $K = 1$ describes the extreme case in which the individual receives a medical treatment in a given consumption period and has to pay for it immediately. $K > 1$ can appear if the medical treatment and associated bills are spread over several periods, or the providers allow for a payment plan of the bills. Setting $K = N$ yields the perfect liquidity case above and has been the implicit assumption in applied work so far.

2.3 Defining Moral Hazard

We distinguish between the chosen and efficient level of medical spending for a given amount of insurance coverage. We write the ex-post utility-maximizing choice of medical spending for an individual of type i with insurance coverage α as $m_i^*(\alpha)$. When an individual has no insurance, their chosen medical spending is denoted $m_i^*(0)$. The individual will select this amount of coverage $m_i^*(\alpha)$ taking the premium cost of insurance as given.

The efficient (i.e., socially optimal) level of medical spending is denoted by $m_i^E(\alpha)$. This is the level of medical spending that individuals of type i, taking the level of insurance α as given, would commit to *ex-ante* if this commitment was binding and the individuals would internalize the full effect of this medical spending on their premiums. To determine the efficient level of medical spending for a given level of insurance, we maximize Equations (1) and (2), setting $p(\alpha) = \pi\alpha m(\alpha)$. The crucial difference between $m_i^*(\alpha)$ and $m_i^E(\alpha)$ is that $m_i^*(\alpha)$ is chosen holding fixed the level of premiums, while $m_i^E(\alpha)$ is chosen accounting for its effect on the cost of insurance. In the next section we explore the first order conditions that govern the efficient and chosen levels of spending.

It is worth noting two distinctions about our definition of efficient medical spending. First, this definition of efficient spending is contingent on the level of insurance. As such, it is distinct from a potential notion of the "optimal" spending that the individual would want to contract on if they could determine this spending jointly with the level of insurance. Second, our definition differs from the definition used by Nyman (1999b) and summarized in Nyman et al. (2018). Nyman defines efficient spending as the level that would arise from receiving a lump-sum transfer when sick of

[7] This assumption of smooth premium payments matches the empirical situation that is typical for health insurance contracts in the United States. See Ericson and Sydnor (2018) for a discussion of alternative premium-payment timing.

the amount the individual would have spent under insurance (see also Chetty, 2008). In Appendix Appendix B we present a deeper discussion and derivation of the differences between our measure and the lump-sum measure. While it is true that lump-sum contingent transfers could be used in theory to achieve the efficient level of spending under insurance, setting the lump sum amount equal to the amount the individual would spend under insurance will not achieve the efficient level of spending. The problem is that the total amount being spent when insured is inefficient and hence the lump-sum transfer is too large. We believe our definition of efficient spending is the correct one, since it is derived from the full internalization of the utility cost of spending given the level of insurance.

With our definitions of spending in place, we can then define three different moral hazard concepts:

1. $MH_i(\alpha) = m_i^*(\alpha) - m_i^*(0)$
2. $MH_i^E(\alpha) = m_i^E(\alpha) - m_i^*(0)$
3. $MH_i^I(\alpha) = m_i^*(\alpha) - m_i^E(\alpha)$

The first empirical object $MH_i(\alpha)$ is the total observed change in medical spending when an individual has insurance level α versus when they are uninsured. Prior literature typically refers to this as the observed moral hazard. The observed moral hazard can be disentangled into an efficient ($MH_i^E(\alpha)$) and inefficient ($MH_i^I(\alpha)$) component. Note that $MH_i(\alpha) = MH_i^E(\alpha) + MH_i^I(\alpha)$. The efficient component of moral hazard is the change in spending that the individual would optimally choose, while the inefficient component of moral hazard is the "excess" spending.

2.4 Defining the Value of Insurance

Having defined these concepts, we can finally define the concept of the value of insurance. The total value of insurance at coverage level α is the change in expected utility relative to no insurance

$$V_i(\alpha) = EU_i(\alpha, m_i^*(\alpha)) - EU_i(0, m_i^*(0)), \tag{3}$$

where each of the expected utility terms are evaluated at the actuarial fair (i.e., equilibrium) premiums consistent with the chosen level of medical spending ($m_i^*(\alpha)$ and $m_i^*(0)$, respectively).

The total value of insurance for type of individual $i \in \{PL, HTM\}$ can be split into a "risk and financing value" and the moral hazard value such that $V_i(\alpha) = V_i^{MH}(\alpha) + V_i^{RF}(\alpha)$. These are defined as

$$V_i^{RF}(\alpha) = EU_i(\alpha, m_i^*(0)) - EU_i(0, m_i^*(0)) \text{ and} \tag{4}$$

$$V_i^{MH}(\alpha) = EU_i(\alpha, m_i^*(\alpha)) - EU_i(\alpha, m_i^*(0)). \tag{5}$$

The risk and financing value V_i^{RF} is the change in utility from buying actuarially fair insurance, but holding fixed the medical spending at the uninsured level $m_i^*(0)$. This entails using insurance to reduce risk and finance spending but not to change spending.[8]

For a given level of actuarially fair insurance, the moral hazard value $V_i^{MH}(\alpha)$ is the change in utility from allowing the individual to choose medical spending ex-post ($m_i^*(\alpha)$) versus having medical spending fixed at the uninsured level $m_i^*(0)$. We further decompose the value of moral hazard into the value of efficient moral hazard, V_i^{MHE}, and the value of inefficient moral hazard, V_i^{MHI}.

$$V_i^{MHE}(\alpha) = EU_i(\alpha, m_i^E(\alpha)) - EU_i(\alpha, m_i^*(0)) \text{ and} \tag{6}$$

$$V_i^{MHI}(\alpha) = EU_i(\alpha, m_i^*(\alpha)) - EU_i(\alpha, m_i^E(\alpha)). \tag{7}$$

By the definitions and Equation (5), it is obvious that $V_i^{MH}(\alpha) = V_i^{MHE}(\alpha) + V_i^{MHI}(\alpha)$. It is typically assumed that $V_i^{MH}(\alpha)$ is negative, but our next section will show that it can be positive.

3 Model Results

In what follows, we first begin with an intuitive discussion of how the analysis of moral hazard changes when we consider the liquidity and income-effects of insurance. We present a set of simple graphical depictions that make it possible to visualize both the moral-hazard and welfare implications of insurance. We then present results of numerical simulations that help to highlight the potential magnitude of the differences in insurance value and specifically the impact of moral hazard. In the final subsection, we present formal theoretical propositions under more general conditions with proofs provided in the appendix. Some readers with less interest in the technical formality may choose to skip this final subsection without losing intuitions for the core results.

3.1 Graphical Analysis and Intuition

We begin with an intuitive discussion of the key results. We highlight the following key points:

1. The liquidity benefits of insurance lead part of observed moral hazard to be efficient for hand-to-mouth agents. There can be positive moral hazard value from insurance for hand-to-mouth agents even when the sick state is sure to occur.

2. When the sick state is not sure to occur there is also an income effect of insurance ("Nyman effect"). This leads part of observed moral hazard to be efficient for both perfectly liquid and hand-to-mouth agents.

[8] As Ericson and Sydnor (2018) discuss and we highlight in the next section, for those with perfect liquidity insurance has only a risk-reducing benefit, but has an additional financing benefit for those with liquidity constraints.

3.1.1 Illustrating the liquidity effect using the sure-loss case ($\pi = 1$)

When losses are sure to occur ($\pi = 1$), the perfect-liquidity case conforms to the standard economic intuition introduced by Pauly (1968). For those with perfect liquidity, the efficient level of spending is the level that would be chosen when uninsured. To see this, recall the expected utility for the perfect liquidity case from Equation 1:

$$EU_{PL} = \pi \left[Nu\left(\frac{y - (1-\alpha)m(\alpha) - p}{N} \right) + h(m(\alpha)) \right] + (1-\pi) Nu\left(\frac{y-p}{N} \right). \tag{8}$$

If we note that premiums are defined by $p = \pi\alpha m$ and that we are assuming here that $\pi = 1$, this reduces simply to:

$$EU_{PL} = Nu\left(\frac{y-m}{N} \right) + h(m). \tag{9}$$

We observe that this utility does not depend on the level of insurance α, since any increase in spending must be paid for fully either via uninsured spending or insurance premiums. As such, the first order condition implicitly determining the optimal level of spending when uninsured ($m^*_{PL}(0)$) and the efficient level of spending ($m^E_{PL}(\alpha)$) is the same and given by:

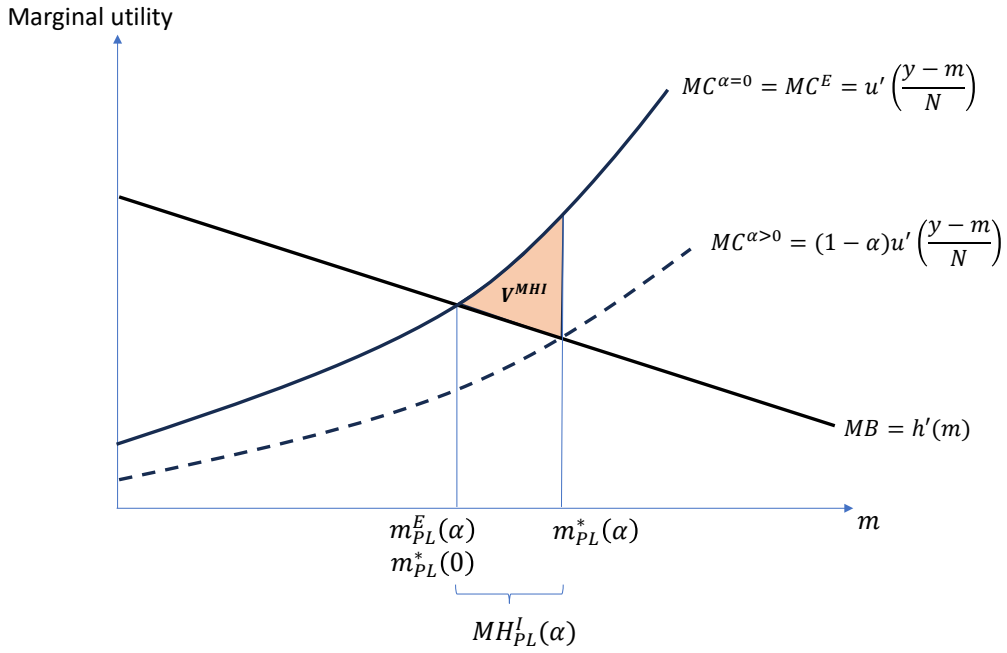
$$FOC^E_{PL} = FOC^0_{PL} : u'\left(\frac{y-m}{N} \right) = h'(m). \tag{10}$$

Insurance, though, reduces the perceived price of spending and leads to inefficient moral hazard. The reason is that the individual takes the premium as given when deciding on the optimal level of insured spending ($m^*_{PL}(\alpha)$), which results in the following first order condition:

$$FOC^*_{PL} : (1-\alpha)u'\left(\frac{y-m}{N} \right) = h'(m). \tag{11}$$

Figure 1 gives a graphic illustration of this standard case of inefficient moral hazard for an individual with perfect liquidity. The vertical axis is the marginal utility cost and benefit of additional medical spending. The horizontal axis is the level of medical spending. The marginal benefit (MB) of spending is given by $h'(m)$, which is downward sloping given our baseline assumptions on $h(m)$. We then plot the marginal costs (MC) of medical spending, which is the (perceived) marginal consumption utility given the level of medical spending (i.e., the left-hand side of the first-order conditions in Equations 10 and 11). These MC lines slope upward due to the concavity of the utility function ($u'' < 0$)). The line $MC^{(\alpha=0)}$ is the marginal utility cost of foregone consumption with medical spending m when uninsured. Here it lies directly on top of MC^E, as noted above. The uninsured and efficient levels of spending coincide: $m^*(0) = m^E(\alpha)$. The dashed line, $MC^\alpha > 0$, is the perceived marginal utility cost of foregone consumption through out of pocket costs given insurance α at medical spending level m. It is shifted down, since insurance means out-of-pocket costs are lower for any given amount of medical spending. As a result, the medical spending $m^*(\alpha)$ chosen when insured is higher, with the additional spending representing inefficient moral haz-

Figure 1 – Standard Analysis of Moral Hazard (Perfect Liquidity)



Note: Schematic illustration. Assumes perfect liquidity and $\pi = 1$.

ard ($MH^I_{PL}(\alpha)$). The shaded area represents the negative welfare cost of inefficient moral hazard (V^{MHI}).

The analysis is different for those living hand to mouth. In their case, there is a difference between the marginal consumption-utility cost of medical spending governing the uninsured case and the efficient case with insurance. To see this, we recall the expected utility for the hand-to-mouth individuals from Equation (2), which setting $\pi = 1$ and focusing on the full hand-to-mouth case with $K = 1$ we can write as

$$EU_{HTM} = \left[(N-1)u\left(\frac{y-\alpha m}{N}\right) + u\left(\frac{y-\alpha m}{N} - (1-\alpha)m(\alpha)\right) + h(m(\alpha))\right]. \tag{12}$$

We can again look at the first order conditions that would govern spending levels. When uninsured we have that:

$$FOC^0_{HTM} : u'\left(\frac{y}{N} - m\right) = h'(m). \tag{13}$$

The difference from the perfect-liquidity case in Equation (10) is that those living hand to mouth with $K = 1$ have to absorb the entire medical spending in a single period rather than spreading it across N consumption periods.

The first order condition for the efficient spending level for the hand-to-mouth individuals is

$$FOC^{E}_{HTM}:$$
$$\underbrace{(1-\alpha)u'\left(\frac{y-\alpha m}{N}-(1-\alpha)m\right)}_{\text{Marginal consumption-utility cost of medical spending born through out-of-pocket costs}}-\underbrace{\alpha\left(\frac{1}{N}u'\left(\frac{y-\alpha m}{N}-(1-\alpha)m\right)+\frac{N-1}{N}u'\left(\frac{y-\alpha m}{N}\right)\right)}_{\text{Marginal consumption-utility cost of medical spending born through premiums}}=h'(m). \tag{14}$$

For hand-to-mouth individuals, the marginal consumption-utility costs of medical spending are lower with insurance, resulting in a higher efficient than uninsured spending. The key reason is that the insured portion of spending, αm, is spread out across all N consumption periods.[9]

At the same time, there will still be some level of inefficient moral hazard in the hand-to-mouth case. When choosing actual medical spending, the individual takes premiums as given and does not internalize the impact of spending on premiums. The first order condition for the chosen level of insurance only includes the first term on the left-hand-side of Equation 14 and is given by

$$FOC^{*}_{HTM}:(1-\alpha)u'\left(\frac{y-\alpha m}{N}-(1-\alpha)m\right)=h'(m). \tag{15}$$

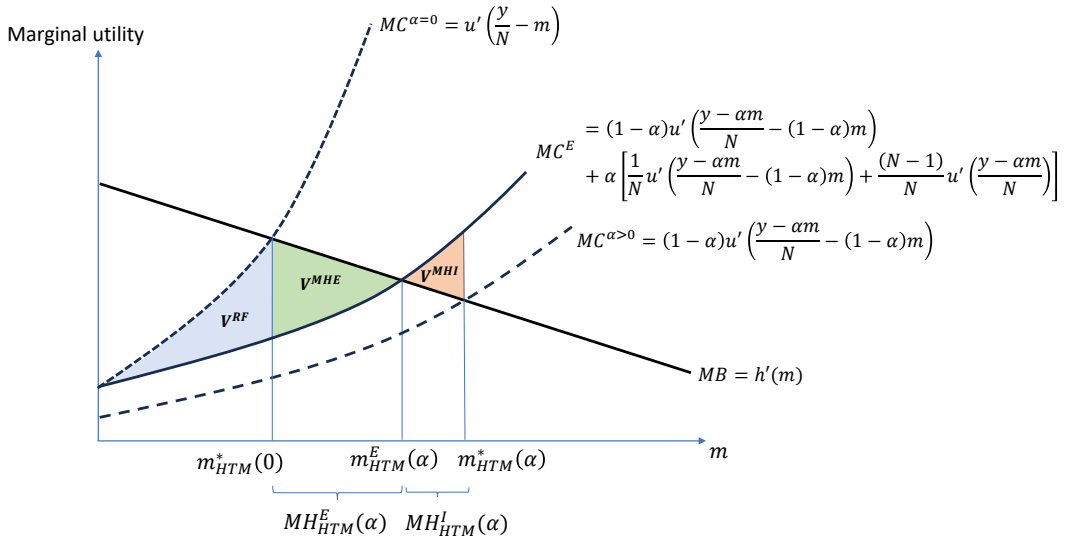
Figure 2 shows the hand-to-mouth case graphically. The full marginal cost under insurance including premiums (MC^{E}) lies in between the uninsured marginal cost and the (perceived) marginal cost under insurance. This implies that there is both efficient and inefficient moral hazard.

There are now three shaded regions denoting the welfare impacts of insurance and moral hazard specifically. The V^{MHI} area shared in pink is the same inefficiency of moral hazard as we saw in the perfect liquidity case–resulting from the fact that the level of spending chosen when insured is higher than the efficient level of spending. However, we also have the green-shaded area V^{MHE}, which represents the utility value of the efficient portion of moral hazard – resulting from the fact that the efficient level of spending is higher than the uninsured level. Moreover, we see the shaded dashed area V^{RF} is the risk and financing value. This represents the welfare improvement holding fixed spending at the uninsured level $m^{*}_{HTM}(0)$ that comes from being able to insure against that spending. It is positive (even though $\pi=1$) because of the financing benefit of insurance for the liquidity constrained. Each dollar of spending has a lower impact on consumption utility when it is spread out evenly as insurance premiums across N consumption periods.

This illustration shows a visual example where the net welfare value of moral hazard is positive, since the welfare gain from efficient moral hazard is larger than the welfare loss from inefficient

[9] As such, the marginal consumption-utility cost in the period experiencing the loss is lower with insurance. In addition, the $(N-1)$ consumption periods where no loss is experienced and only premiums are paid have higher levels of consumption and thus lead to a lower average marginal consumption-utility cost for premiums than for uninsured spending. Mathematically we have that: $\frac{1}{N}u'\left(\frac{y-\alpha m}{N}-(1-\alpha)m\right)+\frac{N-1}{N}u'\left(\frac{y-\alpha m}{N}\right)<u'\left(\frac{y-\alpha m}{N}-(1-\alpha)m\right)<u'\left(\frac{y}{N}-m\right)$.

Figure 2 – Analysis of Moral Hazard for Hand-to-Mouth Individuals



Note: Schematic illustration. Assumes hand-to-mouth behavior and $\pi = 1$.

moral hazard. This will not always be the case in the hand-to-mouth case, but there will always be an efficient level of moral hazard that helps to offset the inefficient moral hazard.

3.1.2 Illustrating the income effect using the full-insurance case ($\alpha = 1$)

When the sick state is not sure to happen ($\pi < 1$), there is an additional benefit of insurance that we refer to as the "income effect" following Nyman (1999a). The income effect creates efficient moral hazard for both the hand-to-mouth and perfect-liquidity types. The key idea is that every dollar of insured spending only ends up affecting consumption by its expected costs π via premiums that are shared across those in the sick state (π share) and the non-sick states ($(1-\pi)$ share). We provide formal propositions for the general case in Section 3.3, but here we illustrate the intuition under full insurance.

At full insurance the expected utility coincides for both types. Because premiums are paid smoothly over all N periods and there are no uninsured cost-shocks, the hand-to-mouth individuals in our model become essentially perfectly liquid. That is we have

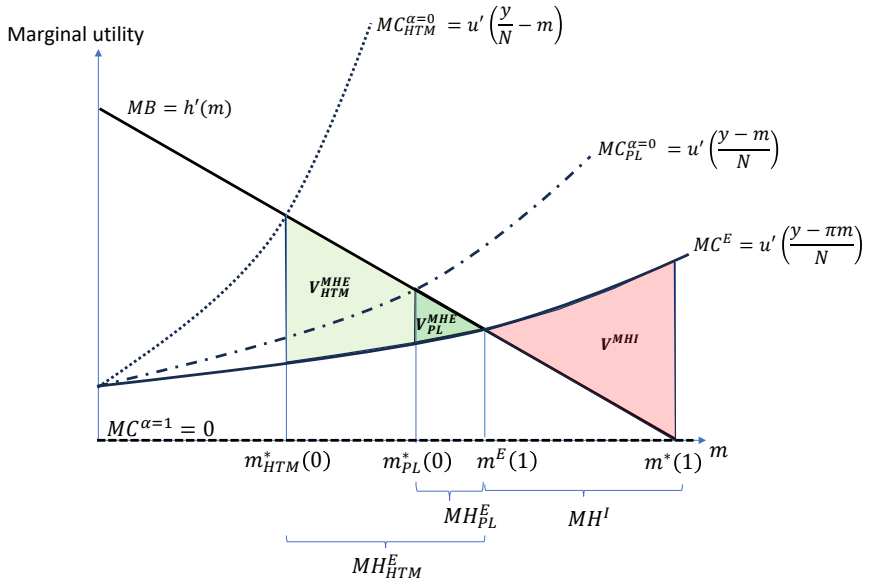
$$EU_{PL}(\alpha = 1) = EU_{HTM}(\alpha = 1) = \pi\left[Nu\left(\frac{y - \pi m(1)}{N}\right) + h(m(1))\right] + (1-\pi)Nu\left(\frac{y - \pi m(1)}{N}\right). \quad (16)$$

It is straightforward to show that the efficient level of spending $m^E(1)$, which will be the same for both types, will be govered by the first order condition

$$FOC^E : u'\left(\frac{y - \pi m}{N}\right) = h'(m). \quad (17)$$

Full insurance guarantees that consumption is steady and based on income minus premiums at $\frac{y-\pi m}{N}$ in every period, regardless of whether the loss occurs or not. As such, the efficient spending level is determined by where the marginal consumption utility from paying premiums equals the marginal health benefit. This level of marginal consumption-utility cost is lower than the uninsured levels.

Figure 3 – Analysis of Moral Hazard for Both Types under Full Insurance



Note: Schematic illustration. Assumes full insurance $\alpha = 1$. Note that the subscript PL denotes the perfect-liquidity type and subscript HTM is the hand-to-mouth type. Curves, spending levels, and moral hazard ranges without subscript are the same for both the PL and HTM.

Figure 3 shows the full insurance case graphically. The income effect for the perfect-liquidity case is generated by the difference between the uninsured marginal consumption-utility cost $u'\left(\frac{y-m}{N}\right)$ (Equation (10)) and the efficient marginal cost, $u'\left(\frac{y-\pi m}{N}\right)$. This difference comes from sharing the medical spending costs with uninsured states through premiums. The gap is bigger the smaller is the probability of the sick state π. The efficient level of spending at full insurance $m^E(1)$ is higher than the uninsured spending, implying that there is efficient moral hazard for the perfect-liquidity case. The positive welfare value of the efficient moral hazard is given by the darker green shaded region V_{PL}^{MHE}. At the same time, because the individual perceives no cost to medical spending under full insurance, they over-consume at the point $m^*(1)$, leading to inefficient moral hazard. In this graphical representation, the net welfare value of moral hazard for the liquidity constrained individual is negative since the losses from inefficient moral hazard are larger than the gains from efficient moral hazard. There can be situations, however, where the efficiency gains from the income effect lead to positive net moral hazard value for those with perfect liquidity. We give conditions

for that to happen in the general case in our formal propositions below and provide numerical examples in the final subsection.

The moral hazard benefits of insurance are larger for the hand-to-mouth individuals because they have both the liquidity effect and the income effect of insurance. The liquidity effect can be seen in the figure as going from the marginal cost from the uninsured level for the hand-to-mouth $u'\left(\frac{y}{N}-m\right)$ to the uninsured marginal cost under perfect liquidity. The liquidity effect spreads the medical spending across consumption periods, while the income effect spreads the costs across sick and non-sick states via premiums. The level of efficient moral hazard is greater for the hand-to-mouth case because the uninsured level of spending is lower, and the corresponding size of the welfare gain from efficient moral hazard V_{HTM}^{MHE} (denoted by the larger light green region) is larger. The level of inefficient moral hazard is the same for hand-to-mouth types as it is for those with perfect liquidity because the chosen level of spending is the same under full insurance. As we show in the formal propositions, because the hand-to-mouth types have both the liquidity effect and income effect, the net value of moral hazard is more likely to be positive for the hand-to-mouth types. An implication is that a benevolent social planner would typically set a higher level of insurance for hand-to-mouth types than for perfect-liquidity types.

3.2 Numerical examples

This subsection provides numerical examples to help quantify the plausible size of the welfare effects of moral hazard and to draw out a few other important comparisons related to the results highlighted so far.

To help simplify this analysis we use a set of linear approximations to the marginal consumption-utility costs in the first-order conditions that govern uninsured, efficient, and chosen levels of spending under insurance. We use first-order Taylor expansions of the marginal consumption utility terms around the marginal utility at baseline consumption $u'\left(\frac{y}{N}\right)$. We then normalize the entire first order condition by dividing by $u'\left(\frac{y}{N}\right)$. This results in a set of linear marginal (consumption-utility) cost curves that are in monetary units with intuitive functional forms. Appendix Appendix C provides the full set of derivations for general levels of insurance and probability of sickness.

The linear approximations to the first-order conditions governing uninsured spending in the perfect-liquidity and hand-to-mouth cases (with $K=1$) are:

$$1+r\frac{m_{PL}(0)}{N}\approx H'(m_{PL}(0)) \tag{18}$$

$$1+rm_{HTM}(0)\approx H'(m_{HTM}(0)). \tag{19}$$

The left-hand side of these equations is the marginal consumption-utility cost of medical spending. The slope of the marginal costs are governed in part by r, which is the Arrow-Pratt measure of absolute risk aversion at baseline consumption ($r=-\frac{u''\left(\frac{y}{N}\right)}{u'\left(\frac{y}{N}\right)}$). We see that without insurance the marginal cost grows with m at a rate of $\frac{r}{N}$ in the perfect-liquidity case and at a rate of r in the hand-

to-mouth case. The marginal consumption-utility cost is N times steeper for the hand-to-mouth individuals who have to absorb the entire spending in one period.

It helps to build intuition to examine the first-order condition for efficient spending under full insurance. As we highlighted in the prior subsection, the first order conditions are the same for efficient spending under full insurance for perfect-liquidity and hand-to-mouth cases. This first order condition is in the linear approximation is:

$$1 + \pi r \frac{m^E(1)}{N} \approx H'(m^E(1)) \tag{20}$$

$$\tag{21}$$

The efficient marginal cost under full insurance rises with m at a rate of $\pi \frac{r}{N}$. The income effect of insurance generates efficient moral hazard for the perfect-liquidity case by lowering the slope of the marginal cost relative to the uninsured case by a factor of π. For the hand-to-mouth case, the efficiency of moral hazard under full insurance arises because the marginal cost under full insurance is reduced by both π and $\frac{1}{N}$.

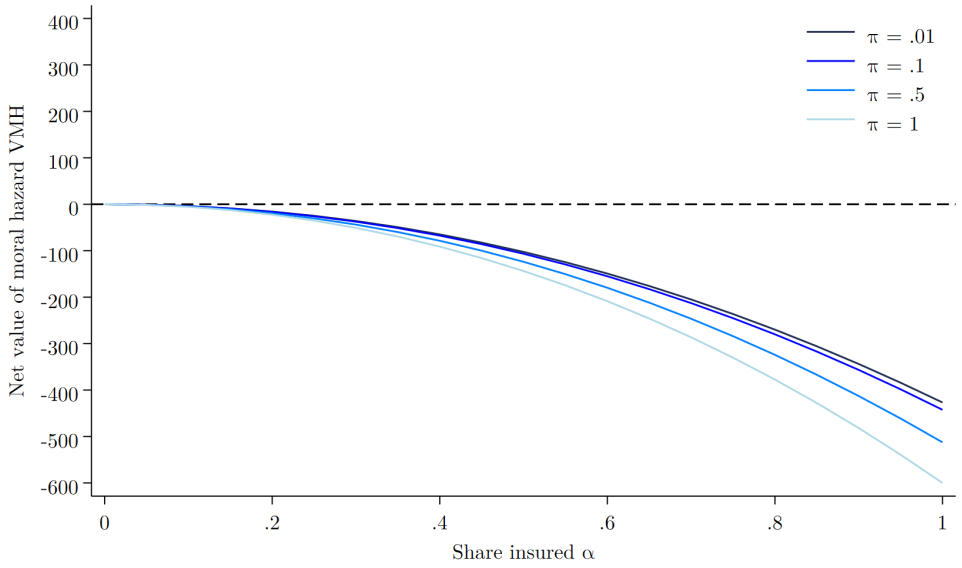
For our numerical example we pin down these approximate marginal cost curves by assuming $r = 0.0006$. This is the level of absolute risk aversion that corresponds to a Constant Relative Risk Aversion utility function $u = \frac{c^{(1-\rho)}}{(1-\rho)}$ with $\rho = 3$ and evaluated at baseline consumption for annual income $y = \$60,000$ and monthly consumption periods $N = 12$.

The H' terms on the right-hand side of the first-order conditions are the marginal health benefit of medical spending (h') normalized by dividing by $u'\left(\frac{y}{N}\right)$. We assume that the marginal health benefit is linear. Under this linearity assumption, the H' curve can be pinned down if we know two levels of spending. For our nummerical example we assume that uninsured spending for those with perfect liquidity is $m^*_{PL}(0) = \$3,000$ and that the spending by those individuals under full insurance would be $m^*(1) = \$4,000$. With all of the curves pinned down, the welfare values of moral hazard illustrated in the shaded regions of Figures 1 to 3 become triangles that can be easily quantified.

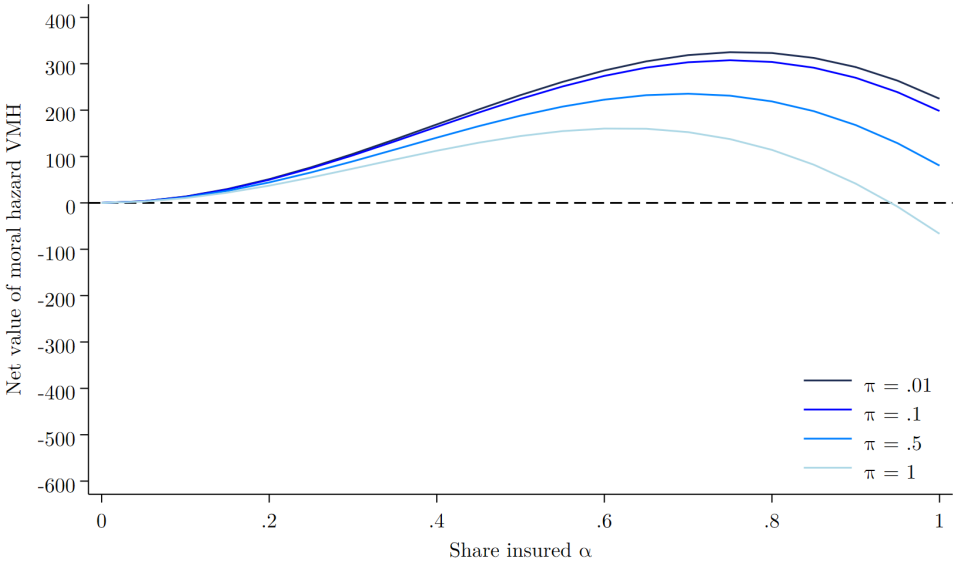
Figure 4 plots the resulting net moral hazard value ($VMH = VMH^E + VMH^I$) for insurance levels ranging from no ($\alpha = 0$) to full insurance ($\alpha = 1$) and for four different levels of the probability of sick state ranging from a 1 percent chance to a sure sick state. Panel a) plots the results for individuals with perfect-liquidity. We see that for this numerical example, the net moral hazard value is negative for those with perfect liquidity and worse as the level of insurance gets higher. At higher levels of insurance, moral hazard reduces welfare by around \$300 to \$600. Due to the income effect there is some level of efficient moral hazard when $\pi < 1$, which can be seen by noting that the net value of moral hazard at every level of insurance is higher for lower values of π. However, the value of efficient moral hazard is low relative to the losses from inefficient moral hazard, leading to negative moral hazard value across the range of values explored here.

For hand-to-mouth individuals, however, the value of moral hazard is often significantly positive. In this example, the value of the net value of moral hazard peaks at relatively high levels of

Figure 4 – Numerical Examples of Moral Hazard Value



(a) Perfect Liquidity $K = N$



(b) Hand to Mouth $K = 1$

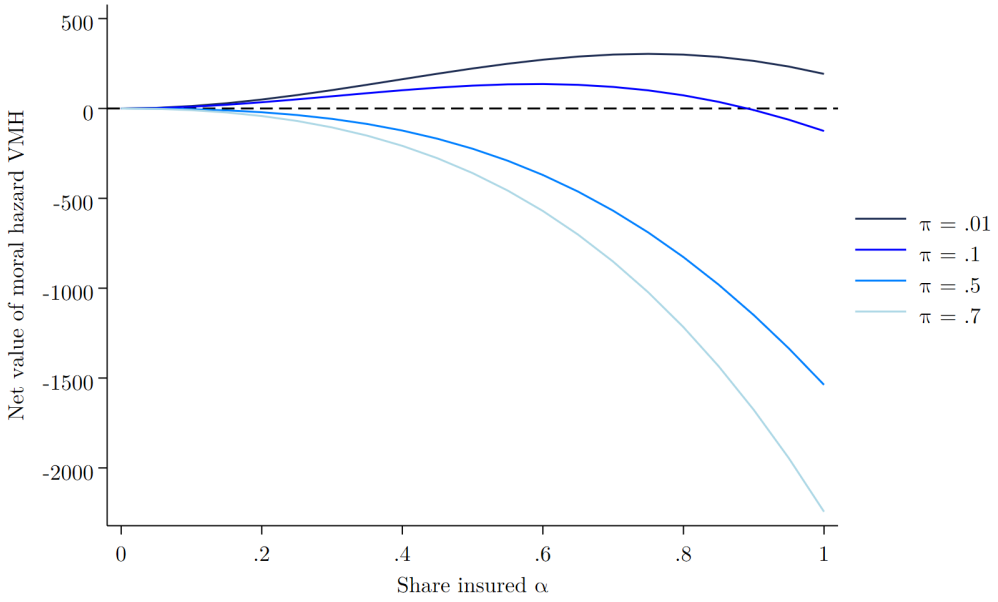
Note: These figures show the net value of moral hazard for different levels of insurance (α) and probability of sick state (π). We use the linear approximation to the marginal utility of consumption outlined in this subsection. The parameters governing the numerical exercise are that a) the number of consumption periods $N = 12$, b) the Arrow-Pratt measure of absolute risk aversion $r_A = 0.0006$, c) the uninsured spending under perfect liquidity is $m^*_{PL}(0) = \$3,000$, and d) the maximum spending observed under full insurance is $m^*(1) = \$4,000$. As described in the text, we assume a linear marginal utility of health function $h'(m) = c - bm$ and the parameters are pinned down by the assumptions about $m^*_{PL}(0)$ and $m^*(1)$. Panel a) shows the perfect liquidity case where $K = N$ and Panel b) shows the full hand-to-mouth case where $K = 1$.

insurance, around 80% insurance for probabilities of sickness of 10% or less. When we note that the risk and financing value is rising with the level of insurance, this implies that the optimal level of insurance will be close to full insurance for the hand-to-mouth. The value of moral hazard can be quite significant, reaching over $300 for higher levels of insurance against lower-probabilities of sickness. We also note that even when the sick state is sure to arise, the net value of moral hazard is positive up to nearly full insurance (crossing negative around 95% insurance). This means that in this example, hand-to-mouth individuals derive positive moral hazard benefits from insurance that helps them finance medical expenditures they are sure to need and that it can be beneficial to finance nearly all such expenditures. This is true even despite the fact that insurance generates some degree of inefficient spending due to distortions in the perceived price of care.

It might be tempting to think about liquidity constraints as simply representing a case of very strong risk aversion, but there is an important distinction between the moral hazard value of insurance under liquidity constraints and under high risk aversion but perfect liquidity. The efficiency gains of moral hazard under insurance arise in the hand-to-mouth case because the marginal consumption-utility cost curve is very steep when uninsured relative to when insured. It is also true that a much higher level of absolute risk aversion can generate a similarly steep marginal cost curve when uninsured for those who have perfect liquidity. Very high levels of absolute risk aversion would arise for those with low annual incomes or when the cost of medical care are high, such that medical spending is traded off against very essential consumption. However, the distinction between the value of insurance for those with liquidity constraints and for those with out liquidity constraints but very high levels of absolute risk aversion is that the efficiency benefits without liquidity constraints arise only from the income effect, which depends on low probability of the sick state. That is, the gap between the uninsured and the efficient marginal cost curves under perfect liquidity depends on π.

Figure 5 provides an example of this. For this figure we repeat the numerical analysis from Figure 4 for the perfect liquidity case but under the assumption that absolute risk aversion is 12 times the original absolute risk aversion in the prior figure ($r'_A = 12r_A$=0.0072). As such, in this example the uninsured marginal consumption-utility cost for the perfect liquidity individual is now the same as the uninsured marginal consumption-utility cost for the hand-to-mouth in the numerical example in Figure 4 panel b. We use here also the same calibrated marginal utility of health function $H'(m)$ from the prior numerical example, so the uninsured spending in this case matches the uninsured spending for the hand-to-mouth individuals from the prior figure. We see now that the net value of moral hazard is positive at low levels of π. In particular, if the likelihood of the sick state were 1%, the highly-risk-averse individual with perfect liquidity derives up to around $300 in value from moral hazard at moderately high level of insurance and significantly positive value from moral hazard even under full insurance. However, as the likelihood of the sick state rises, the value of moral hazard falls dramatically and becomes substantially negative. Those with high absolute risk aversion benefit from moral hazard when premium costs are low, but as the likelihood of sickness rises and premiums go up, the impact of moral hazard is even worse than it

Figure 5 – Numerical Example Perfect Liquidity and High Risk Aversion



Note: This figure shows the net value of moral hazard for different levels of insurance (α) and probability of sick state (π) for the perfect-liquidity case where $K = N$. We use the linear approximation to the marginal utility of consumption outlined in this subsection. The parameters governing the numerical exercise are that a) the number of consumption periods $N = 12$, b) the Arrow-Pratt measure of absolute risk aversion $r_A = 0.0072$, c) the uninsured spending under perfect liquidity is $m^*_{PL}(0) = \$3,000$, and d) the maximum spending observed under full insurance is $m^*(1) = \$4,000$. As described in the text, we assume a linear marginal utility of health function $h'(m) = c - bm$ and the parameters are pinned down by the assumptions about $m^*_{PL}(0)$ and $m^*(1)$.

would be if the individual were less risk averse (compare Figure 5 to Figure 4 panel a). In contrast, when the high sensitivity to uninsured spending costs comes from the lack of liquidity, as in Figure 4 panel b, the moral hazard value of insurance comes primarily from its liquidity benefit and is much less sensitive to the chance of the sick state.

3.3 Formal propositions

3.3.1 Perfect-liquidity Individuals

First, Proposition 1 shows the standard intuition for individuals with perfect liquidity: for all positive levels of insurance coverage, choose medical spending that is higher than the socially optimal level of insurance coverage. The proposition also covers a different result, known from Nyman (1999a): with insurance coverage, the socially optimal level of medical spending is larger than the level that would be chosen if the individual were uninsured. All proofs are provided in the appendix.

Proposition 1. *For individuals with perfect liquidity*

1. $u''' > 0$ *is a sufficient condition for* $\frac{\partial m^E_{PL}(\alpha)}{\partial \alpha} > 0 \; \forall \; \pi \in]0,1[$,

2. $m^*_{PL}(\alpha) > m^E_{PL}(\alpha) \; \forall \; \alpha \in]0,1], \pi \in]0,1]$,

3. *if* $\pi = 1$, $m^E_{PL}(\alpha) = m^*_{PL}(0) \; \forall \; \alpha \in]0,1]$, *and*

4. $u''' > 0$ *is a sufficient condition for* $m^E_{PL}(\alpha) > m^*_{PL}(0) \; \forall \; \alpha \in]0,1]$ *if* $\pi \in]0,1[$.

The following Proposition 2 demonstrates how the different spending levels transfer into the value components of insurance. When losses are certain to appear, individuals with perfect liquidity have a negative total value of insurance: there is no risk and financing value ($V^{RF}_{PL}(\alpha) = 0$) since there is no uncertainty. The moral hazard value of insurance is negative ($V^{MH}_{PL}(\alpha) < 0 \; \forall \; \alpha > 0$), as the efficient level of medical spending is the level that would be chosen when uninsured. That is, insurance simply brings a distortion in this case.

If we introduce risk to the decision-situation, two effects appear. Because insurance now has a positive risk and financing value, the total value of insurance can, in theory, be positive. Further, the result on efficient spending from Proposition 1 lets us state the argument of Nyman (1999a) formally: there can be situations in which insurance has a positive moral hazard value.

Proposition 2. *For individuals with perfect liquidity*

1. *For* $\pi = 1$, $V^{RF}_{PL}(\alpha) = 0$, $V^{MH}_{PL}(\alpha) < 0$ *and* $V^{\Sigma}_{PL}(\alpha) < 0 \; \forall \; \alpha \in]0,1]$.

2. *For* $\pi \in]0,1[$, $V^{RF}_{PL}(\alpha) > 0; \forall \; \alpha \in]0,1]$.

3. *For* $\pi \in]0,1[$, $u''' > 0$ *is a sufficient condition for* $V^{MHE}_{PL}(\alpha) > 0; \forall \; \alpha \in]0,1]$.

4. *For* $\pi \in]0,1[$, *there exists* $\hat{\alpha}$ *such that* $V^{MH}_{PL}(\alpha) > 0; \forall \; \alpha \in]0,\hat{\alpha}]$ *if it holds that*

$$(1-2\pi)u'\left(\frac{y - m^*_{PL}(0)}{N}\right) - 2(1-\pi)u'\left(\frac{y}{N}\right) > m^*_{PL}(0)(1-\pi)\frac{1}{N}u''\left(\frac{y - m^*_{PL}(0)}{N}\right). \quad (22)$$

5. *For* $\pi \in]0,1[$, *there exists* $\hat{\alpha}' > \hat{\alpha}$ *such that* $V^{\Sigma}_{PL}(\alpha) > 0; \forall \; \alpha \in]0,\hat{\alpha}']$ *if Condition* (22) *holds.*

The inequality in (22) states when a positive moral hazard value can be possible. Note that the condition is more likely to appear if π gets smaller. This reflects the argument in Nyman (1999a) that smaller probabilities of getting sick lead to higher transfers of healthy people to sick people through the insurance system.

3.3.2 Hand-to-mouth Individuals

Next we consider the case of an individual who live hand-to-mouth. Proposition 3 below begins by analyzing optimal spending levels.

Proposition 3. *For hand-to-mouth individuals and with* $\pi \in]0,1]$,

1. $m^*_{HTM}(\alpha) > m^E_{HTM}(\alpha) \; \forall \; \alpha \in]0,1]$,

2. $u''' \geq 0$ *is a sufficent condition for* $m^E_{HTM}(\alpha) > m^*_{HTM}(0) \; \forall \; \alpha \in]0,1]$.

The key difference to perfect liquidity is that now there is efficient moral hazard even if there is no risk: the socially optimally level of spending $m^E_{HTM}(\alpha)$ is higher than the level $m^*_{HTM}(0)$ that would be chosen when uninsured even at $\pi = 1$.[10] The reason for this result is that insurance provides financing to spread medical spending across more consumption periods, allowing spending to be borne in lower marginal utility periods than when uninsured. Both items of the proposition taken together show that for hand-to-mouth individuals, independent of the probability of loss, privately optimal medical spending is higher than the socially efficient medical spending at the same level of insurance, which is in turn higher than the uninsured level of medical spending.

The next proposition considers how the results on efficient spending carry over to the value of insurance and its individual components.

Proposition 4. *For $\pi \in]0,1]$, hand-to-mouth individuals have*

1. $V^{RF}_{HTM}(\alpha) > 0 \; \forall \; \alpha \in]0,1]$,
2. $u''' \geq 0$ *is a sufficient condition that* $V^{MHE}_{HTM}(\alpha) > 0 \; \forall \; \alpha \in]0,1]$.
3. *there exists* $\hat{\alpha} > 0$ *such that for* $\alpha \in]0,\hat{\alpha}]$, $V^{MH}_{HTM}(\alpha) > 0$ *if it holds that*

$$(N-2K\pi)u'\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right) - 2(N-K\pi)u'\left(\frac{y}{N}\right) > m^*_{HTM}(0)\frac{N-K\pi}{K}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right). \tag{23}$$

4. *there exists* $\hat{\alpha}' > \hat{\alpha}$ *such that for* $\alpha \in]0,\hat{\alpha}']$, $V_{HTM}(\alpha) > 0$ *if Condition* (23) *holds.*

First, item 1 of Proposition 4 considers the "risk and financing" value that holds fixed medical spending at the uninsured level. It is positive even for $\pi = 1$ when there is no uncertainty and thus no standard risk-reduction value from insurance. It becomes positive for the same reason why efficient spending with insurance is higher than $m^*_{HTM}(0)$ even if $\pi = 1$: insurance enables the financing of medical payments across all periods, allowing expenses to be borne in periods with lower marginal utility of consumption.

We now consider the moral hazard induced by the insurance coverage. We show in item 2 of Proposition 4 that individuals with liquidity constraints have a positive value of efficient moral hazard. And item 3 implies that under certain conditions this can be sufficiently high such that the entire moral hazard value of insurance is positive. Again, this result does not rely on $\pi < 1$ such that the result derived here is independent of that shown by (Nyman, 1999a).

Items 3 and 4 of the proposition allow us to answer the question whether insurance can be welfare increasing for hand-to-mouth individuals. Intuitively, this is dependent on several factors. First, when there is no downside to medical spending because insurance covers all costs, spending is going to be equal $\hat{m}$, that is, it is going to maximize the health benefits $h(m)$. If this maximal level of

[10] We assume $u''' \geq 0$, which is sufficient but not necessary. Most commonly used utility functions, including CARA and CRRA, satisfy this condition (Brockett and Golden, 1987).

spending multiplied by the probability of sickness is high compared to the annual income, insurance with a high coverage level is likely to be welfare decreasing. Second, increasing insurance coverage leads to disutility in all consumption periods due to an increase in the premium. This is offset by a decrease in out-of-pocket spending, which increases utility in the period in which medical spending has to be paid. If the out of pocket spending is sufficiently large (for example, because the marginal benefit of medical spending to health is high) then the net effect will be positive. otherwise, it can be negative, leading to insurance being welfare decreasing. Lastly, with increased curvature of the utility function, differences in marginal utility between the different consumption periods become stronger. This increases the just-described offsetting effect and increases the insurance value for hand-to-mouth individuals.

3.3.3 Comparing the Types of Individuals

In what way does living hand-to-mouth change the value of insurance for individuals? Propositions 1 to 4 answer this question for the case of certain losses. Here it is clear that under perfect liquidity, insurance only decreases welfare of the individual. The value of insurance is the highest when coverage is 0. For hand-to-mouth individuals, on the other hand, the value of insurance can indeed be positive such that a coverage level larger than 0 is increasing welfare for the individual. Intuitively, hand-to-mouth individuals benefit from the financing provided by insurance coverage while this benefit does not exist for perfect liquidity.

When introducing risk, the comparison gets more complicated. There is now the potential of efficient moral hazard for individuals with perfect liquidity due to the effect described by Nyman (1999a): insurance serves as a redistribution system from the healthy to the sick, making consumption higher in the sick state. This state has high marginal utility of consumption for uninsured individuals because medical spending has lowered consumption. Thus the redistribution increases expected utility. This effect gets stronger with lower loss probabilities and higher medical spending. Because medical spending is higher for individuals with perfect liquidity, this effect is larger for them than it is for hand-to-mouth individuals.

We can nevertheless make certain comparisons. The first one is an obvious result stemming from the different ways in which individuals can finance their medical spending:

Proposition 5. *For $K < N$, $m^*_{HTM}(\alpha) < m^*_{PL}(\alpha)$ for all $\alpha \in [0, 1[$.*

The first comparison on the value of insurance is concerning the situations in which the moral hazard value of insurance can be positive, at least for some coverage levels.

Proposition 6. *For $K < N$, if*

$$(1-2\pi)u'\left(\frac{y-m^*_{PL}(0)}{N}\right) - 2(1-\pi)u'\left(\frac{y}{N}\right) = m^*_{PL}(0)(1-\pi)\frac{1}{N}u''\left(\frac{y-m^*_{PL}(0)}{N}\right). \tag{24}$$

then Condition (23) *holds.*

The implications of this result are that Condition (23) is necessary for Condition (22) to hold, but that the opposite is not true. Thus, it is more likely that insurance has a positive moral hazard value for at least some coverage level when individuals are hand-to-mouth than when they have perfect liquidity. The next proposition makes a simplifying assumption on the health benefits function to establish that the existences of a positive moral hazard value is not only more likely for hand-to-mouth individuals than for those with perfect liquidity, but also that the range of coverage levels with a postive moral hazard value will be larger.

Proposition 7. *Assume that $K < N$, $u''' \geq 0$, and that benefits from medical spending are approximately linear in the relevant ranges of m_i. If for both types $\hat{\alpha}_i \in]0,1[$ exists such that $V_i^{MH}(\alpha) > 0$ if and only if $\alpha \in]0, \hat{\alpha}]$, then $\hat{\alpha}_{HTM} > \hat{\alpha}_{PL}$.*

Lastly, this result also establishes that a social planner, with the goal to maximize individual welfare, will choose a higher level of insurance coverage for hand-to-mouth individuals than for those with perfect liquidity.

Proposition 8. *For $K < N$, if benefits from medical spending are approximately linear in the relevant ranges of m_i and the optimal insurance coverage is characterized by an interior solution, then $\alpha^*_{HTM} > \alpha^*_{PL}$.*

4 Revising Estimates of the Value of Medicaid

4.1 Model

Finkelstein et al. (2019) (hereafter, FHL) derive a framework for evaluating the welfare consequence of the Medicaid expansion using data from the Oregon Health Insurance Experiment. Here, we adapt the model in their paper using our hand-to-mouth framework and derive an adjustment to one of the key equations in their analysis for the hand-to-mouth situation. We use that adjustment to re-estimate the value of Medicaid to recipients, focusing specifically on the impact of moral hazard on that value.

FHL lay out a variety of approaches to using data from the Oregon Health Insurance Experiment to evaluate Medicaid. We follow their consumption-based optimization approach, for which the baseline model and assumptions are close to the theoretical analysis we have presented above. In particular, the consumption-based optimization approach in FHL makes the assumption that people select a continuous level of health spending given a realized health shock by optimally trading off medical spending and consumption using a separable utility structure like we have presented in our baseline model. FHL discuss reasons why this approach might be in appropriate in practice (e.g. mistakes in allocating health spending, or lumpy health spending such that the first order conditions do not hold). These potential flaws are the same for the analysis we present below and we believe neither our results below nor the original FHL analysis using the consumption-based optimization are perfect measures of the value of Medicaid to recipients. The point of this exercise, however,

is to examine how different the existing estimates would be if we incorporate the assumption that Medicaid recipients live hand-to-mouth.

We follow the notation and setup in FHL, which differ a little from our model setup in Section 2. In the FHL model, individuals have utility over consumption c and health h, where health is a function of medical spending m: $U(c,h) = u(c) + h(m)$. Health status is indexed by θ. Finally, the level of insurance is $q \in \{0,1\}$, where $q = 1$ is insured and $q = 0$ is uninsured. The out-of-pocket spending on medical care is $x(q) = p(q)m(q;\theta)$, which is a function of total medical spending and its price p.

The key object in the FHL setup is $\gamma(q)$, which is a measure of Medicaid recipients willingness to pay for insurance and can be thought of as the premium that if paid would lead to the same utility level as being uninsured. That is, let $V(q)$ be the indirect utility of insurance level q:

$$V(q) = \max_{m(q;\theta)} \mathbb{E}_\theta \left[(N-K)u\left(\frac{y-\gamma(q)}{N}\right) + (K)u\left(\frac{y-\gamma(q)}{N} - \frac{x(q;\theta)}{K}\right) + h(m(q;\theta)) \right]$$

This equation is almost identical to the key utility function presented in FHL, escept that we let premiums (γ) be spread across N periods and let the annual medical spending be spread across K periods. Moreover, consistent with our modeling framework and the implicit assumptions of static models like those used in FHL, we assume that the realization of the health state occurs at the start of the insured period so that the individual with perfect liquidity can full smooth consumption across periods in the insured year. When $K = N$ (perfect liquidity), our version reduces to the FHL model. When $K = 1$, we have the hand-to-mouth case.

Our assumption about K for this analysis can be thought of as a joint assumption about the arrival of medical bills over time and the individual's underlying liquidity position. When $K = N$ we are assuming that equivalently that either individuals can fully smooth their consumption through costless borrowing and saving during the insured year or that bills for medical spending are spread out evenly throughout the year on a full payment plan. When $K = 1$ we are assuming that the individual has to pay for all medical spending in a single consumption period and is unable to borrow from or save in other consumption periods to help absorb the shock. Both the implicit assumption of perfect liquidity in FHL ($K = N$) nor the full hand-to-mouth case $K = 1$ are realistic in practice. In reality, medical spending shocks can arrive in a variety of temporal patterns and sizes throughout the year. In addition, even those with strong liquidity constraints may be offered payment plans and grace periods that provide some degree of financing for medical bills. Our framework could incorporate these realities if there were better data available on the arrival patterns of medical shocks over the course of the year and the availability of partial financing within the health system. For now, we highlight that the results for $K = N$ using the original FHL approach and for $K = 1$ for hand-to-mouth should provide a bounding of the potential value of Medicaid to recipients.

We now examine how willingness to pay, γ, changes with insurance. Following the derivation in FHL, adapted to the possibility of spreading premiums and medical expenses across difference numbers of periods, we get

$$\frac{d\gamma(q)}{dq} = \frac{\mathbb{E}[u'_L]}{\mathbb{E}\left[\frac{N-K}{N}u'_{NL} + \frac{K}{N}u'_L\right]}(p(0)-p(1))\mathbb{E}[m(q;\theta)] + \text{Cov}\left[\frac{u'_L}{\mathbb{E}\left[\frac{N-K}{N}u'_{NL} + \frac{K}{N}u'_L\right]}, (p(0)-p(1))m(q;\theta)\right], \tag{25}$$

where u'_{NL} is the marginal utility of consumption in the consumption periods where no out-of-pocket costs are incurred, so $u'_{NL} = u'\left(\frac{y-\gamma(q)}{N}\right)$. Similarly, u'_L is the marginal utility of consumption in the periods where out-of-pocket costs are incurred, so $u'_L = u'\left(\frac{y-\gamma(q)}{N} - \frac{x(q;\theta)}{K}\right)$.

Note that when $K = N$, this formula reduces to Equation 13 in FHL with income and spending values translated to the consumption period (i.e., monthly) level:

$$\frac{d\gamma(q)}{dq} = (p(0)-p(1))\mathbb{E}[m(q;\theta)] + \text{Cov}\left[\frac{u'\left(\frac{y-\gamma(q)-x(q;\theta)}{N}\right)}{\mathbb{E}\left[u'\left(\frac{y-\gamma(q)-x(q;\theta)}{N}\right)\right]}, (p(0)-p(1))m(q;\theta)\right] \tag{26}$$

FHL denote the first term as the "transfer term" of insurance and the second term as the "pure-insurance term". The transfer term in FHL is the change in out-of-pocket spending: the difference in the out-pocket price of medical care with and without insurance times expected medical spending at q.

When accounting for hand-to-mouth behavior with $K < N$, we see in Equation 25 that the transfer term is multiplied by a ratio of marginal utilities. The numerator, $\mathbb{E}[u'_L]$, is the expected marginal utility in periods when out-of-pocket medical costs are paid– that is, the benefit of lowering out-of-pocket spending via insurance. The denominator, $\mathbb{E}\left[\frac{N-K}{N}u'_{NL} + \frac{K}{N}u'_L\right]$, is the expected average marginal utility across all periods– that is, the utility cost of that insurance born across all consumption periods via increased premiums.

The multiplier on the transfer term can be quite large, because the expected marginal utility in the one period when you have to pay out for insurance losses can be much larger than the average marginal utility.

Turning to the "pure-insurance" term, it will also likely be larger in the hand-to-mouth case, as the first term in the covariance, the ratio of marginal utility in the periods suffering a loss to expected marginal utility, will be larger.

Finally, to get get the value of full insurance, FHL integrate this equation over q from 0 to 1. Since intermediate values of q are not observed, they approximate that value by assuming $\gamma(1) \approx \frac{1}{2}\left(\frac{d\gamma(0)}{dq} + \frac{d\gamma(1)}{dq}\right)$. We do the same here.

4.2 Data

In order to estimate the values in Equation 25 it is necessary to have data on Medical spending under Medicaid and for the same population when uninsured. FHL use data from the Oregon Health Insurance Experiment on medical spending and the randomization within that experiment to estimate the difference in spending due to insurance.

For our multiplier on the transfer term it is necessary to observe the distribution of out-of-pocket spending for the Medicaid population when uninsured. In addition, to estimate both the original "pure insurance" term in FHL and our modification of it, it is necessary to have data on the joint distribution of consumption and out-of-pocket spending for the uninsured.

FHL use two approaches for this and we follow their simpler approach, which they call the "consumption proxy approach". In this approach, they start with an average value of consumption for the low-income uninsured from the Consumer Expenditure Survey (CEX), that they estimate at \$9,214 for the time period and sample they use. They then add to that the average per-capita out-of-pocket spending for the uninsured in the Oregon Health Insurance Experiment to get a total baseline average income level of $y = \$9,505$. They then use the distribution of reported out-of-pocket spending for the uninsured in the Oregon Health Insurance Experiment and assume that the only variation in consumption comes from absorbing these out-of-pocket costs when uninsured. With Medicaid offering full insurance, the assumption in FHL is that the fully insured will all have fixed annual consumption at the baseline \$9,505.

The resulting distribution of consumption per year for the uninsured is plotted as Figure 1 in FHL. We used the replication packet available through the *Journal of Political Economy* to extract the underlying distribution used to make that plot. We use that information and the assumption about baseline income from FHL described above to estimate the values in Equation 25. We follow FHL in assuming that the consumption utility function takes the constant relative risk aversion (CRRA) form with coefficient of relative risk averion $\rho = 3$.

There is a complication that arises in the hand-to-mouth case with $K = 1$ due to the size of losses and the possibility of negative consumption. In the FHL paper, they impose an annual consumption floor of about \$2,000 (relative to starting annual income per person of \$9,505). As such, they cap the largest medical spending loss for the uninsured at about \$7,500 out of pocket. Under the hand-to-mouth (K = 1) assumption with $N = 12$, the monthly consumption from that annual \$9,500 is only \$792. The annual consumption floor of \$2k would imply a monthly consumption floor of \$167 and a maximum medical spending in any consumption period of \$625. The distribution of annual out-of-pocket medical expenses from FHL, though, has a fair number of losses much higher than \$625 (all the way to \$7,500). To deal with this, we assume that in cases where the individual faces a large medical bill, they are pushed to the consumption floor for approximately as many periods as it takes to cover the loss. So for example, assume the annual spending is \$1,250, then we'd have two periods of medical spending of \$625 and 10 periods (in N = 12 case) of no medical spend. The

relevant marginal utility then is the marginal utility at that per-period consumption floor.[11] As such, we are implicitly allowing for a degree of financing or payment plans for larger hospital bills but only in cases where the medical spending pushes the individual to the consumption floor. This may be a reasonable approximation to hospital financing plans provided to the uninsured with low incomes.

4.3 Estimates

Table 1 below shows our implementation of the FHL accounting for hand-to-mouth behavior where premiums are spread over $N = 12$ months and expenses borne in $K = 1$ months. We present in the first column of our table the results using our data and approach under the assumption of perfect liquidity $K = N$. These values can be compared to those in the second column of FHL Table 3. Column 2 shows the hand-to-mouth case with $K = 1$.

Table 1 – The Value of Medicaid under Liquidity Constraints

	Perfect Liquidity $K = 12$	Hand to Mouth $K = 1$
$\gamma(1)$, Estimated WTP	2,342	3,761
T, Transfer Component	683	1,514
I, Pure Insurance Component	1,659	2,247
Moral Hazard Cost	767	-733

Note: Note Note Note.

We estimate a transfer component term of $683 under perfect liquidity, which is very close to the $661 reported by FHL.[12] Given that Medicaid involves a transfer of $1,450 to these individuals, this implies a "moral hazard cost" using FHL's definition of that term of $767. While this is not the same as our definition of the value of moral hazard presented in Section 2, as FHL discuss it is one way of quantifying the gap between cost and valuation that arises due to moral hazard.

The transfer component after adjusting for our multiplier due to the liquidity value of insurance for the hand-to-mouth individual rises is more than twice as high at $1,514. This is more than the full transfer cost of Medicaid, which implies a *negative* moral hazard cost (i.e., benefit) of $733.

[11] We implement this procedure by rounding to avoid issues with "loss periods" having different consumption levels and hence different marginal utilities. For example, suppose the loss was $1,300. In this case after two periods of paying $625 you would still be $50 short of covering the full loss. We rounded to the nearest full number of periods required to pay the loss. So for $1,300, we'd have two periods of $625 but for a case of $1,625 we'd have 3 periods of paying $625 and technically overspend relative to the baseline loss. This rounding is unlikely to have a major effect on the estimates, since sometimes it rounds up and sometimes down.

[12] We expect small differences due to computational differences and because we are using the distribution of per-capita spending they report in Figure 1, while they are using household-level data and normalizing by household size.

We also estimate a "pure insurance" component using FHL's terminology that is $831 higher under the hand-to-mouth assumption.[13] The resulting estimated WTP for Medicaid is 1.6 times higher for the hand-to-mouth individuals. We note that not only is the WTP for the hand-to-mouth individual above the cost of providing Medicaid to the individuals who receive it, but it is also even a little above the full cost of Medicaid including the portion that copmensates health care providers for uncompensated medical care for the uninsured (which accounts for about 60% of costs according to the calculations in FHL).

These results suggest that the value of Medicaid could be substantially understated if the recipients of Medicaid tend to be highly liquidity constrained, which is a reasonable assumption and consistent with some evidence on the liquidity-sensitivity of medical utilization. The exact valuation estimated here is unlikely to be correct, for the reasons outlined above, but provides a useful upper bound on the value to compare with the original estimates. The fact that the valuation is sensitive to liquidity constraints and that the interpretation of moral hazard's welfare impact reverses under the hand-to-mouth assumption suggests there would be substantial policy value to additional data on the liquidity positions of recipients and the underlying patterns of medical spending and consumption so that policy recommendations can reflect the value of insurance under liquidity constraints.

5 Conclusion

This paper reexamined the interpretation of observed moral hazard in the presence of liquidity constraints. It provides a decomposition into efficient and inefficient moral hazard, in contrast to the traditional view of moral hazard as being wasteful and valued at less than cost. Because insurance effectively offers a way to smoothly finance lumpy expenditures, the socially optimal amount of spending will increase when an individual gets access to insurance.

Accounting for liquidity constraints is important when evaluating the value of expanding insurance programs, particularly for low-income populations. Our reevaluation of the value of Medicaid expansion shows that liquidity constrained recipients would receive a much higher benefit than previously estimated. This would affect the normative evaluation of the expansion.

Our empirical application shows that in the hand-to-mouth model, efficient moral hazard is quite large and meaningfully changes our normative interpretation of results. The hand-to-mouth model is a reasonable model for many low-income individuals, but further work could examine both the role of high borrowing costs as well as behavioral biases, such as present-focus or overconfidence.

Our model changes the interpretation of moral hazard. Our empirical application considers access to Medicaid– a move from uninsurance to insurance that requires virtually no cost-sharing. Our results could also be extended to examine the optimal *level* of insurance, trading off the costs

[13] Those familiar with the FHL paper will note that our estimate of the "pure insurance" component under perfect liquidity is substantially larger than the value estimated in the original FHL paper. We believe this discrepancy is due to some errors in the calculation of the covariance terms in the original FHL paper.

(and benefits) of additional moral hazard against the risk protection gains. Accounting for liquidity constraints is also necessary to determine the optimal level of cost-sharing in many different health insurance programs, and our approach will generally imply a different level of optimal coverage for people with liquidity constraints.

Finally, while we have focused on health insurance, liquidity constraints affect the interpretation of moral hazard in many other insurance domains, such as auto insurance (see Cummins and Tennyson (1996)), including social insurance such as workers' compensation insurance (see Dionne and St-Michel (1991)), or unemployment insurance (see Chetty (2008)).

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Appendix A Proofs

A.1 Proof of Proposition 1

Proof. Item 1: Define $A(m) = \frac{y-\alpha\pi m}{N}$ and $B(m) = \frac{y-(1-\alpha)m-\alpha\pi m}{N}$. Then, $m^E_{PL}(\alpha)$ is implicitly defined by

$$h'(m^E_{PL}(\alpha)) - (1-\pi)\alpha u'(A(m^E_{PL}(\alpha))) - (1-\alpha(1-\pi))u'(B(m^E_{PL}(\alpha))) = 0. \tag{A1}$$

We label Equation (A1) as F and apply the implicit function theorem to obtain $\frac{\partial m^E_{PL}(\alpha)}{\partial \alpha} = -\frac{\frac{\partial F}{\partial \alpha}}{\frac{\partial F}{\partial m}}$. From

$$\frac{\partial F}{\partial m} = h''(m^E_{PL}(\alpha)) + \frac{1-\pi}{N}\alpha^2\pi u''(A(m^E_{PL}(\alpha))) + \frac{(1-\alpha(1-\pi))^2}{N}u''(B(m^E_{PL}(\alpha))) < 0 \tag{A2}$$

we know that $sgn\left(\frac{\partial m^E_{PL}(\alpha)}{\partial \alpha}\right) = sgn\left(\frac{\partial F}{\partial \alpha}\right)$ where $sgn(\cdot)$ denotes the sign of an expression. Taking the partial derivative and rearranging renders

$$\begin{aligned}\frac{\partial F}{\partial \alpha} =& (1-\pi)[u'(B(m^E_{PL}(\alpha))) - u'(A(m^E_{PL}(\alpha)))] - (1-\pi)(1-\alpha)\frac{m}{N}u''(B(m^E_{PL}(\alpha))) \\ &+ (1-\pi)\pi\alpha\frac{m}{N}[u''(A(m^E_{PL}(\alpha))) - u''(B(m^E_{PL}(\alpha)))].\end{aligned} \tag{A3}$$

The first and second terms are positive from $u'' < 0$. The third term is positive if $u''' > 0$. This establishes $u''' > 0$ as a sufficient condition for $\frac{\partial m^E_{PL}(\alpha)}{\partial \alpha} > 0$.

Item 2: We abbreviate $EU_{PL}(\alpha, m^E_{PL}(\alpha))$ as EU^E_{PL} for legibility. Note that $\pi F = \frac{\partial EU^E_{PL}}{\partial m}$. Thus, by Equation (A2), the second order condition for $m^E_{PL}(\alpha)$ is fulfilled. Further, $m^*_{PL}(\alpha)$ is implicitly defined by

$$h'(m^*_{PL}(\alpha)) - (1-\alpha)u'(B(m^*_{PL}(\alpha))) = 0. \tag{A4}$$

We evaluate $\frac{\partial EU^E_{PL}}{\partial m}$ at $m^*_{PL}(\alpha)$ and obtain:

$$\left.\frac{\partial EU^E_{PL}}{\partial m}\right|_{m^*_{PL}(\alpha)} = -\pi(1-\pi)u'(A(m^*_{PL}(\alpha))) - \pi^2\alpha u'(B(m^*_{PL}(\alpha))) < 0. \tag{A5}$$

It follows that $m^E_{PL}(\alpha) > m^*_{PL}(\alpha)\ \forall\ \alpha \in]0,1]$.

Item 3: Analogous to item 2, we evaluate $\frac{\partial EU^E_{PL}}{\partial m}$ at $m^*_{PL}(0)$ and obtain

$$\left.\frac{\partial EU^E_{PL}}{\partial m}\right|_{m^*_{PL}(0)} = \pi u'\left(\frac{y - m^*_{PL}(0)}{N}\right) - (1-\pi)\alpha u'(A(m^E_{PL}(0))) - (1-\alpha(1-\pi))u'(B(m^E_{PL}(0))). \tag{A6}$$

Setting $\pi = 1$, the above reduces to $\left.\frac{\partial EU^E_{PL}}{\partial m}\right|_{m^*_{PL}(0)} = u'\left(\frac{y-m^*_{PL}(0)}{N}\right) - u'\left(\frac{y-\alpha m^*_{PL}(0)-(1-\alpha)m^*_{PL}(0)}{N}\right) = 0$. Thus $m^E_{PL}(\alpha) = m^*_{PL}(0)\ \forall\ \alpha \in]0,1]$ if $\pi = 1$.

Item 4: Setting $\alpha = 0$ in Equation (A1) shows that $m^E_{PL}(0) = m^*_{PL}(0)$. Item 4 then follows from item 1. □

A.2 Proof of Proposition 2

Proof. Item 1: From Proposition 1 we know that under perfect liquidity and $\pi = 1$,

$$V^{MH}_{PL}(\alpha) = EU_{PL}(\alpha, m^*_{PL}(\alpha)) - EU_{PL}(\alpha, m^E_{PL}(\alpha)). \tag{A7}$$

Further, $m^E_{PL}(\alpha)$ is the level of m that at coverage level α maximizes expected utility if $p = \pi\alpha m$. Since we know from Proposition 1 that $m^*_{PL}(\alpha) \neq m^E_{PL}(\alpha)$, $EU_{PL}(\alpha, m^*_{PL}(\alpha)) < EU_{PL}(\alpha, m^E_{PL}(\alpha))$ and thus $V^{MH}_{PL}(\alpha) < 0$. Further, because for $\pi = 1$, $EU_{PL}(\alpha, m^*_{PL}(0)) = Nu\left(\frac{y-(1-\alpha)m^*_{PL}(0)-\alpha m^*_{PL}(0)}{N}\right) + h(m^*_{PL}(0)) = Nu\left(\frac{y-m^*_{PL}(0)}{N}\right) + h(m^*_{PL}(0)) = EU(0, m^*_{PL}(0))$ it follows that $V^{RF}_{PL}(\alpha) = 0$. Thus $V_{PL}(\alpha) < 0$.

Item 2: We rearrange $V^{RF}_{PL}(\alpha)$ and utilize $u'' < 0$ to obtain

$$\begin{aligned} V^{RF}_{PL}(\alpha) = {} & \pi N\left[u\left(\frac{y-(1-\alpha(1-\pi))m^*_{PL}(0)}{N}\right) - u\left(\frac{y-m^*_{PL}(0)}{N}\right)\right] \\ & + (1-\pi)N\left[u\left(\frac{y-\alpha\pi m^*_{PL}(0)}{N}\right) - u\left(\frac{y}{N}\right)\right] \qquad \text{(A8)} \\ > {} & m^*_{PL}(0)\alpha\pi(1-\pi)N\left[u'\left(\frac{y-(1-\alpha(1-\pi))m^*_{PL}(0)}{N}\right) - u'\left(\frac{y-\alpha\pi m^*_{PL}(0)}{N}\right)\right] > 0 \qquad \text{(A9)} \end{aligned}$$

Item 3: From Proposition 1 we know that $u''' \geq 0$ is sufficient for $m^E_{PL}(\alpha) > m^*_{PL}(0)\ \forall\ \alpha \in]0,1]$ when $\pi \in]0,1[$. Because $m^E_{PL}(\alpha)$ maximizes expected utility for coverage level α, it follows that $EU_{PL}(\alpha, m^E_{PL}(\alpha)) > EU_{PL}(\alpha, m^*_{PL}(0))$ and thus $V^{MHE}_{PL}(\alpha) > 0$.

Item 4: From Equation (5), we can see that $V^{MH} = 0$ if $\alpha = 0$. Abbreviating $\pi\alpha m^*_{PL}(\alpha)$ as p_α and $\pi\alpha m^*_{PL}(0)$ as p_0, we have

$$\begin{aligned} \frac{\partial V^{MH}}{\partial\alpha} = {} & \pi\left[\left(m^*_{PL}(\alpha) - \frac{\partial p_\alpha}{\partial\alpha} - \frac{\partial m^*_{PL}(\alpha)}{\partial\alpha}(1-\alpha)\right)u'(B(m^*_{PL}(\alpha))) + \frac{\partial m^*_{PL}(\alpha)}{\partial\alpha}h'(m^*_{PL}(\alpha))\right] \\ & - (1-\pi)\frac{\partial p_\alpha}{\partial\alpha}u'(A(m^*_{PL}(\alpha))) - \pi\left(m^*_{PL}(0) - \frac{\partial p_0}{\partial\alpha}\right)u'(B(m^*_{PL}(0))) \\ & - (1-\pi)\frac{\partial p_0}{\partial\alpha}u'(A(m^*_{PL}(0))) \end{aligned} \tag{A10}$$

Substituting the first order condition, we obtain

$$\begin{aligned} \frac{\partial V^{MH}}{\partial\alpha} = {} & \pi\left(m^*_{PL}(\alpha) - \frac{\partial p_\alpha}{\partial\alpha}\right)u'(B(m^*_{PL}(\alpha))) - (1-\pi)\frac{\partial p_\alpha}{\partial\alpha}u'(A(m^*_{PL}(\alpha))) \\ & - \pi\left(m^*_{PL}(0) - \frac{\partial p_0}{\partial\alpha}\right)u'(B(m^*_{PL}(0))) - (1-\pi)\frac{\partial p_0}{\partial\alpha}u'(A(m^*_{PL}(0))) \end{aligned} \tag{A11}$$

At $\alpha = 0$, $\frac{\partial p_\alpha}{\partial \alpha} = 0\frac{\partial m^*(\alpha)}{\partial \alpha}\pi + m^*(0)\pi = \frac{\partial p_0}{\partial \alpha}$. Thus, $\left.\frac{\partial V^{MH}}{\partial \alpha}\right|_{\alpha=0} = 0$. Further

$$\begin{aligned}
\frac{\partial^2 V^{MH}}{\partial \alpha^2} =& \pi\left(\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha} - \frac{\partial^2 p_\alpha}{\partial \alpha^2}\right) u'(B(m^*_{PL}(\alpha))) \\
&- \pi\left(m^*_{PL}(\alpha) - \frac{\partial p_\alpha}{\partial \alpha}\right)\left(\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha}(1-\alpha) - m^*(\alpha) + \frac{\partial p_\alpha}{\partial \alpha}\right)\frac{1}{N}u''(B(m^*_{PL}(\alpha))) \\
&- (1-\pi)\left[\frac{\partial^2 p_\alpha}{\partial \alpha^2}u'(A(m^*_{PL}(\alpha))) - \left(\frac{\partial p_\alpha}{\partial \alpha}\right)^2\frac{1}{N}u''(A(m^*_{PL}(\alpha)))\right] \\
&+ \pi\left[\frac{\partial^2 p_0}{\partial \alpha^2}u'(B(m^*_{PL}(0))) - \left(m^*_{PL}(0) - \frac{\partial p_0}{\partial \alpha}\right)^2\frac{1}{N}u''(B(m^*_{PL}(0)))\right] \\
&- (1-\pi)\left[\frac{\partial^2 p_0}{\partial \alpha^2}u'(A(m^*_{PL}(0))) - \left(m^*_{PL}(0) - \frac{\partial p_0}{\partial \alpha}\right)^2\frac{1}{N}u''(A(m^*_{PL}(0)))\right] \qquad \text{(A12)}
\end{aligned}$$

Observe $\frac{\partial^2 p_\alpha}{\partial \alpha^2} = 2\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha}\pi + \alpha\frac{\partial^2 m^*_{PL}(\alpha)}{\partial \alpha^2}\pi$ and $\frac{\partial^2 p_0}{\partial \alpha^2} = 0$. Evaluating at $\alpha = 0$ and again using that in this case $\frac{\partial p_\alpha}{\partial \alpha} = \frac{\partial p_0}{\partial \alpha}$ we can see that

$$\begin{aligned}
\left.\frac{\partial^2 V^{MH}}{\partial \alpha^2}\right|_{\alpha=0} =& \pi\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha}\left[(1-2\pi)u'(B(m^*_{PL}(0))) - m*_{PL}(0)(1-\pi)\frac{1}{N}u''(B(m^*_{PL}(0)))\right] \\
&- \pi\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha}2(1-\pi)u'(A(m^*_{PL}(0))) \qquad \text{(A13)}
\end{aligned}$$

If V^{MH} is zero with slope zero at $\alpha = 0$, then it most be positive for some values of α to the right of 0 if it is convex at $\alpha = 0$. From Equation (A4) and the implicit function theorem, we can see that

$$\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha} = -\frac{u'(B(m^*_{PL}(\alpha))) - (1-\alpha)\frac{m}{N}u''(B(m^*_{PL}(\alpha)))}{h''(m^*_{PL}(\alpha)) + \frac{(1-\alpha)^2}{N}u''(B(m^*_{PL}(\alpha)))} > 0. \qquad \text{(A14)}$$

Thus, $\left.\frac{\partial^2 V^{MH}}{\partial \alpha^2}\right|_{\alpha=0}$ is positive if Condition (22) is fulfilled.

Item 5: Follows immediately from $V^{\Sigma}_{PL} = V^{RF}_{PL} + V^{MH}_{PL}$ and items 2 and 3. □

A.3 Proof or Proposition 3

Proof. Item 1: For the hand-to-mouth individuals we abbreviate $\frac{y-\alpha\pi m}{N} = A(m)$ and $\frac{y-\alpha\pi m}{N} - \frac{(1-\alpha)m}{K} = B(m)$.[14] We further abbreviate $EU_{HTM}(\alpha, m^E_{HTM}(\alpha))$ as EU^E_{HTM} for legibility. To find the efficient level of medical spending, we assume that the individual can commit on a level of

[14] We do not index for the type of individual for legibility unless it is necessary.

medical spending *ex-ante* such that the first order condition for this level is given by

$$\begin{aligned}\frac{\partial EU^E_{HTM}}{\partial m} =&\pi h'(m^E_{HTM}(\alpha)) - (1-\pi)\alpha\pi u'(A(m^E_{HTM}(\alpha))) \\ &- \pi\left[\frac{N-K}{N}\alpha\pi u'(A(m^E_{HTM}(\alpha))) + \left(\frac{\alpha\pi K}{N} + (1-\alpha)\right)u'(B(m^E_{HTM}(\alpha)))\right] = 0.\end{aligned} \tag{A15}$$

The second order condition is fulfilled as can be seen by

$$\begin{aligned}\frac{\partial^2 EU^E_{HTM}}{\partial m^2} =&\pi\left[(N-K)\left(\frac{\alpha\pi}{N}\right)^2 u''(A(m^E_{HTM}(\alpha))) + K\left(\frac{\alpha\pi}{N} + \frac{1-\alpha}{K}\right)^2 u''(B(m^E_{HTM}(\alpha)))\right] \\ &+ \pi h''(m^E_{HTM}(\alpha)) + (1-\pi)\frac{(\alpha\pi)^2}{N}u''(A(m^E_{HTM}(\alpha))) < 0.\end{aligned} \tag{A16}$$

We now evaluate $\frac{\partial EU^E_{HTM}}{\partial m}$ at $m^*_{HTM}(\alpha)$ which is implicitly defined by

$$h'(m^*_{HTM}(\alpha)) - (1-\alpha)u'(B(m^*_{HTM}(\alpha))) = 0 \tag{A17}$$

and obtain

$$\begin{aligned}\left.\frac{\partial EU^E_{HTM}}{\partial m}\right|_{m^*_{HTM}(\alpha)} =& -\pi^2\alpha\left[\frac{N-K}{N}u'(A(m^*_{HTM}(\alpha))) + \frac{K}{N}u'(B(m^*_{HTM}(\alpha)))\right] \\ &- (1-\pi)u'(A(m^*_{HTM}(\alpha))) < 0\end{aligned} \tag{A18}$$

Item 2: From the implicit function theorem, we can then infer that $sgn\left(\frac{\partial m^E_{HTM}(\alpha)}{\partial\alpha}\right) = sgn\left(\frac{\partial^2 EU^E_{HTM}}{\partial m\partial\alpha}\right)$. The relevant expression is

$$\begin{aligned}\frac{\partial^2 EU^E_{HTM}}{\partial m\partial\alpha} =& -\pi\left[\left(\frac{N-K}{N}\pi + (1-\pi)\right)u'(A(m^E_{HTM}(\alpha))) + \left(\frac{K}{N}\pi - 1\right)u'(B(m^E_{HTM}(\alpha)))\right] \\ &+ u''(A(m^E_{HTM}(\alpha)))m^E_{HTM}(\alpha)\pi\left[\pi^2\alpha\frac{N-K}{N^2} + (1-\pi)\pi\alpha\frac{1}{N}\right] \\ &- u''(B(m^E_{HTM}(\alpha)))m^E_{HTM}(\alpha)\pi\left[\pi\alpha\frac{N-K\pi}{N^2} + (1-\alpha)\frac{N-K\pi}{NK}\right].\end{aligned} \tag{A19}$$

The first line equals $\pi\left(1-\frac{K}{N}\pi\right)\left(u'(B(m^E_{HTM}(\alpha))) - u'(A(m^E_{HTM}(\alpha)))\right)$ and is thus positive due to $u'' < 0$. From $u''' > 0$, we know that $u''(B(m^E_{HTM}(\alpha))) < u''(A(m^E_{HTM}(\alpha)))$. For the second and third line to be positive, it thus remains to be shown that $\pi^2\alpha\frac{N-K}{N^2} + (1-\pi)\pi\alpha\frac{1}{N} \leq \pi\alpha\frac{N-K\pi}{N^2} + (1-\alpha)\frac{N-K\pi}{NK}$. This expression reduces to $0 \leq (1-\alpha)\frac{N-K\pi}{NK}$ which is true for $\alpha \in [0,1]$. Thus $u''' > 0$ is sufficient for $\frac{\partial m^E_{HTM}(\alpha)}{\partial\alpha} > 0$. For any $\alpha > 0$, it follows that $m^E_{HTM}(\alpha) > m^E_{HTM}(0) = m^*_{HTM}(0)$. □

A.4 Proof or Proposition 4

The proof to this proposition follows the same steps as that for the corresponding items in the proof to Proposition 2. When the proofs differ, the steps are nevertheless stated for completeness.

Proof. Item 1: By virtue of $u'' < 0$, it follows that

$$
\begin{aligned}
V^{RF}_{HTM}(\alpha) &= EU_{HTM}(\alpha, m^*_{HTM}(0)) - EU_{HTM}(0, m^*_{HTM}(0)) && \text{(A20)}\\
&= \pi \left[(N-K) \left[u\left(\frac{y - \pi\alpha m^*_{HTM}(0)}{N} \right) - u\left(\frac{y}{N} \right) \right] \right.\\
&\quad \left. Ku\left(\frac{y - \pi\alpha m^*_{HTM}(0)}{N} - \frac{(1-\alpha) m^*_{HTM}(0)}{K} \right) - u\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K} \right) \right]\\
&\quad + (1-\pi)N \left[u\left(\frac{y - \pi\alpha m^*_{HTM}(0)}{N} \right) - u\left(\frac{y}{N} \right) \right] && \text{(A21)}\\
&> \alpha m^*_{HTM}(0) \left(1 - \frac{\pi K}{N} \right) \left[u'\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K} \right) - u'\left(\frac{y - \pi\alpha m^*_{HTM}(0)}{N} \right) \right] && \text{(A22)}
\end{aligned}
$$

This expression is positive, because $u'\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K} \right) > u'\left(\frac{y - \pi\alpha m^*_{HTM}(0)}{N} \right)$ by $u'' < 0$.

Item 2: Proof is analogous to item 3 in Proposition 2.

Item 3: As in the PL case, we can see from Equation 5 that $V^{MH}_{HTM} = 0$ if $\alpha = 0$. Using the definitions of $A(m)$ and $B(m)$ as above and abbreviating $\pi\alpha m^*_{HTM}(\alpha)$, we write

$$
\begin{aligned}
\frac{\partial V^{MH}_{HTM}}{\partial \alpha} =& -\pi \left[\frac{N-K}{N} \frac{\partial p_\alpha}{\partial \alpha} u'(A(m^*_{HTM}(\alpha))) + K \left(\frac{1}{N} \frac{\partial p_\alpha}{\partial \alpha} + \frac{1-\alpha}{K} \frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha} \right.\right.\\
&\left.\left. -\frac{1}{K} m^*_{HTM}(\alpha) \right) u'(B(m^*_{HTM}(\alpha))) \right] - (1-\pi) \frac{\partial p_\alpha}{\partial \alpha} u'(A(m^*_{HTM}(\alpha)))\\
&+ \pi \frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha} h'(m^*_{HTM}(\alpha)) + (1-\pi)\pi m^*_{HTM}(0) u'(A(m^*_{HTM}(0)))\\
&+ \pi m^*_{HTM} \left[\frac{N-K}{N} \pi(0) u'(A(m^*_{HTM}(0))) + K \left(\frac{\pi}{N} - \frac{1}{K} \right) u'(B(m^*_{HTM}(0))) \right] && \text{(A23)}
\end{aligned}
$$

We substitute the first-order condition for $m^*_{HTM}(\alpha)$ and obtain:

$$
\begin{aligned}
\frac{\partial V^{MH}_{HTM}}{\partial \alpha} =& -\pi \left[\frac{N-K}{N} \frac{\partial p_\alpha}{\partial \alpha} u'(A(m^*_{HTM}(\alpha))) + K \left(\frac{1}{N} \frac{\partial p_\alpha}{\partial \alpha} - \frac{1}{K} m^*_{HTM}(\alpha) \right) u'(B(m^*_{HTM}(\alpha))) \right]\\
&- (1-\pi) \frac{\partial p_\alpha}{\partial \alpha} u'(A(m^*_{HTM}(\alpha))) + (1-\pi)\pi m^*_{HTM}(0) u'(A(m^*_{HTM}(0)))\\
&+ \pi m^*_{HTM} \left[\frac{N-K}{N} \pi(0) u'(A(m^*_{HTM}(0))) + K \left(\frac{\pi}{N} - \frac{1}{K} \right) u'(B(m^*_{HTM}(0))) \right] && \text{(A24)}
\end{aligned}
$$

At $\alpha = 0$, $\frac{\partial p_\alpha}{\partial \alpha} = \pi m^*_{HTM}(0)$ and thus $\left.\frac{\partial V^{MH}_{HTM}}{\partial \alpha}\right|_{\alpha=0} = 0$. Further

$$\begin{aligned}
\frac{\partial^2 V^{MH}_{HTM}}{\partial \alpha^2} =& \pi \frac{N-K}{N} \frac{\partial^2 p_\alpha}{\partial \alpha^2} u'(A(m^*_{HTM}(\alpha))) + \pi \frac{N-K}{N} \left(\frac{\partial p_\alpha}{\partial \alpha}\right)^2 u''(A(m^*_{HTM}(\alpha))) \\
&- \pi K \left(\frac{1}{N}\frac{\partial^2 p_\alpha}{\partial \alpha^2} - \frac{1}{K}\frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha}\right) u'(B(m^*_{HTM}(\alpha))) \\
&+ \pi K \left(\frac{1}{N}\frac{\partial p_\alpha}{\partial \alpha} - \frac{m^*_{HTM}(\alpha)}{K}\right)\left(\frac{1}{N}\frac{\partial p_\alpha}{\partial \alpha} + (1-\alpha)\frac{1}{K}\frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha} - \frac{m^*_{HTM}(\alpha)}{K}\right) u''(B(m^*_{HTM}(\alpha))) \\
&- (1-\pi)\frac{\partial^2 p_\alpha}{\partial \alpha^2} u'(A(m^*_{HTM}(\alpha))) + (1-\pi)\left(\frac{\partial p_\alpha}{\partial \alpha}\right)^2 \frac{1}{N} u''(A(m^*_{HTM}(\alpha))) \\
&- \pi \frac{N-K}{N^2} (\pi m^*_{HTM}(0))^2 u''(A(m^*_{HTM}(0))) - (1-\pi)\frac{1}{N}(\pi m^*_{HTM}(0))^2 u''(A(m^*_{HTM}(0))) \\
&- \pi K \left(\frac{\pi m^*_{HTM}(0)}{N} - \frac{m^*_{HTM}(0)}{K}\right)^2 u''(B(m^*_{HTM}(0))) \qquad \text{(A25)}
\end{aligned}$$

Observe that as in the PL case $\frac{\partial^2 p_\alpha}{\partial \alpha^2} = 2\frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha}\pi + \alpha \frac{\partial^2 m^*_{HTM}(\alpha)}{\partial \alpha^2}\pi$. Evaluating at $\alpha = 0$ and again using that in this case $\frac{\partial p_\alpha}{\partial \alpha} = \pi m^*_{HTM}(0)$ we can see that

$$\begin{aligned}
\left.\frac{\partial^2 V^{MH}_{HTM}}{\partial \alpha^2}\right|_{\alpha=0} =& \pi \frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha}\Big[(N - 2K\pi)u'(B(m^*_{HTM}(0))) - 2(N - K\pi)u'(A(m^*_{HTM}(0))) \\
&- \frac{N - \pi K}{K} u''(B(m^*_{HTM}(0)))\Big] \qquad \text{(A26)}
\end{aligned}$$

Note that from the implicit definition of $m^*_{HTM}(\alpha)$ we can show

$$\frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha} = -\frac{u'(B(m^*_{HTM}(\alpha))) - (1-\alpha)\frac{m}{K}u''(B(m^*_{HTM}(\alpha)))}{h''(m^*_{HTM}(\alpha)) + \frac{(1-\alpha)^2}{K}u''(B(m^*_{HTM}(\alpha)))} > 0. \qquad \text{(A27)}$$

We can thus conclude that $\left.\frac{\partial^2 V^{MH}_{HTM}}{\partial \alpha^2}\right|_{\alpha=0} > 0$ if and only if Condition (23) holds.

Item 4: Follows immediately from $V^{\Sigma}_{HTM} = V^{RF}_{HTM} + V^{MH}_{HTM}$ and items 1 and 3. □

A.5 Proof or Proposition 5

We consider the first order condition for $m^*_{HTM}(\alpha)$ in Equation (A17) and evaluate it at $m^*_{PL}(\alpha)$ as implicitly defined in Equation (A4). We obtain

$$(1-\alpha)\left[u'\left(\frac{y - \alpha\pi m^*_{PL}(\alpha) - (1-\alpha)m^*_{PL}(\alpha)}{N}\right) - u'\left(\frac{y - \alpha\pi m^*_{HTM}(\alpha)}{N} - \frac{(1-\alpha)m^*_{HTM}(\alpha)}{K}\right)\right]. \qquad \text{(A28)}$$

From $\frac{y-\alpha\pi m^*_{PL}(\alpha)-(1-\alpha)m^*_{PL}}{N} > \frac{y-\alpha\pi m^*_{HTM}(\alpha)}{N} - \frac{(1-\alpha)m^*_{HTM}}{K}$ and $u'' < 0$, we know that the above expression is negative. The second order condition for $m^*_{HTM}(\alpha)$ is fulfilled as can be seen by

$$h''(m^*_{HTM}(\alpha)) + \frac{(1-\alpha)^2}{K}u''\left(\frac{y - \alpha\pi m^*_{HTM}(\alpha)}{N} - \frac{(1-\alpha)m^*_{HTM}}{K}\right) < 0. \qquad \text{(A29)}$$

Thus we can conclude that $m^*_{PL}(\alpha) > m^*_{HTM}(\alpha)$.

A.6 Proof of Proposition 6

Proof. Note that for $K = N$ Condition (23) is equivalent to Condition (22). Treating K as continuous for simplicity, we consider the slope of the term $F = (N - 2K\pi)u'\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right) - 2(N - K\pi)u'\left(\frac{y}{N}\right) - m^*_{HTM}(0)\frac{N-K\pi}{K}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)$ in K.

$$\begin{aligned}\frac{\partial F}{\partial K} =& 2\pi\left(u'\left(\frac{y}{N}\right) - u'\left(\frac{y}{N} - \frac{m^*_{PL}(0)}{K}\right)\right) - (N - 2K\pi)\frac{\frac{\partial m^*_{HTM}(0)}{\partial K}K - m^*_{HTM}(0)}{K^2}u''\left(\frac{y}{N} - \frac{m^*_{PL}(0)}{K}\right)\\ &- \left(\frac{\partial m^*_{HTM}(0)}{\partial K}\frac{N - K\pi}{K} - \frac{m^*_{HTM}(0)N}{K}\right)u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)\\ &+ m^*_{HTM}(0)\frac{N - K\pi}{K}\frac{\frac{\partial m^*_{HTM}(0)}{\partial K}K - m^*_{HTM}(0)}{K^2}u'''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right) \qquad \text{(A30)}\end{aligned}$$

Now consider $\frac{\partial m^*_{HTM}(0)}{\partial K}$. From the implicit definition of $m^*_{HTM}(0)$, we can see that

$$\frac{\partial m^*_{HTM}(0)}{\partial K} = -\frac{-\frac{m^*_{HTM}(0)}{K^2}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)}{h''(m^*_{HTM}(0)) + \frac{1}{K}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)} > 0. \qquad \text{(A31)}$$

Notice further that

$$\frac{\partial m^*_{HTM}(0)}{\partial K} < \frac{\frac{m^*_{HTM}(0)}{K^2}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)}{\frac{1}{K}u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)} = \frac{m^*_{HTM}(0)}{K} \qquad \text{(A32)}$$

We substitute this into Equation (A30) and reduce the expression to see that

$$\frac{\partial F}{\partial K} < 2\pi\left(u'\left(\frac{y}{N}\right) - u'\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right)\right) + \frac{m^*_{HTM}(0)}{K}\pi u''\left(\frac{y}{N} - \frac{m^*_{HTM}(0)}{K}\right) < 0. \qquad \text{(A33)}$$

Thus, when K decreases, F becomes larger. If $F = 0$ at $K = N$, it thus has to be positive for $K < N$. □

A.7 Proof or Proposition 7

We again refrain from indexing individual types for brevity. All equations below pertain to hand-to-mouth individuals. We abbreviate $\frac{y-\alpha\pi m^*(\alpha)}{N} = A(m^*)$, $\frac{y-\alpha\pi m^*(0)}{N} = A(m^0)$, $\frac{y-\alpha\pi m^*(\alpha)}{N} - \frac{(1-\alpha)m^*(\alpha)}{K} = B(m^*)$, and $\frac{y-\alpha\pi m^*(0)}{N} - \frac{(1-\alpha)m^*(0)}{K} = B(m^0)$. We consider how the critical value of $\hat{\alpha}$ changes in K. To do this, we implicitly define $\hat{\alpha}$ as $V^{MH}(\hat{\alpha}) = 0$. We then apply the implicit function theorem such that $\frac{\partial\hat{\alpha}}{\partial K} = -\frac{\partial V^{MH}}{\partial K}/\frac{\partial V^{MH}}{\partial\hat{\alpha}}$. From the proof or Proposition 4 We know that if $\hat{\alpha}$ exists in $]0,1[$, then $V^{MH}(\alpha)$ crosses the x-axis from above. As such, $\frac{\partial V^{MH}}{\partial\hat{\alpha}} < 0$. The sign of

$\frac{\partial \hat{\alpha}}{\partial K}$ is thus equivalent to that of $\frac{\partial V^{MH}}{\partial K}$. Because $h(m)$ is approximately linear, we approximate it as φm.

$$\begin{aligned}\frac{\partial V^{MH}}{\partial K} =&\pi[u(B(m^*)) - u(A(m^*))] + \pi(N-K)\frac{\partial A(m^*)}{\partial K}u'(A(m^*)) + \pi K\frac{\partial B(m^*)}{\partial K}u'(B(m^*)) \\ &+ \pi\varphi\frac{\partial m^*(\alpha)}{\partial K} + (1-\pi)N\frac{\partial A(m^*)}{\partial K}u'(A(m^*)) - \pi[u(B(m^0)) - u(A(m^0))] \\ &- \pi(N-K)\frac{\partial A(m^0)}{\partial K}u'(A(m^0)) - \pi K\frac{\partial B(m^0)}{\partial K}u'(B(m^0)) - \pi\varphi\frac{\partial m^*(0)}{\partial K} \\ &- (1-\pi)N\frac{\partial A(m^0)}{\partial K}u'(A(m^0)) \end{aligned} \tag{A34}$$

From the abbreviations, we know that $\frac{\partial A(m^*)}{\partial K} = -\frac{\alpha\pi}{N}\frac{\partial m^*(\alpha)}{\partial K}$, $\frac{\partial A(m^0)}{\partial K} = -\frac{\alpha\pi}{N}\frac{\partial m^*(0)}{\partial K}$, $\frac{\partial B(m^*)}{\partial K} = -\frac{\alpha\pi}{N}\frac{\partial m^*(\alpha)}{\partial K} - \frac{(1-\alpha)\frac{\partial m^*(\alpha)}{\partial K}K-(1-\alpha)m^*(\alpha)}{K^2}$, and $\frac{\partial B(m^0)}{\partial K} = -\frac{\alpha\pi}{N}\frac{\partial m^*(0)}{\partial K} - \frac{(1-\alpha)\frac{\partial m^*(0)}{\partial K}K-(1-\alpha)m^*(0)}{K^2}$. To determine $\frac{\partial m^*(\alpha)}{\partial K}$ and $\frac{\partial m^*(0)}{\partial K}$, we rely on the implicit definitions of $m^*(\alpha)$ and $m^*(0)$ and apply the implicit function theorem. $m^*(\alpha)$ is implicitly defined by $F = \varphi - (1-\alpha)u'(B(m^*)) = 0$. Thus

$$\frac{\partial m^*(\alpha)}{\partial K} = -\frac{\frac{\partial F}{\partial K}}{\frac{\partial F}{\partial m^*(\alpha)}} = -\frac{-(1-\alpha)^2 m^*(\alpha)K^{-2}u''(B(m^*))}{(1-\alpha)^2K^{-1}u''(B(m^*))} = \frac{m^*(\alpha)}{K}. \tag{A35}$$

Similarly

$$\frac{\partial m^*(0)}{\partial K} = -\frac{\frac{\partial F}{\partial K}}{\frac{\partial F}{\partial m^*(0)}} = -\frac{-m^*(0)K^{-2}u''(B(m^0))}{K^{-1}u''(B(m^0))} = \frac{m^*(0)}{K}. \tag{A36}$$

This establishes $\frac{\partial A(m^*)}{\partial K} = \frac{\partial B(m^*)}{\partial K} = -\frac{\alpha\pi m^*(\alpha)}{NK}$ and $\frac{\partial A(m^0)}{\partial K} = \frac{\partial B(m^0)}{\partial K} = -\frac{\alpha\pi m^*(0)}{NK}$. We substitute these results into Equation (A34) to obtain

$$\begin{aligned}\frac{\partial V^{MH}}{\partial K} =&\pi[u(A(m^0)) - u(A(m^*))] + \pi[u(B(m^*)) - u(B(m^0))] + \frac{\pi\varphi}{K}(m^*(\alpha) - m^*(0)) \\ &+ \frac{\alpha\pi(\pi(N-K)+(1-\pi)N)}{NK}(m^*(0)u'(A(m^0)) - m^*(\alpha)u'(A(m^*)) \\ &+ \pi\frac{\alpha\pi}{N}(m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*)). \end{aligned} \tag{A37}$$

We substitute the implicit definition of $\hat{\alpha}$: $(\pi(N-K) + (1-\pi)N)[u(A(m^0)) - u(A(m^*))] - \pi K[u(B(m^*)) - u(B(m^0))] = \pi\varphi(m^* - m^0)$ to obtain

$$\begin{aligned}\frac{\partial V^{MH}}{\partial K} =&\frac{N}{K}[u(A(m^0)) - u(A(m^*))] + \alpha\pi\frac{N-\pi K}{NK}[m^*(0)u'(A(m^0)) - m^*(\alpha)u'(A(m^*))] \\ &+ \alpha\pi\frac{\pi}{N}[m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*))]. \end{aligned} \tag{A38}$$

From Proposition 1, we know that $m^*(\alpha) > m^*(0)$ and thus $A(m^*) < A(m^0)$. By $u'' < 0$, we can ascertain that

$$\begin{aligned}
\frac{\partial V^{MH}}{\partial K} &< \alpha\pi\frac{N}{NK}u'(A(m^*))[m^*(\alpha) - m^*(0)] + \alpha\pi\frac{N-\pi K}{NK}[m^*(0)u'(A(m^0)) - m^*(\alpha)u'(A(m^*))] \\
&\quad + \alpha\pi\frac{\pi}{N}[m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*))] \qquad \text{(A39)} \\
&= \frac{\alpha\pi}{K}\Bigg[u'(A(m^*))[m^*(\alpha) - m^*(0)] + [m^*(0)u'(A(m^0)) - m^*(\alpha)u'(A(m^*))] \\
&\quad + \frac{\pi K}{N}[m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*)) - m^*(0)u'(A(m^0)) + m^*(\alpha)u'(A(m^*))]\Bigg] \qquad \text{(A40)} \\
&< \frac{\alpha\pi}{K}\Bigg[u'(A(m^*))[m^*(\alpha) - m^*(0)] + [m^*(0)u'(A(m^*)) - m^*(\alpha)u'(A(m^*))] \\
&\quad + \frac{\pi K}{N}[m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*)) - m^*(0)u'(A(m^0)) + m^*(\alpha)u'(A(m^*)]\Bigg] \qquad \text{(A41)} \\
&= \frac{\alpha\pi^2 K}{NK}[m^*(0)u'(B(m^0)) - m^*(\alpha)u'(B(m^*)) - m^*(0)u'(A(m^0)) + m^*(\alpha)u'(A(m^*))] \qquad \text{(A42)} \\
&< \frac{\alpha\pi^2 K}{NK}m^*(\alpha)[u'(B(m^0)) - u'(B(m^*)) - u'(A(m^0)) + u'(A(m^*))]. \qquad \text{(A43)}
\end{aligned}$$

The last inequality follows, because $B(m^0) < A(m^0)$ and thus $m^*(0)(u'(B(m^0)) - u'(A(m^0))) < m^*(\alpha)(u'(B(m^0)) - u'(A(m^0)))$. We know that $B(m^0) - B(m^*) = (m^*(0) - m^*(\alpha))\left(\frac{\alpha\pi}{N} + \frac{1-\alpha}{K}\right) > (m^*(0) - m^*(\alpha))\frac{\alpha\pi}{N} = A(m^0) - A(m^*)$. Thus, by $B(m^*) < A(m^*)$, $u'' < 0$ and $u''' \geq 0$ it follows that $u'(B(m^0)) - u'(B(m^*)) \leq u'(A(m^0)) - u'(A(m^*))$. As a consequence, the right-hand-side of Equation (A43) is negative or zero and it follows that $\frac{\partial V^{MH}}{\partial K} < 0$. Thus, as long as $\hat{\alpha}$ exists, it is decreasing in K and this includes the case of $K = N$. This concludes the proof.

A.8 Proof or Proposition 8

We abbreviate $\frac{y-\alpha\pi m}{N}$ as $A_{PL}(m)$ or $A_{HTM}(m)$, $\frac{y-\alpha\pi m-(1-\alpha)m}{N} = B_{PL}(m)$, and $\frac{y-\alpha\pi m}{N} - \frac{(1-\alpha)m}{K} = B_{HTM}(m)$. Because $h(m)$ is approximately linear, we approximate it as φm. $m_i^*(\alpha)$ is implicitly defined by $\varphi - (1-\alpha)u'(B_i(m_i^*(\alpha))) = 0$. This implies $B_{PL}(m_{PL}^*(\alpha)) = B_{HTM}(m_{HTM}^*(\alpha))$ and thus $m_{PL}^*(\alpha) = \frac{\alpha\pi+(1-\alpha)\frac{N}{K}}{\alpha\pi+(1-\alpha)}m_{HTM}^*(\alpha) < \frac{N}{K}m_{HTM}^*(\alpha)$ which obviously implies $m_{PL}^*(\alpha) > m_{HTM}^*(\alpha)$ for $K < N$.

We abbreviate the premium as $p_i = \alpha\pi m_i^*(\alpha)$ and state the first order condition for the coverage level of individuals with perfect liquidity as

$$\begin{aligned}
\frac{\partial EU_{PL}}{\partial\alpha} =& -\pi\frac{\partial p_{PL}}{\partial\alpha}u'(B_{PL}(m_{PL}^*(\alpha))) + \pi m_{PL}^*(\alpha)u'(B_{PL}(m_{PL}^*(\alpha))) - \pi(1-\alpha)\frac{\partial m_{PL}^*(\alpha)}{\partial\alpha}u'(B_{PL}(m_{PL}^*(\alpha))) \\
&+ \pi\frac{\partial m_{PL}^*(\alpha)}{\partial\alpha}\varphi - (1-\pi)\frac{\partial p_{PL}}{\partial\alpha}u'(A_{PL}(m_{PL}^*(\alpha))). \qquad \text{(A44)}
\end{aligned}$$

Substituting the implicit definition of $m^*_{PL}(\alpha)$ and rearranging renders

$$\pi u'(B_{PL}(m^*_{PL}(\alpha))) = \frac{\partial p_{PL}}{\partial \alpha} \frac{\pi u'(B_{PL}(m^*_{PL}(\alpha))) + (1-\pi)u'(A_{PL}(m^*_{PL}(\alpha)))}{m^*_{PL}(\alpha)}. \tag{A45}$$

Similarly, we consider the first order condition for hand-to-mouth individuals and substitute the implicit definition of $m^*_{HTM}(\alpha)$ to obtain

$$\begin{aligned}\frac{\partial EU_{HTM}}{\partial \alpha} =& m^*_{HTM}(\alpha)\pi u'(B_{HTM}(m^*_{HTM}(\alpha))) - \frac{\partial p_{HTM}}{\partial \alpha}\Bigg[\pi\frac{N-K}{N}u'(A_{HTM}(m^*_{HTM}(\alpha))) \\ &+ \pi\frac{K}{N}u'(B_{HTM}(m^*_{HTM}(\alpha))) + (1-\pi)u'(A_{HTM}(m^*_{HTM}(\alpha)))\Bigg]\end{aligned} \tag{A46}$$

We now evaluate $\frac{\partial EU_{HTM}}{\partial \alpha}$ at α^*_{PL}. From $B_{PL}(m^*_{PL}(\alpha)) = B_{HTM}(m^*_{HTM}(\alpha))$:

$$\begin{aligned}\left.\frac{\partial EU_{HTM}}{\partial \alpha}\right|_{\alpha=\alpha^*_{PL}} =& \, m^*_{HTM}(\alpha)\frac{\partial p_{PL}}{\partial \alpha}\frac{\pi u'(B_{PL}(m^*_{PL}(\alpha))) + (1-\pi)u'(A_{PL}(m^*_{PL}(\alpha)))}{m^*_{PL}(\alpha)} \\ &- \frac{\partial p_{HTM}}{\partial \alpha}\Bigg[\pi\frac{N-K}{N}u'(A_{HTM}(m^*_{HTM}(\alpha))) + \pi\frac{K}{N}u'(B_{HTM}(m^*_{HTM}(\alpha))) \\ &+ (1-\pi)u'(A_{HTM}(m^*_{HTM}(\alpha)))\Bigg]\end{aligned} \tag{A47}$$

The sign of this expression is equivalent to the sign of

$$\begin{aligned}F =& \frac{\frac{\partial p_{PL}}{\partial \alpha}}{m^*_{PL}(\alpha)}\pi u'(B_{PL}(m^*_{PL}(\alpha))) + (1-\pi)u'(A_{PL}(m^*_{PL}(\alpha))) \\ &- \frac{\frac{\partial p_{HTM}}{\partial \alpha}}{m^*_{HTM}(\alpha)}\Bigg[\pi\frac{N-K}{N}u'(A_{HTM}(m^*_{HTM}(\alpha))) + \pi\frac{K}{N}u'(B_{HTM}(m^*_{HTM}(\alpha))) \\ &+ (1-\pi)u'(A_{HTM}(m^*_{HTM}(\alpha)))\Bigg]\end{aligned} \tag{A48}$$

We now note that $\frac{\partial p_i}{\partial \alpha} = \pi m^*_i(\alpha) + \alpha\pi\frac{\partial m^*_i(\alpha)}{\partial \alpha}$. Applying the implicit function theorem to the definitions of the optimal medical spending (noting that second order conditions are fulfilled) renders

$$\frac{\partial m^*_{PL}(\alpha)}{\partial \alpha} = \frac{Nu'(B_{PL}(m^*_{PL}(\alpha))) - (1-\alpha)m^*_{PL}(\alpha)u''(B_{PL}(m^*_{PL}(\alpha)))}{-(1-\alpha)^2u''(B_{PL}(m^*_{PL}(\alpha)))} \tag{A49}$$

and

$$\frac{\partial m^*_{HTM}(\alpha)}{\partial \alpha} = \frac{Ku'(B_{HTM}(m^*_{HTM}(\alpha))) - (1-\alpha)m^*_{HTM}(\alpha)u''(B_{PL}(m^*_{HTM}(\alpha)))}{-(1-\alpha)^2u''(B_{HTM}(m^*_{HTM}(\alpha)))}. \tag{A50}$$

We thus know that

$$\frac{\frac{\partial p_{PL}}{\partial \alpha}}{m^*_{PL}(\alpha)} = \pi + \alpha\pi\frac{\frac{N}{m^*_{PL}(\alpha)}u'(B_{PL}(m^*_{PL}(\alpha))) - (1-\alpha)m^*_{PL}(\alpha)u''(B_{PL}(m^*_{PL}(\alpha)))}{-(1-\alpha)^2u''(B_{PL}(m^*_{PL}(\alpha)))}. \tag{A51}$$

Applying $m^*_{PL}(\alpha) < \frac{N}{K} m^*_{HTM}(\alpha)$ renders

$$\frac{\frac{\partial p_{PL}}{\partial \alpha}}{m^*_{PL}(\alpha)} > \pi + \alpha\pi \frac{\frac{N}{\frac{N}{K} m^*_{HTM}(\alpha)} u'(B_{PL}(m^*_{PL}(\alpha))) - (1-\alpha) m^*_{PL}(\alpha) u''(B_{PL}(m^*_{PL}(\alpha)))}{-(1-\alpha)^2 u''(B_{PL}(m^*_{PL}(\alpha)))} \tag{A52}$$

$$= \pi + \alpha\pi \frac{\frac{K}{m^*_{HTM}(\alpha)} u'(B_{PL}(m^*_{PL}(\alpha))) - (1-\alpha) m^*_{PL}(\alpha) u''(B_{PL}(m^*_{PL}(\alpha)))}{-(1-\alpha)^2 u''(B_{PL}(m^*_{PL}(\alpha)))} \tag{A53}$$

$$= \frac{\frac{\partial p_{HTM}}{\partial \alpha}}{m^*_{HTM}(\alpha)} \tag{A54}$$

We can apply this relationship to Equationa (A48) and see that

$$\begin{aligned} F > & \frac{\frac{\partial p_{HTM}}{\partial \alpha}}{m^*_{HTM}(\alpha)} \pi u'(B_{PL}(m^*_{PL}(\alpha))) + (1-\pi) u'(A_{PL}(m^*_{PL}(\alpha))) \\ & - \frac{\frac{\partial p_{HTM}}{\partial \alpha}}{m^*_{HTM}(\alpha)} \Bigg[\pi \frac{N-K}{N} u'(A_{HTM}(m^*_{HTM}(\alpha))) + \pi \frac{K}{N} u'(B_{HTM}(m^*_{HTM}(\alpha))) \\ & + (1-\pi) u'(A_{HTM}(m^*_{HTM}(\alpha))) \Bigg] \end{aligned} \tag{A55}$$

The sign of the right-hand-side is equivalent to

$$\begin{aligned} G = & \pi u'(B_{PL}(m^*_{PL}(\alpha))) + (1-\pi) u'(A_{PL}(m^*_{PL}(\alpha))) - \Bigg[\pi \frac{N-K}{N} u'(A_{HTM}(m^*_{HTM}(\alpha))) \\ & + \pi \frac{K}{N} u'(B_{HTM}(m^*_{HTM}(\alpha))) + (1-\pi) u'(A_{HTM}(m^*_{HTM}(\alpha))) \Bigg] \end{aligned} \tag{A56}$$

$$\begin{aligned} = & (1-\pi)[u'(A_{PL}(m^*_{PL}(\alpha))) - u'(A_{HTM}(m^*_{HTM}(\alpha)))] \\ & + \pi \frac{N-K}{N} [u'(B_{PL}(m^*_{PL}(\alpha))) - u'(A_{HTM}(m^*_{HTM}(\alpha)))] \end{aligned} \tag{A57}$$

From $m^*_{PL}(\alpha) > m^*_{HTM}(\alpha)$ and $u'' < 0$ it follows that $A_{PL}(m^*_{PL}(\alpha)) < A_{HTM}(m^*_{HTM}(\alpha))$ and thus $u'(A_{PL}(m^*_{PL}(\alpha))) > u'(A_{HTM}(m^*_{HTM}(\alpha)))$. Because $B_{PL}(m^*_{PL}(\alpha)) < A_{PL}(m^*_{PL}(\alpha))$, then also $B_{PL}(m^*_{PL}(\alpha)) < A_{HTM}(m^*_{HTM}(\alpha))$ and thus $u'(B_{PL}(m^*_{PL}(\alpha))) > u'(A_{HTM}(m^*_{HTM}(\alpha)))$. Thus $G > 0$ and in consequence $\frac{\frac{\partial p_{PL}}{\partial \alpha}}{m^*_{PL}(\alpha)} > 0$, implying $\alpha^*_{HTM} > \alpha^*_{PL}$ if we assume an interior solution and thus second-order conditions to hold.

Appendix B Comparison of the Efficient Market Approach to the Lump-Sum Approach of Nyman (1999b)

Nyman (1999b) defines efficient moral hazard as the difference between m^L and $m^*(0)$. Here, m^L is the amount of medical spending by an individual who received a lump-sum payment equal to the amount of medical spending that an insured individual would have made. In terms of our model, we can define it implicitly through

$$h'(m^L) - u'\left(\frac{y + (1-\pi)\alpha m^*(\alpha) - m^L}{N}\right) = 0. \tag{B1}$$

This concept is not exactly equal to our definition of efficient moral hazard which is given by $m^E - m^*(0)$. We exemplify this for $\alpha = 1$. First, it is easy to see for this case that $m^*(\alpha) > m^L$. $m^*(\alpha)$ is defined by $h'(m^*(\alpha)) = 0$ and because $u'\left(\frac{y+(1-\pi)\alpha m^*(\alpha)-m^L}{N}\right) > 0$, it will always be the case that $h'(m^L) > 0$ and thus $m^*(\alpha) > m^L$. Second, we can also show that $m^L > m^E$. For $\alpha = 1$, m^E is defined by

$$h'(m^E) - u'\left(\frac{y - \pi m^E}{N}\right) = 0. \tag{B2}$$

Evaluating the first-order condition for m^E at m^L renders

$$u'\left(\frac{y + (1-\pi)m^*(1) - m^L}{N}\right) - u'\left(\frac{y - \pi m^L}{N}\right). \tag{B3}$$

given that the second-order condition for m^E is fulfilled, $m^L > m^E$ is equivalent to the above expression being negative. Rearranging and realizing that $u'' < 0$ renders

$$\frac{y + (1-\pi)m^*(1) - m^L}{N} > \frac{y - \pi m^L}{N} \tag{B4}$$

This is equivalent to $m^*(1) > m^L$ which we know to be true. Thus, $m^L > m^E$ which means that the Nyman (1999b) definition overstates the amount of efficient moral hazard compared to our definition. This is because the cash transfer of the lump-sum insurance contract is too large. $m^*(\alpha)$ includes the price effect, which needs to be excluded to calculate the correct amount. Our definition arises naturally, because we simply assume an efficient market without any information asymmetries.

Appendix C Simplified First-Order Conditions for Intuitive Illustration

The following appendix utilizes Taylor approximations to derive linear versions of the first-order conditions used in the results of the papers. These linear approximations are not used to show any additional results, but simply illustrate the mechanisms explored in the paper usingt simple and thus intuitive functional forms.

C.1 Perfect Liquidity Individuals

We use the first-order conditions in Equations (A1) and (A4) to show how the three levels of medical spending, $m^*_{PL}(0)$, $m^E_{PL}(\alpha)$ and $m^*_{PL}(\alpha)$, can be approximated using linear equations.

We begin with optimal medical spending in the absence of insurance. From

$$u'\left(\frac{y - m^*_{PL}(0)}{N}\right) = h'(m^*_{PL}(0)) \tag{C1}$$

we use a first-order Taylor approximation of $u'(\cdot)$ around the base income $\frac{y}{N}$ to obtain

$$\Rightarrow u'\left(\frac{y}{N}\right) - u''\left(\frac{y}{N}\right)\frac{m^*_{PL}(0)}{N} \approx h'(m^*_{PL}(0)) \tag{C2}$$

$$\Leftrightarrow 1 + r_A\frac{m^*_{PL}(0)}{N} \approx H'(m^*_{PL}(0)). \tag{C3}$$

Here, r_A is the coefficient of absolute risk aversion and $H'(m) = h'(m)/u'\left(\frac{y}{N}\right)$ is a normalized version of the marginal utility from health. Because the left-hand side of (C3) is in monetary terms, $H'(m)$ is approximately in monetary terms, too. This is intuitive, because the marginal utility derived from medical spending is divided by that derived from monetary consumption.

For efficient medical spending of insured individuals, we again start at the first-order condition and use a first-order Taylor approximation of $u'(\cdot)$ around the base income $\frac{y}{N}$ to obtain

$$\begin{aligned}
&((1-\alpha)+\pi\alpha)\,u'\left(\frac{y-(1-\alpha)m^E_{PL}(\alpha)-\pi\alpha m^E_{PL}(\alpha)}{N}\right)\\
&+(1-\pi)\alpha u'\left(\frac{y-\pi\alpha m^E_{PL}(\alpha)}{N}\right) = h'(m^E_{PL}(\alpha)) &\text{(C4)}\\
\Rightarrow\ &((1-\alpha)+\pi\alpha)\left[u'\left(\frac{y}{N}\right) - [(1-\alpha)+\pi\alpha]\,u''\left(\frac{y}{N}\right)\frac{m^E_{PL}(\alpha)}{N}\right]\\
&+(1-\pi)\alpha\left[u'\left(\frac{y}{N}\right) - \pi\alpha u''\left(\frac{y}{N}\right)\frac{m^E_{PL}(\alpha)}{N}\right] \approx h'(m^E_{PL}(\alpha)) &\text{(C5)}\\
\Leftrightarrow\ &1 + (1-(1-\pi)\alpha(2-\alpha))\,r\frac{m^E_{PL}(\alpha)}{N} \approx H'(m^E_{PL}(\alpha)) &\text{(C6)}
\end{aligned}$$

Comparing Equations (C3) and (C6), we can see item 4 of Proposition 1, namely that $m^E_{PL}(\alpha) > m^*_{PL}(0)$ for $\alpha > 0$. This is because $1-(1-\pi)\alpha(2-\alpha) < 1$ and we thus know that the slope for the efficient spending with insurance is lower than that in the case without insurance.

Lastly, we consider medical spending under moral hazard. We again start at the first order condition, apply the approximation and rearrange.

$$(1-\alpha)u'\left(\frac{y-(1-\alpha)m^*_{PL}-\pi\alpha m^*_{PL}}{N}\right) = h'(m^*_{PL}) \tag{C7}$$

$$\Rightarrow (1-\alpha) + \left(1-(2-\pi)\alpha+(1-\pi)\alpha^2\right) r\frac{m^*_{PL}(\alpha)}{N} \approx H'(m^*_{PL}). \tag{C8}$$

Thus, for the linearized definition of $m^*_{PL}(\alpha)$, both the intersection with the y axis and the slope is smaller than for the line defining efficient medical spending. As a result, $m^*_{PL}(\alpha) > m^E_{PL}(\alpha)\ \forall\ \alpha \in]0,1], \pi \in]0,1]$, which is item 2 of Proposition 1.

C.2 Hand-to-mouth Individuals

The process here is the same as above. For optimal medical spending, we begin at the first-order condition defined in Equation (A17) and apply the first-order Taylor approximation to $u'(\cdot)$ around the base income $\frac{y}{N}$. Thus

$$u'\left(\frac{y}{N}-\frac{m^*_{HTM}(0)}{K}\right) = h'(m^*_{HTM}(0)) \tag{C9}$$

$$\Rightarrow 1 + r\frac{m^*_{HTM}(0)}{K} \approx H'(m^*_{HTM}(0)). \tag{C10}$$

Because $K < N$, we know that the slope is steeper for HTM individuals than for PL individuals. This lets us conclude that $m^*_{HTM}(0) < m^*_{PL}(0)$, as is the consequence of Proposition 5.

For the efficient medical spending of insured individuals, we follow the same process as above, using the first-order condition in Equation (A15). Abbreviating $m^E_{HTM}(\alpha)$ as m in the first two lines for legibility, we obtain

$$\begin{aligned}
&\frac{N-K}{N}\alpha\pi u'\left(\frac{y-\alpha\pi m}{N}\right) + \left(\frac{\alpha\pi K}{N}+(1-\alpha)\right)u'\left(\frac{y-\alpha\pi m}{N}-\frac{(1-\alpha)m}{K}\right)\\
&+(1-\pi)\alpha u'\left(\frac{y-\alpha\pi m}{N}\right) = h'(m)
\end{aligned} \tag{C11}$$

$$\begin{aligned}
\Rightarrow\ &\frac{N-K}{N}\alpha\pi u'\left(\frac{y}{N}\right) - \frac{N-K}{N}(\alpha\pi)^2 u''\left(\frac{y}{N}\right)\frac{m}{N} + \left(\frac{K}{N}\alpha\pi+(1-\alpha)\right)u'\left(\frac{y}{N}\right)\\
&-\left(\frac{K}{N}\alpha\pi+(1-\alpha)\right)\alpha\pi u''\left(\frac{y}{N}\right)\frac{m}{N} - \left(\frac{K}{N}\alpha\pi+(1-\alpha)\right)(1-\alpha)u''\left(\frac{y}{N}\right)\frac{m}{K}\\
&(1-\pi)\alpha u'\left(\frac{y}{N}\right) - (1-\pi)\alpha^2\pi u''\left(\frac{y}{N}\right)\frac{m}{N} \approx h'(m)
\end{aligned} \tag{C12}$$

$$\Leftrightarrow 1 + \left((2-\alpha)\alpha\pi\frac{K}{N}+(1-\alpha)^2\right) r\frac{m^E_{HTM}(\alpha)}{K} \approx H'(m^E_{HTM}(\alpha)). \tag{C13}$$

With $K < N$, it is obvious that $(2-\alpha)\alpha\pi\frac{K}{N} + (1-\alpha)^2 < 1$ and thus $m^E_{HTM}(\alpha) > m^*_{HTM}(0)$, as is described in item 2 of Proposition 3.

Lastly, we again consider medical spending under moral hazard. Using the same procedure as above renders

$$(1-\alpha)u'\left(\frac{y-\pi\alpha m^*_{HTM}(\alpha)}{N} - \frac{(1-\alpha)m}{K}\right) = h'(m^*_{HTM}(\alpha)) \tag{C14}$$

$$\Rightarrow (1-\alpha) - \left((1-\alpha)\pi\alpha\frac{K}{N} + (1-\alpha)^2\right) r\frac{m^*_{HTM}(\alpha)}{K} \approx H'(m^*_{HTM}(\alpha)) \tag{C15}$$

Interpretations are the same as for the perfect liquidity case. The intersection with the y axis is lower and the slope is smaller because $(2-\alpha)\alpha\pi\frac{K}{N} + (1-\alpha)^2 - \left((1-\alpha)\pi\alpha\frac{K}{N} + (1-\alpha)^2\right) = \alpha\pi\frac{K}{N} > 0$ for $\alpha > 0$. Thus $m^*_{HTM}(\alpha) > m^E_{HTM}(\alpha)\ \forall\ \alpha \in]0,1]$ as is stated in item 1 of Proposition 3.

C.3 Specific scenarios

The two scenarios for certain losses (that is, $\pi = 1$) and full insurance (that is, $\alpha = 1$) are particularly helpful to build intuition. We cover both of them below.

C.3.1 Certain losses: $\pi = 1$

The three medical spending levels for perfect liquidity individuals are described by

$$1 + r\frac{m^*_{PL}(0)}{N} \approx H'(m^*_{PL}(0)) \tag{C16}$$

$$1 + r\frac{m^E_{PL}(\alpha)}{N} \approx H'(m^E_{PL}(\alpha)) \tag{C17}$$

$$(1-\alpha) + (1-\alpha)\, r\frac{m^*_{PL}(\alpha)}{N} \approx H'(m^*_{PL}(\alpha)). \tag{C18}$$

We can easily see that $m^*_{PL}(0) = m^E_{PL}(\alpha)\ \forall\ \alpha$. Further, slope and intersect are lower for medical spending under moral hazard such that $m^*_{PL}(\alpha) > m^E_{PL}(\alpha)$. This implies that for perfect liquidity individuals, under certain losses there is no value of efficient moral hazard, $V^{MHE}_{PL}(\pi = 1) = 0$, while the value of inefficient moral hazard is negative, $V^{MHI}_{PL}(\pi = 1) < 0$ and thus the total moral hazard value will always be negative: $V^{MH}_{PL}(\pi = 1) < 0$.

Considering HTM individuals, we see that

$$1 + r\frac{m^*_{HTM}(0)}{K} \approx H'(m^*_{HTM}(0)) \tag{C19}$$

$$1 + \left((2-\alpha)\alpha\frac{K}{N} + (1-\alpha)^2\right) r\frac{m^E_{HTM}(\alpha)}{K} \approx H'(m^E_{HTM}(\alpha))) \tag{C20}$$

$$(1-\alpha) - \left((1-\alpha)\alpha\frac{K}{N} + (1-\alpha)^2\right) r\frac{m^*_{HTM}(\alpha)}{K} \approx H'(m^*_{HTM}(\alpha)). \tag{C21}$$

This lets us see relatively easily that $m^*_{HTM}(\alpha) > m^E_{HTM}(\alpha) > m_{HTM}(0)$. The latter relationship contrasts the HTM and PL cases.[15] From it, it is obvious that even in the presence of certain losses, there is a positive value of efficient moral hazard for hand-to-mouth individuals, $V^{MHE}_{HTM}(\pi = 1) > 0$. Combined with the negative value of inefficient moral hazard, the sign of the total moral hazard value is undetermined for the hand-to-mouth case.

C.4 Full insurance: $\alpha = 1$

The case of full insurance is particularly informative to compare the medical spending of both types of individuals. We restate the definition of medical spending without any insurance as

$$1 + r\frac{m_{PL}(0)}{N} \approx H'(m_{PL}(0)) \tag{C22}$$

$$1 + r\frac{m_{HTM}(0)}{K} \approx H'(m_{PL}(0)). \tag{C23}$$

Because of $K < N$, we know that $m_{PL}(0) > m_{HTM}(0)$.

Under moral hazard, both types will show the same spending with full insurance

$$0 = H'(m^*_{PL}(\alpha)) = H'(m^*_{HTM}(\alpha)). \tag{C24}$$

This result obtains, because full insurance makes hand-to-mouth individuals act as if they had perfect liquidity. Thus, both types also have the same efficient medical spending as can be seen by

$$1 + \pi r\frac{m^E_{PL}(\alpha)}{N} \approx H'(m^E_{PL}(\alpha)) \tag{C25}$$

$$1 + \pi r\frac{m^E_{HTM}(\alpha)}{N} \approx H'(m^E_{HTM}(\alpha)). \tag{C26}$$

For full insurance, the two types only differ in their counterfactual of no insurance. This difference has implications for the difference in the values of efficient moral hazard. Because all other levels of medical spending are the same, we know that $V^{MHE}_{HTM}(\alpha = 1) > V^{MHE}_{PL}(\alpha = 1)$ and thus $V^{MH}_{HTM}(\alpha = 1) > V^{MH}_{PL}(\alpha = 1)$. This is a consequence of Proposition 6.

[15] We can see this from $(2 - \alpha)\alpha\frac{K}{N} + (1 - \alpha)^2 < (2 - \alpha)\alpha + (1 - \alpha)^2$. The latter expression is 1 at $\alpha = 1$ and increasing in α so will be smaller 1 as α decreases.