Patient-Level Competitive Bidding and Risk Selection in Health Care Entitlement Programs*

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Prospective payment encourages managed care organizations to select low-risk patients. This article models an entitlement program utilizing patient-level competitive bidding to mitigate risk selection. Three mechanisms are tested: uniform payment, pure bidding, and a mix of payment and bidding. Results show selection always occurs under optimal uniform payment, but never under either bidding mechanism. Mixed bidding eliminates risk selection at the lowest cost. Competitive bidding Pareto dominates uniform payment over 83% of simulated parameter sets. Compared to uniform payment, bidding enrolls 14% more beneficiaries at 24% lower cost, showing the potential for bidding to improve entitlement program access and sustainability.

Key words: risk selection, entitlement programs, competitive bidding;

JEL codes: I13, H51, D82.

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I. Introduction

Prospective payment encourages health plans and providers to avoid policyholders and patients likely to require expensive care. This practice is known more generally as risk selection; the efforts to enroll or treat a cohort of policyholders with lower cost or risk than the population on which payments are based\(^1\). It requires enrolling those patients believed to be low-risk or low-cost and disenrolling high-risk or high-cost patients (Pauly 1984, Eggleston 2000). The problem persists when heterogeneity in expected treatment cost goes unpriced because payers either cannot distinguish between risk types, or are committed to community rating along certain dimensions associated with risk. Where successful, risk selection results in broken pooling arrangements where sponsors overpay for those patients accepted or enrolled, and must find alternative (often inferior) arrangements for those rejected (Van de Ven et al. 2003).

Recent evidence shows that risk selection is practiced in health care entitlement programs, despite attempts by regulators to prohibit or dissuade it by risk-adjusting prospective payments. As regulators risk-adjust according to one set of patient characteristics, managed care organizations (MCOs) are able to redirect selection efforts toward unadjusted characteristics (Brown et al. 2012). Sickness funds in the German Social Health Insurance system respond and en-

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1. Technically, this is “active” selection or selective enrollment (Newhouse et al. 1989), “cream skimming” or “preferred” risk selection (van de Ven and van Vliet 1992), “creaming, skimping, and dumping” (Ellis 1998), or “linkage C” risk selection (Ellis and Fernandez 2013). It is the selection resulting from plan or provider behavior rather than that of consumers or patients.
gage with patients having profitable unadjusted geographic characteristics more than with unprofitable ones (Bauhoff 2012). From its inception, Medicare Part C or “Medicare Advantage” in the United States has attracted lower-risk beneficiaries compared to Traditional Medicare (Langwell and Hadley 1988, Brown et al. 1993, Miller and Luft 1994, Congressional Budget Office 1997). Even though beneficiary behavior could be partly responsible for selection through self-sorting into plans meeting their expected needs, several MCO practices have been successful in selecting healthy enrollees. These include offering supplementary benefits, such as gym memberships, attractive to healthy types and unappealing to the disabled (Cooper and Trivedi 2012), selective advertising to healthy individuals and in healthy areas (Aizawa and Kim 2013), and increased spending on services used by high-profit patients (Ellis et al. 2013). Risk selection thus exists and could be creating inefficiency in the country’s public health insurance program for the elderly and disabled.

Risk selection is also a problem in health care entitlement programs for the poor. In the United States, Medicaid Managed Care plans successfully lobby to have the most risky or costly beneficiaries placed in alternative health insurance programs (Howell et al. 2012). Kuziemko et al. (2013) show that MCOs selected risks on the basis of race once Medicaid Managed Care was established in Texas. On average, profitable Hispanic beneficiaries enjoyed improved health outcomes while those of black ones declined, with black mothers more often directed to alternate safety-net care or abortion clinics. With 13.3 million Medicare Advantage beneficiaries (Song et al. 2012); over 33 million existing Medicaid Managed
Care beneficiaries, 13 million of whom are children; and an expected 16 million new enrollees under the Affordable Care Act (Howell et al. 2012), risk selection presents a potentially large source of inefficiency in the United States’ health care entitlement programs. Mitigating this problem would improve health outcomes for the most vulnerable of these beneficiaries and reduce the burden of these programs on taxpayers. Given that existing efforts at comprehensive risk adjustment have preserved incentives to select, it is worth investigating alternative methods for achieving this goal.

This article examines patient-level competitive bidding as a mechanism for eliminating risk selection. In an abstract sense, risk selection occurs because a payer offers a uniformly-priced contract to a set of potential suppliers, each of which can condition their responses on the perceived costliness or riskiness of the contract. In such cases of unpriced heterogeneity, a procurement auction can achieve several important objectives. Auctions both motivate the revelation of private information and result in an equilibrium within the set of core (and thus efficient) allocations (Milgrom 1987). Furthermore, while risk adjustment is slow to evolve and quickly outdated, competitive bids over patients can adjust rapidly to provider- or industry-specific changes in production costs and reward firms for cost-reducing innovations. Applying the auction environment to the problem of risk selection; with payer as the principal, MCOs or health plans as bidders, and patient enrollment as a contract; could bring these advantages to health care entitlement programs.

Competitive bidding arrangements are not new to health care; they have
been proposed both in past health policy discussions (Hogan 1983, Christianson and Smith 1984, Pauly et al. 1991, Keijser and Kirkman-Liff 1992) and in more recent ones (Berwick and Hackbarth 2012, Feldman et al. 2012). Bidding was incorporated into the health care systems of New York, Massachusetts, California, Wisconsin, and Arizona (Christianson and Smith 1984, Schlesinger et al. 1986, Bovbjerg et al. 1987, McCombs and Christianson 1987, Paringer and McCall 1991) and at the federal level in the United States to set prospective benchmarks in Medicare Advantage, for durable medical equipment (Mechanic and Altman 2010), and laboratory services (Waters 2006). The effectiveness of these competitive bidding systems has been mixed, but they have generally lowered costs. The most common problems include opposition from suppliers, poorly designed rules (Katzman and McGeary 2008), lack of transparency (Hillman and Christiansen 1984, Waters 2006), unpredictable supply prices, and concerns about both not enough competition (Hoerger and Waters 1993) and “too much” competition where small and rural providers are priced out (Waters 2006, Garrott 2007).

Almost exclusively, existing attempts and proposals use competitive bidding to set uniform prices on patient enrollment. While this may be appropriate for setting group-level prices, any remaining within-group heterogeneity can preserve selection incentives. This article examines an alternative application of competitive bidding: setting separate prospective payments for the enrollment of individual, heterogeneous beneficiaries. The closest real world example of this “patient-level” competitive bidding is CareAuction.nl in the Netherlands. Al-
though designed to induce provision of high-quality maternity care rather than allocate heterogeneous patients at the lowest cost, it utilized electronic auctions to conduct bidding at the patient-level (Smits and Janssen 2008). Such a mechanism was extreme or impractical in the past (Enthoven 1988, Newhouse 1996), but advances in health information technology have made patient-level competitive bidding a more plausible option today. Finally, whereas existing proposals frame competitive bidding and uniform pricing as alternative or separate mechanisms, this article outlines a single mechanism utilizing both pricing methods. It thus investigates for any complementarities arising from the use of bidding and uniform pricing together and evaluates whether this mixed mechanism produces better outcomes than the separate ones.

This article proceeds by modeling the interactions of beneficiaries, a payer, and managed care organizations capable of practicing risk selection in a health care entitlement program. Three different reimbursement mechanisms, incorporating different degrees of competitive bidding, are evaluated. The first is a traditional uniform prospective payment system, where MCOs are offered a fixed fee per beneficiary enrolled. Any beneficiaries failing to gain enrollment receive care in an inappropriate setting; an emergency department, for example. The second is pure competitive bidding, offering no prospective payment but instead allocating each individual beneficiary to an MCO based on submitted bids. Finally, a mixed payment mechanism is evaluated, offering an initial prospective payment for enrollment, but then allocating any unenrolled beneficiary by submitted bids. After solving for the optimal prospective payments,
the three mechanisms are compared on the practice of risk selection, the total cost of the entitlement program, and the expected utility of beneficiaries.

The results show that, regardless of the magnitude and variation in unpriced enrollment costs, risk selection always occurs at the optimal uniform payment, but never occurs under competitive bidding. It also shows that the optimal mixed payment system ex ante Pareto dominates pure bidding. Finally, the article shows necessary and sufficient conditions under which the bidding mechanisms dominate the uniform payment system. Numerical analysis shows that these sufficient conditions hold for 83% to 84%, of simulated parameter sets. Furthermore, on average, competitive bidding results in an additional 14% of beneficiaries enrolled and reduces the total cost of the entitlement program by 24%. These findings indicate the potential for patient-level competitive bidding to mitigate risk selection in health care entitlement programs, making even the most costly beneficiaries profitable to private MCOs, without increasing the programs’ burden on taxpayers.

II. The Model

There is a population of consumers of measure 1. A share $D$ of these are “beneficiaries”, those entitled to government-sponsored health insurance, and the remaining $(1 - D)$ share, or “taxpayers”, bear the tax burden of the program. All consumers have preferences represented by the quasi-concave utility function $U(y, H)$, where $y$ is consumption and $H$ is health status. Beneficia-
ries are endowed with income $m_1$ and taxpayers are endowed with $m_2$, where $m_2 > m_1$. Health status is binary and determined by whether or not the beneficiary is enrolled with a health plan in the event of illness \(^2\), which for simplicity is assumed to occur with probability 1. Beneficiaries enrolled with a health plan enjoy health status $H_1$ and those without enjoy $H_2$, where $H_1 > H_2$. Taxpayers’ health status is $H_1$ and not subject to change. Beneficiaries are heterogeneous in ex ante risk type $k$, which is unobservable to consumers. There are $K \in \mathbb{Z}^{++}$ different types and the share of beneficiaries of risk type $k$ is $\alpha_k$, where $\sum_{k=1}^{K} \alpha_k = 1$.

Beneficiaries match randomly and sequentially with each of $n \in \mathbb{Z}^{++}$ identical managed care organizations, where $n \geq 2$. Each MCO is unaware of its place in the order of these matches. The simplest interpretation of $n$ is the total number of MCOs open to enrolling beneficiaries. Alternatively, even though the steps are not modelled here, $n$ could be the number of MCOs visited before either falling ill or giving up the search. MCOs are risk-neutral profit maximizers. The cost to MCO $j$ of taking on beneficiary $i$ of risk type $k$ is $c_{ijk}$. These costs are drawn independently from the distribution $F_k(c)$, with corresponding probability density function $f_k(c)$ over $[\underline{c}, \bar{c}]$, a support common across all risk types\(^3\). Assume that these distributions are smooth, continuous, atomless, and that distribution $F_{k-1}(c)$ is first-order stochastically dominated by distribution $F_k(c)$ for all $k \geq 2$. This implies that the average cost of treating a beneficiary is increasing in ex ante risk type. Assume that risk type is verifiable among MCOs,

\(^2\)Like Kifmann and Lorenz (2011), beneficiary interactions with MCOs post-match are not modelled here, though incentives would be the same in any of the payment mechanisms investigated.

\(^3\)The assumption of a common support ensures that other players cannot directly infer risk type based on any reports of $c_{ijk}$. 

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but \(c_{ijk}\) is private information held by MCO \(j\). Any MCO is able to engage in risk selection, and can thus reject excessively costly beneficiaries. Beneficiary utility is unaffected by the number of rejections as long as there is an eventual acceptance.

There is a government-sponsored payer managing the health care entitlement program, with the objective of maximizing aggregate expected consumer utility. The payer takes in revenue of \(\tau\) from each taxpayer and compensates MCOs for enrolling beneficiaries. The payer cannot condition compensation on risk type. This is either due to superiority of information among MCOs, or a conscious effort by the payer (or government) to disregard a set of variables affecting risk type when community-rating. Therefore, any prospective payment \(w\) at which MCOs are compensated is constant across all risk types. For those beneficiaries failing to enroll with an MCO, the payer bears a cost \(w_{ER}\). This is the cost of the beneficiary’s care if left uncoordinated by an MCO; delivered instead in an emergency department or acute care setting for a preventable illness. Finally, assume for this set of beneficiaries that universal enrollment is first-best optimal for the payer, implying that:

\[\left(\frac{D}{1-D}\right)\Delta U \geq U\left[m_2 - \left(\frac{D_{wER}}{1-D}\right), H_1\right] - U\left[m_2 - \left(\frac{Dc}{1-D}\right), H_1\right] \forall c \in [\underline{c}, \bar{c}] (1)\]

where \(\Delta U = U(m_1, H_1) - U(m_1, H_2)\). The assumption ensures that the payer would rather enroll every beneficiary, regardless of treatment cost or risk type, than leave any unenrolled\(^4\). Condition (1) always holds if \(w_{ER} \geq \bar{c}\), and holds in

\(^4\)Any consumers for whom Condition (1) does not hold are presumed excluded or enrolled in alternative public programs
cases where \( w_{ER} < \bar{c} \) if and only if the extra expense of enrollment to taxpayers is justified by a sufficient boost in aggregate utility to beneficiaries.

### III. Equilibrium: Uniform Payment

The first compensation method evaluated is a simple uniform prospective payment, where the payer sets a fixed payment \((w_u)\) to MCOs per beneficiary enrolled. Given this payment, and because they can select risks, MCOs take on those beneficiaries they find profitable and reject the rest. MCO \( j \)'s problem when confronted with a beneficiary with cost of treatment \( c_{ijk} \) is whether to accept or reject. For each acceptance, it would receive \( w_u \) in revenue and bear cost \( c_{ijk} \). In rejecting a beneficiary, the MCO takes in no revenue and bears no cost. Therefore, in this subgame, each MCO \( j \) has a simple optimal strategy: accept if \( w_u - c_{ijk} \geq 0 \), and reject otherwise. Due to the randomness of treatment costs, the probability that a given beneficiary of risk type \( k \) will be unacceptable to an MCO is \( 1 - F_k(w_u) \). As these costs are drawn independently across MCOs, the probability that all \( n \) MCOs find this beneficiary unacceptable is \( [1 - F_k(w_u)]^n \). The payer’s problem thus becomes:

\[
\max_{w_u} \left( EU_u(w_u) = D \left[ U(m_1, H_1) - \sum_{k=1}^{K} \alpha_k [1 - F_k(w_u)]^n : \Delta U \right] + (1 - D) U(m_2 - \tau_u, H_1) \right)
\]

where \((1 - D) \tau_u = D \left[ w_u + \sum_{k=1}^{K} \alpha_k [1 - F_k(w_u)]^n (w_{ER} - w_u) \right] \). Even though a higher uniform payment increases the chance that any beneficiary secures an acceptance, it also increases the amount of overpayment on each beneficiary ac-
cepted. The optimal uniform payment \( (w_u^*) \) recognizes this trade-off, satisfying:

\[
n \left( \frac{\Delta U}{MU_y} + w_{ER} - w_u \right) \sum_{k=1}^{K} \alpha_k [1 - F_k(w_u)]^{n-1} f_k(w_u) = 1 - \sum_{k=1}^{K} \alpha_k [1 - F_k(w_u)]^n
\]

where \( MU_y \) is taxpayers' marginal utility of consumption. The term on the left is the benefit of a marginal increase in the uniform payment. Specifically, it is the increase in the measure of beneficiaries both forgoing emergency room care (thus costing \( w_u \) instead of \( w_{ER} \)) and also the boost in utility for beneficiaries from enrollment (\( \Delta U \)), the value of which is measured in units of consumption once divided by \( MU_y \). The increase in costs due to the marginally higher uniform payment on the measure of beneficiaries already receiving care in expectation is on the right.

**Proposition 1.** For any equilibrium uniform payment \( (w_u^*) \):

i) \( [1 - F_k(w_u^*)]^n > 0 \) \( \forall \ k \), and

ii) \( [1 - F_{k-1}(w_u^*)]^n < [1 - F_k(w_u^*)]^n \) \( \forall \ k \geq 2 \)

**Proof.** By Condition (1) and the concavity of \( U(y, H) \), the left side of Condition (2) remains positive as \( w_u \) approaches \( \underline{c} \) from above, while the right side approaches zero. As \( w_u \) approaches \( \bar{c} \) from below, the left side is driven to zero while the right side approaches 1. Due to the continuity in \( w \) of both sides of Condition (2), by the Intermediate Value Theorem, there exists \( w_u \in (\underline{c}, \bar{c}) \) such that Condition (2) holds. Because \( w_u^* < \bar{c} \) and the expected cost of treating beneficiaries of any risk type is distributed over the common support \( [\underline{c}, \bar{c}] \),
then \([1 - F_k(w^*_u)]^n > 0 \forall k\). Stochastic dominance assumptions imply that \(F_1(w^*_u) > \ldots > F_K(w^*_u)\), and thus \([1 - F_1(w^*_u)]^n < \ldots < [1 - F_K(w^*_u)]^n\).  

Proposition 1 states that the equilibrium uniform payment leaves a positive measure of beneficiaries rejected by all MCOs, and within this universally rejected group, higher risk types are over-represented. Intuitively, higher acceptance rates become increasingly costly to achieve as the rate approaches 1. This is because the payment is uniform; it must increase for all accepted beneficiaries, not just the marginal one. As \(w_u\) approaches \(\bar{c}\) from below, the burden of higher payments on all accepted beneficiaries eventually outweighs the benefit of the marginal beneficiary’s acceptance. The equilibrium uniform payment is therefore below \(\bar{c}\), leaving those beneficiaries with treatment costs only between \(w^*_u\) and \(\bar{c}\) universally rejected. Higher risk types are more likely to draw the highest expected treatment costs, leaving them over-represented in this group.

IV. EQUILIBRIUM: MIXED PAYMENT

The mixed payment mechanism begins similarly to the uniform method. MCOs are offered a payment \((w_x)\) for each beneficiary enrolled, beneficiaries and MCOs interact to draw \(c_{ijk}\) values, and MCOs take on those they find acceptable. The difference is that under mixed payment, upon rejecting beneficiary \(i\), an MCO must report to the payer an amount \((\beta_{ij})\) at which beneficiary \(i\) would be acceptable. These amounts are the MCOs’ “bids”. For those beneficiaries rejected by all \(n\) MCOs, the payer awards the contract to enroll the
beneficiary to the MCO submitting the lowest bid, and pays this MCO and amount equal to the second-lowest bid. The payer funds this reimbursement method by charging $\tau_x$ to each taxpayer.

Working backward, an MCO $j$ that has rejected beneficiary $i$ must decide on the amount to submit as a bid to enroll beneficiary $i$. If this beneficiary is subsequently accepted by a different MCO, then MCO $j$’s resulting payoff is zero. MCO $j$’s payoff is affected by its bid if and only if the beneficiary is rejected by the other $n-1$ MCOs. The process under this universal rejection outcome is equivalent to a second-price, sealed-bid reverse or procurement auction. The payer is the principal, all $n$ rejecting MCOs are bidders, and the enrollment of the universally rejected beneficiary is the object. It is well established in the literature that bidder $j$’s optimal bid in such an auction ($\beta_{ij}^*$) is the opportunity cost of the object for auction ($c_{ijk}$). As this bid weakly dominates all bids in the universal-rejection outcome, and payoff is independent of bid in any other outcome, this bid is also optimal ex ante.

Before submitting a bid, the MCO must first decide whether to accept or reject. It is assumed, following Kirkman-Liff et al. (1985), that an MCO $j$ can construct subjective estimates of the probability that a beneficiary $i$ is accepted following a rejection, as well as the probability and expected payment in the event that $\beta_{ij}^* = c_{ijk}$ is the lowest bid. Given the prospective payment offered by the payer, the value of accepting is the same as in the uniform system ($w_x - c_{ijk}$). For any $w_x < \bar{c}$, the value to the MCO of rejecting is strictly positive because there is a positive probability that the $n - 1$ other MCOs also reject and the
beneficiary is allocated based on bids. In such a case, each rejecting MCO has a non-negative expected payoff. Should MCO \( j \)'s bid of \( c_{ijk} \) be the lowest, then it would receive the lowest of the set of bids higher than \( c_{ijk} \). This second-lowest bid \((\hat{c}_k)\) is a random variable distributed according to the cumulative distribution function \(1 - G_k(\hat{c}_k) = 1 - [1 - F_k(\hat{c}_k)]^{n-1} \). Therefore, the expected payment conditional on \( c_{ijk} \) being the lowest bid is:

\[
E(\hat{c}_k | \hat{c}_k > c_{ijk}) = c_{ijk} + \int_{c_{ijk}}^{\hat{c}_k} \frac{G_k(x)}{G_k(c_{ijk})} \, dx. \tag{3}
\]

This would be the bid of an MCO with cost \( c_{ijk} \) in a first-price reverse auction (Milgrom and Weber 1982, Huh and Roundy 2002), and also the expected payment to a winning MCO bidding \( c_{ijk} \) in a second-price reverse auction due to the Revenue Equivalence Theorem (Myerson 1981). Let \( h_k \) be the highest expected treatment cost at which it is a best response for an MCO to accept a beneficiary of risk type \( k \). This means that any MCO would reject a consumer with \( c_{ijk} > h_k \). Therefore, the expected value of rejecting a beneficiary is the product of the probability that the \( n - 1 \) other MCOs also reject \((G_k(h_k))\), the probability that \( c_{ijk} \) represents the lowest bid \((\frac{G_k(c_{ijk})}{G_k(h_k)})\), and the expected payoff conditional on \( c_{ijk} \) being the lowest bid \((E(\hat{c}_k | \hat{c}_k > c_{ijk}) - c_{ijk})\). Thus, unlike the uniform payment system, an MCO’s accept or reject decision under mixed payment is:

\[
\text{accept if } w_x - c_{ijk} \geq G(h_k) \cdot \frac{G_k(c_{ijk})}{G(h_k)} \int_{c_{ijk}}^{\hat{c}_k} \frac{G_k(x)}{G_k(c_{ijk})} \, dx \tag{4}
\]

reject otherwise.

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Condition (4) defines $h_k$:

$$h_k = h_k(w_x, n)$$

such that

$$h_k + \int_{h_k}^{\bar{c}} G_k(x) \, dx = w$$

The right side of (4) is increasing in $c_{ijk}$. Therefore, when facing a beneficiary of type $k$, a payment $w_x$, and $n - 1$ other providers, MCO $j$ would accept beneficiary $i$ if $c_{ijk} < h_k$. Due to $\int_{h_k}^{\bar{c}} G_k(x) \, dx \geq 0$, it is clear that $h_k(w_x, n) < w_x$ for all $w_x < \bar{c}$ and $h_k(\bar{c}, n) = \bar{c}$. Intuitively, facing a given payment to enroll a given beneficiary, rejecting is more attractive under mixed payment than under uniform payment due to the prospect of realizing a positive payoff in the auction stage. This means that any choice of payment would induce more rejections under mixed payment relative to uniform payment.

Rather than the actual costs taken on by the MCOs, the payment ($\pi$) to winning MCOs (ie. the second-lowest bid) is relevant to the payer’s problem. When allocating a beneficiary of type $k$ according to bids, the probability that the second-lowest bid is less than $\pi$ is the probability that any two MCOs (of which there are $n(n-1)$ combinations) both bid below $\pi$ while the remaining $n-2$ other MCOs bid higher. This means that the payment for a type $k$ beneficiary is a random variable distributed according to the probability density function

$$j_k(\pi \mid h_k) = n(n-1)[1 - F_k(h_k)]^{-n} f_k(\pi) [F_k(\pi) - F_k(h_k)] [1 - F_k(\pi)]^{n-2}.$$ 

Therefore, the payer’s expected payment to MCOs per beneficiary of type $k$ allocated by bids is:

$$E[\pi_k \mid w_x, n] = \int_{h_k}^{\bar{c}} \pi j_k(\pi \mid h_k) \, d\pi$$
Under the mixed payment system, each beneficiary is either accepted by an MCO during an initial match, or allocated to the lowest bidding MCO in the auction stage. This means that all beneficiaries ultimately become enrolled and enjoy health status $H_1$. Beneficiaries enjoy the utility $U(m_1, H_1)$ and taxpayers the utility $U(m_2 - \tau_x, H_1)$, meaning the payer’s problem becomes the minimization of expected cost per beneficiary:

$$\min_{w_x} \left\{ w_x + \sum_{k=1}^{K} \alpha_k \left\{ [1 - F_k(h_k)]^{n-1} \cdot (E[\pi_k | w_x, n] - w_x) \right\} \right\}$$

with the optimal payment ($w_x^*$) characterized by:

$$n \sum_{k=1}^{K} \alpha_k \left\{ [1 - F_k(h_k)]^{n-1} \cdot f_k(h_k) \frac{\partial h_k}{\partial w_x} (E(\pi_k | w_x, n) - w_x) \right\}$$

$$= 1 - \sum_{k=1}^{K} \alpha_k [1 - F_k(h_k)]^{n-1} \sum_{k=1}^{K} \alpha_k \left\{ [1 - F_k(h_k)]^{n} \frac{\partial E(\pi_k | w_x, n)}{\partial w_x} \right\}. \quad (6)$$

The left side of the equation represents the marginal benefit of increasing the prospective payment in the mixed system. It is the reduction in the measure of beneficiaries expected to be allocated in the auction stage, each of whom costs an additional $(E(\pi_k | w, n) - w_x)$ above the prospective payment. The right side of the equation is the marginal cost, which includes the increased expense of both higher payments on the measure of beneficiaries avoiding the auction stage as well as higher expected payments in the auction stage for those who do not.

Proposition 2. $\sum_{k=1}^{K} \alpha_k [1 - F_k(h_k(w_x^*, n))]^{n} < 1$ in any equilibrium under the mixed payment system.
Proof. Define \( w_{x,k} = w_{x,k}(n) \) such that \( h_k(w_{x,k}, n) = c \). This is the highest prospective payment such that MCOs still reject all beneficiaries of type \( k \), regardless of \( c_{ijk} \). The value of \( w_{x,k} \) increases in \( k \). Obtaining the first derivatives of \( h_k(w_x) \) and \( E(\pi_k | w_x, n) \):

\[
\frac{\partial h_k}{\partial w_x} = \begin{cases} 
\frac{1}{1 - G_k(h_k)} & \text{if } h_k(w_x, n) \geq c; \\
0 & \text{otherwise.}
\end{cases}
\]

\[
\frac{\partial E(\pi_k | w_x, n)}{\partial w_x} = \begin{cases} 
\frac{n f_k(h_k)}{1 - F_k(h_k)} \frac{\partial h_k}{\partial w_x} \left( E(\pi_k | w_x, n) - E(\hat{c}_k | \hat{c}_k > h_k) \right) & \text{if } h_k(w, n) \geq c; \\
0 & \text{otherwise.}
\end{cases}
\]

and using (3) and (5) allows Condition (6) to be rearranged into:

\[
\sum_{k=1}^{K} \alpha_k n f_k(h_k) \int_{h_k}^{\bar{c}} G_k(\pi) \, d\pi = 1 - \sum_{k=1}^{K} \alpha_k [1 - F_k(h_k)]^n.
\]

As \( w_x \) approaches \( w_{x,1} \) from above, the right side of the equation approaches 0 while the left side approaches a value greater than 0. Therefore, costs could be lowered by setting \( w_x \) strictly above \( w_{x,1} \). Because \( w_x^* > w_{x,1} \Rightarrow [1 - F_1(h_1(w_x^*, n))]^n < 1 \), then \( \sum_{k=1}^{K} \alpha_k [1 - F_k(h_k(w_x^*, n))]^n < 1 \).

Proposition 2 states that it is never optimal in the mixed system to set the payment so low that every beneficiary is allocated by auction. Such a low prospective payment would be equivalent to a pure bidding allocation mechanism, delivering expected utility \( EU_x(w_{x,1}) \) and expected costs of \( \sum_{k=1}^{K} \alpha_k E[\pi_k | w_{x,1}, n] \) per beneficiary. Costs can be reduced by having at least an infinitesimally small positive measure of type 1 beneficiaries accepted before the auction stage. Intu-
itively, an MCO drawing \( c_{ijk} = h_k \) is guaranteed to have the lowest bid and win any auction for this beneficiary, and were an auction to happen, can expect to realize a large payoff. When deciding whether or not to accept, such an MCO realizes that this payoff is contingent on every other MCO also rejecting, which is the only case in which an auction occurs. By accepting, however, the MCO assures itself of taking in revenues equal to the prospective payment. The payer can exploit this tension between potential and guaranteed payoffs by increasing the prospective payment. This induces an acceptance by the marginal MCO at the prospective payment rather than paying out a larger payment in an auction to the winning bidder, and thus reduces the expected payment per beneficiary.

Comparison of the three mechanisms examined here requires criteria for the basis of an ordering. The implications of Propositions 1 and 2 allow for at least a partial ordering on the basis of ex ante Pareto dominance. That is, if mechanism \( A \) were to achieve at least as much expected utility for one group of consumers (beneficiaries or taxpayers) as mechanism \( B \), while leaving the other group strictly better off in expectation, then mechanism \( A \) would ex ante Pareto dominate mechanism \( B \). Let \( \geq \) be a binary relation implying ex ante Pareto dominance. Due to the mixed \((X)\) and pure \((P)\) bidding mechanisms both eliminating risk selection, but the mixed mechanism results in lower entitlement program spending (and thus lower taxes) by Proposition 2, therefore \( X \geq P \). The conditions below are necessary and sufficient for additional orderings involving the uniform payment mechanism \((U)\):
\[ \tau_x(w_x^*) \leq \tau_u(w_u^*), \quad \Leftrightarrow \quad X \succeq U. \quad (7) \]

\[ \tau_x(\bar{w}_{x,1}) \leq \tau_u(w_u^*), \quad \Leftrightarrow \quad X \succeq P \succeq U. \quad (8) \]

These follow directly from Proposition 1 because beneficiaries’ prospects for enrollment are higher under either competitive bidding mechanism than under uniform payment. With beneficiaries unambiguously better off, a competitive bidding mechanism dominates uniform payment if the entitlement program spending under the former is no greater than under the latter, leaving taxpayers no worse off. Figures III and IV show examples of cases where Conditions (7) and (8), respectively, would hold for a given risk type \( k \). If the light-grey areas are non-negative in a weighted average across risk types, then the competitive bidding mechanisms achieve cost savings while also improving the provision of care to beneficiaries.

V. Numerical Analysis

The analytical results reveal a partial ordering of competitive bidding mechanisms by ex ante Pareto dominance, as well as necessary and sufficient conditions for additional orderings, including a complete ordering of all three mechanisms. These results, however, do not reveal how likely these conditions are to hold, nor do they quantify the actual cost savings and reduced selection that produce the orderings. Normally this would not be a concern because an ordinal ranking
sufficiently informs the choice of “best” mechanism. In this case, however, it is useful to determine “how much better” each mechanism is for two reasons. First, the models examined here gave no consideration to administrative costs. This is an important consideration if competitive bidding is administratively complex. The mixed bidding system, in particular, may be administratively complex as it essentially runs the other two mechanisms in tandem. Second, from the analytical results alone, it is unclear which distributional characteristics or model parameters are most important in determining the ordering of mechanisms. This knowledge would be useful in determining which situations are most likely to realize program improvements under competitive bidding. To answer these questions, this study proceeds with numerical analysis.

Using MATLAB, 30000 parameter sets were drawn randomly from an eleven-dimensional parameter space. Each element of each parameter set was drawn independently from a uniform distribution between the bounds shown in the Table I summary statistics. Bounds on \(m_1, m_2,\) and \(D\) were chosen so that parameter mean values approximate real conditions in U.S. health care entitlement programs (Kaiser Family Foundation 2013, Noss 2013, Jacobson et al. 2014). In cases where model assumptions restricted the relative sizes of parameter values (ie. \(\bar{c} < c, H_1 > H_2\)), the differences between values were drawn randomly instead of the values themselves. Additional restrictions were placed for ease in computing. The restriction \(m_2 > \max\{w_{ER}, \bar{c}\}\) on each simulation ensures that taxpayer consumption cannot become negative under any prospective payment or mechanism. The values of \(H_1\) and \(H_2\) sum to 10 in each simulation, with \(H_1\)
always greater. As Condition (1) could potentially produce a negative value, 
\( w_{ER} \) was bounded below at 0.75\( \bar{c} \) + 0.25\( \bar{c} \) in each simulation. The upper bound on \( w_{ER} \) was chosen so that the mean value was approximately equal to the mean of \( \bar{c} \), allowing for equally rich investigation of cases in which rejected consumers are both more and less expensive than the most costly acceptance.

Numerical simulations require the choice of functional forms. The utility function is assumed to be Cobb-Douglas, 
\[ U(y, H) = H^{\beta} y^{(1-\beta)}. \]
Each distribution \( F_k(c) \) is truncated normal over \([\bar{c}, \bar{c}]\). Each distribution has the same standard deviation as a share of the support \( \bar{c} - c \) and the means are distributed uniformly over the interval \((\bar{c}, \bar{c})\). Two measures were constructed in order to capture the exogenous characteristics of the simulated distributions \( F_k(c) \).

From Table I, let \( \text{skew} \) be the mass of the unconditional probability density function distributed over the greater half of the support, \((0.5(\bar{c} + \bar{c}), \bar{c})\). Let \( \text{conc} \) be the measure of the support containing 50% of the mass, excluding upper and lower quartiles. These measures allow for investigation into the impact of population distribution characteristics on the equilibrium degree of selection, any cost savings between mechanisms, and the likelihood that each ordering holds.

Given the functional forms, MATLAB’s \texttt{fsolve} function was used to determine the optimal prospective payments under alternative uniform \( (w_u^*) \) and mixed \( (w_x^*) \) payment mechanisms for each simulated parameter set. The initial point was chosen by evaluating twenty values of \( w_u \) and fifty values of \( w_x \), evenly distributed between \( \bar{c} \) and \( \bar{c} \), and selecting the pair delivering the greatest
expected utility. The fsolve outputs were examined for satisfaction of second-order conditions and for consistency with Propositions 1 and 2. Inconsistencies occurred in 13 out of 30,000 simulations, and in these cases, the evaluated \{w_u, w_x\} delivering the highest expected utility in their respective mechanisms were recorded as solutions. Let \(\text{Cond}(7)\) and \(\text{Cond}(8)\) be indicator functions, respectively equal to 1 if Conditions (7) and (8) hold. Also determined were the measures of beneficiaries that would not be accepted at the optimal prospective payments (\(\text{Select}_u\) under uniform payment and \(\text{Select}_x\) under mixed payment) and the total spending per beneficiary under each of the three alternative reimbursement methods (\(\text{Spend}_u\), \(\text{Spend}_p\), and \(\text{Spend}_x\)). Summary statistics of these equilibria appear in Table I.

Competitive bidding mechanisms achieved higher expected consumer utility, relative to uniform payment, in approximately 88% of simulated parameter sets. One reason for this is that, whereas the entire beneficiary population is enrolled under competitive bidding, an average 14% of beneficiaries are left unenrolled under the optimal uniform payment. Due to stochastic dominance assumptions, enrollment increases are greatest among the most risky beneficiary types. Additionally, competitive bidding mechanisms reduce spending by 24% on average compared to uniform payment, thus reducing the burden of the entitlement program on taxpayers. Regarding ex ante Pareto dominance, Condition (7) holds in 84% of cases and Condition (8) holds in 83%. This shows that competitive bidding outperforms uniform payment, for both beneficiaries and taxpayers, over the vast majority of the parameter space.
Condition (8) implies Condition (7), so the simulations show that there are very few cases (134 out of 30,000) in which mixed bidding, but not pure bidding, dominates uniform payment. This is because, even though Proposition 2 proves that mixed bidding is less expensive than pure bidding, the simulations reveal the additional savings to be relatively small. The majority of savings (23% on average) are achieved by moving from uniform payment to pure bidding, while pure to mixed bidding only saves an average additional 0.7%. Over all simulations, the maximum additional savings achieved by mixed over pure bidding is 4.9%. Despite the negligible difference in savings, the mean value of $Select_x$ shows that, on average, 27% of beneficiaries in the mixed system are accepted at the optimal prospective payment. This shows that, even though beneficiary enrollment is identical and spending nearly is, the differences in operation between the mixed- and pure-bidding systems are non-negligible. Therefore, the relative appropriateness of the two bidding mechanisms would likely depend on administrative simplicity.

As competitive bidding dominates uniform payment over many, but not all, simulated parameter sets, it is important to determine the parameter values at which dominance is most likely, as well as the parameters to which dominance is most sensitive. Table II shows summary statistics of key parameters, conditional on whether or not the competitive bidding mechanisms dominate uniform payment. The table provides intuition for when and why competitive bidding mechanisms would dominate uniform payment. In cases where $w_{ER}$ and $\beta$ are high, risk selection is a significant source of inefficiency in the entitlement pro-
gram. It is very costly to reduce risk selection using uniform payment, but the competitive bidding mechanisms eliminate it completely and tend to do so at lower cost. There is a measure of the parameter space, however, where eliminating risk selection is not very important. This is where the marginal cost of enrollment is high (low $w_{ER}$ relative to $\bar{c}$) and the marginal utility of enrollment is low (low $\beta$). In such cases, eliminating risk selection is not worth the cost, and as Table II shows, it is better to set a uniform payment so low that nearly half of beneficiaries can expect universal rejection.

Table III shows the marginal effects of the simulated parameters and constructed distribution characteristics on $Cond(7)$ and $Cond(8)$, respectively, evaluated at parameter means. Two linear probability model specifications were estimated, both with and without key interactions. Due to the near-perfect correlation of $Cond(7)$ and $Cond(8)$, the effects of parameter values on the two conditions are nearly identical in significance, sign, and value in Table III. The marginal effects of $\bar{c}$, $\bar{\sigma}$, and $conc$ are all negative, meaning that dominance is less likely to hold in cases where the average treatment cost distribution is spread out over a wide support. Under these conditions, there is a greater chance for an MCO drawing a low treatment cost to realize a large payoff in the mixed system if the patient is allocated by auction. This makes auctions less effective due to greater auction payments and a higher incidence of rejection. Notice also the negative and significant sign on the interaction term $K \times \bar{\sigma}$, which shows that a high number of risk types spreads the distribution over the support in cases where $\bar{\sigma}$ is small. The coefficient on $n$ shows that, even though competi-
tion among MCOs improves all mechanisms, it has a greater positive impact on bidding mechanisms relative to uniform payment. Consistent with the results of Table II, Cond(7) and Cond(8) are most sensitive to parameters $w_{ER}$ and $\beta$, with elasticities of 0.51 and 0.31 respectively.

The interaction term $conc \times \bar{\sigma}$ provides insight into effectiveness of competitive bidding under different sources of unpriced heterogeneity. The two main sources are, first, asymmetric information where the payer cannot distinguish between risk types, and second, the decision or restriction to pool together and community-rate multiple known risk types. The latter case, where sufficient differences exist to make types distinguishable to the payer, suggests that expected treatment costs are more variant across risk types than within. This across-versus-within variance is captured by the interaction term. At a given value of $conc$, a low $\bar{\sigma}$ implies that the mass of each risk type’s probability density function is concentrated over a narrow range of treatment costs, and that these type-specific ranges are spread widely over the support. The highly negative coefficient on the interaction implies that, the more different risk types are from one another, the more likely are competitive bidding mechanisms to dominate uniform payment. This suggests that competitive bidding mechanisms have the greatest potential for improvement over uniform payment in cases where payers attempt to pool together multiple known risk types.

The effects of parameter values on the amount of spending reductions between payment mechanisms are shown in Table IV. In the left two columns, the coefficients and significance on parameters $c$, $\bar{\sigma}$, skew, and $conc$ show that
competitive bidding realizes the greatest program savings over uniform payment
where population treatment costs are spread widely over a broad support. This
implication is the opposite of that found in Table III, revealing a tension between
potential spending reductions and the likelihood of ex-ante Pareto dominance.
Even though wide distributions of cost make enrollment of beneficiaries more
expensive under any payment mechanism, competitive bidding achieves high
enrollment at a lower cost than uniform payment. However, at low values of
\( w_{ER} \) and \( \beta \), enrollment is not important and so is not pursued under uniform
payment. Wider distributions in these circumstances would raise spending un-
der competitive bidding mechanisms, but not under uniform payment, because
high enrollment must occur under competitive bidding but is discretionary un-
der uniform payment. This is further reflected in the elasticities of savings with
respect to parameter values \( w_{ER} \) and \( \beta \), which are 1.38 and 1.81 respectively.
As these parameter values increase, not only does any level of enrollment be-
come more expensive under uniform payment, it also makes enrollment more
important to achieve. This is why these parameters drive up program spending
under uniform payment, but not under competitive bidding.

Multiple significant coefficients show that several key parameters have the
opposite signed effects on \( \text{Spend}_u - \text{Spend}_p \) compared to \( \text{Spend}_p - \text{Spend}_x \). This
shows that, in cases where competitive bidding performs poorly, the mixed
payment mechanism can reduce spending further by allocating more beneficia-
ries by prospective payment. Preference parameters like \( m_2 \), \( H_1 \), and \( \beta \) affect
\( \text{Spend}_u - \text{Spend}_p \), but not \( \text{Spend}_p - \text{Spend}_x \). This is because, under uniform
payment, high values of these parameters would make the payer willing set high uniform payments in an effort to minimize risk selection. This would result in very high spending under uniform payment, while spending under either competitive bidding method is independent of these parameters. This implies that jurisdictions with a wealthy tax base, high quality health care, and a high general preference for health would have the most to gain from incorporating competitive bidding into health care entitlement programs.

VI. Conclusion

This article investigates whether and how the incorporation of competitive bidding into health care entitlement programs can mitigate the problem of risk selection. It compares three allocation mechanisms. The first mechanism allocates beneficiaries to MCOs using a uniform prospective payment. Profitable beneficiaries are accepted by MCOs, and unprofitable ones are rejected. The second mechanism is a mixed reimbursement system, still offering a prospective payment for each beneficiary accepted, but requiring MCOs to submit a bid to the payer on any rejected beneficiary. Any beneficiaries rejected by all MCOs are allocated to the lowest-bidding MCO and paid the second-lowest bid. The final mechanism investigated is one of pure competitive bidding, where MCOs bid as above on all beneficiaries.

Results show that risk selection is always practiced under the optimal uniform prospective payment, but never under either mixed or pure competitive
bidding, and also that mixed payment ex ante Pareto dominates pure bidding. These findings on selection reveal necessary and sufficient conditions for further orderings on ex ante Pareto dominance. Condition (7) implies that mixed payment dominates uniform payment and Condition (8) implies that pure bidding dominates uniform payment. Numerical analysis of 30,000 simulations shows that these conditions hold over 84% and 83%, respectively, of the chosen parameter space. On average, competitive bidding increased enrollment in health plans to an additional 14% of the beneficiary population and reduced spending per beneficiary by 24%. Even though the theoretical analysis proves that mixed reimbursement dominates pure competitive bidding in spending per beneficiary, the numerical analysis shows the difference to be so small that pure bidding may deliver a better outcome if it is simpler to administer. Finally, analysis of the effect of parameter values shows that the only circumstances in which uniform payment is superior to competitive bidding is where insurance enrollment is not important to achieve. This strongly indicates that competitive bidding is the most appropriate mechanism for mitigating risk selection in cases where risk selection is a significant problem.

A number of implications emerge from these findings. First, the addition of a competitive bidding component to widely used prospective payment systems can eliminate risk selection while preserving MCO incentives to contain costs. Competitive bidding does not solve any MCO incentives to undertreat patients, but leaves them unchanged from those under uniform prospective payment. In this way, selection is reduced without increasing inefficiency and without
introducing demand side cost sharing, thus keeping beneficiaries fully insured. Second, competitive bidding eliminates risk selection regardless of the number of beneficiary risk types \( (K) \) or the variance in match-specific treatment costs. This suggests that costly risk adjustment schemes; where payers attempt to measure beneficiary characteristics, estimate their effects on treatment costs, and condition payments on the findings; would be unnecessary for overcoming risk selection once competitive bidding is introduced. This is not to say that risk adjustment is entirely unwarranted, as this model does not investigate whether partitioning the set of beneficiary risk types can reduce the price of health insurance overall. A third implication emerges from the analytical results, which show that prospective payment and competitive bidding can be best utilized in sequence as a mixed allocation mechanism, instead of mutually exclusive options.

The final policy implication concerns the performance of health care entitlement programs in the United States under the new regulatory environment of the Affordable Care Act. As a method of reimbursement in a health care entitlement program, competitive bidding most dominates uniform payment whenever the tax base is wealthy, private health care is high quality, the population holds a high willingness to pay for improved health, and where payers attempt to impose community rating on health plans when pooling multiple known risk types. This is a qualitatively accurate description of the state of health care in the United States, particularly as new regulations on community rating are imposed on insurers. Under these circumstances, the findings here indicate that
the best way to ensure universal coverage and low government expenditure on
health care entitlement programs is to allocate beneficiaries through patient-
level competitive bidding instead of community-rated uniform payments. This
innovation in prospective payment could serve a vital role in improving both the
solvency of health care entitlement programs as well as the provision of health
services to vulnerable populations.

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Figure I: Total spending under a given uniform payment. The light rectangle is expenditure on the share of beneficiaries securing enrollment care and the dark rectangle is expenditure on those rejected by all $n$ MCOs.
Figure II: Total spending under the mixed payment method for a given prospective payment. The light rectangle is expenditure on beneficiaries securing enrollment and the dark rectangle is expenditure on beneficiaries allocated in the auction stage.
Figure III: The difference in spending between the uniform payment and mixed payment mechanisms on risk type $k$. 
Figure IV: The difference in spending between the uniform payment and pure bidding mechanisms on risk type k.
TABLE I: SUMMARY STATISTICS

<table>
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<th>Parameter</th>
<th>Mean (Std. deviation)</th>
<th>Min.</th>
<th>Max.</th>
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TABLE III: Marginal Effects on Conditions (7) and (8)

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<td>H₂</td>
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<td>0.008**</td>
<td>0.007**</td>
<td>0.008**</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>β</td>
<td>0.60**</td>
<td>1.82**</td>
<td>0.62**</td>
<td>1.85**</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.023)</td>
<td>(0.006)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>β²</td>
<td>-0.66**</td>
<td>-0.66**</td>
<td>-0.68**</td>
<td>-0.68**</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.021)</td>
<td>(0.021)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>β × w_{ER}</td>
<td>-4.20e-05**</td>
<td>-4.20e-05**</td>
<td>-4.22e-05**</td>
<td>-4.22e-05**</td>
</tr>
<tr>
<td></td>
<td>(6.87e-07)</td>
<td>(6.90e-07)</td>
<td>(6.90e-07)</td>
<td>(6.90e-07)</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are dummies equal to 1 if the respective condition holds. All specifications are linear probability models. Regressions in columns 2 and 4 include key parameter interaction terms. Significance at the 5% level is indicated by **.
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>$c$</td>
<td>0.22 (0.23)</td>
<td>0.001 (0.004)</td>
<td>0.07** (0.001)</td>
<td>0.07** (2.03e-05)</td>
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<tr>
<td>$\bar{c}$</td>
<td>0.07** (0.001)</td>
<td>0.07** (2.03e-05)</td>
<td>0.07** (0.001)</td>
<td>0.07** (2.03e-05)</td>
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<tr>
<td>$\bar{\sigma}$</td>
<td>-2514** (145.05)</td>
<td>1755.35** (366.01)</td>
<td>327.40** (1639.94)</td>
<td>489.31** (25.36)</td>
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<tr>
<td>$\sigma$</td>
<td>-7888.07** (397.28)</td>
<td>4567.68** (1639.94)</td>
<td>-114.62** (6.24)</td>
<td>-489.31** (25.36)</td>
</tr>
<tr>
<td>$skew$</td>
<td>-12479.18** (1552.88)</td>
<td>358.46** (24.01)</td>
<td>248.97** (7.57)</td>
<td>11.23 (9.62)</td>
</tr>
<tr>
<td>$skew^2$</td>
<td>-12479.18** (1552.88)</td>
<td>358.46** (24.01)</td>
<td>248.97** (7.57)</td>
<td>11.23 (9.62)</td>
</tr>
<tr>
<td>$conc$</td>
<td>6607.48** (482.31)</td>
<td>11923.54** (622.46)</td>
<td>489.31** (25.36)</td>
<td>11.23 (9.62)</td>
</tr>
<tr>
<td>$conc \times \bar{\sigma}$</td>
<td>-14954.36** (1308.19)</td>
<td>992.09** (20.23)</td>
<td>992.09** (20.23)</td>
<td>992.09** (20.23)</td>
</tr>
<tr>
<td>$K$</td>
<td>78.58** (7.97)</td>
<td>154.01** (18.58)</td>
<td>-8.80** (1.03)</td>
<td>-7.88** (0.29)</td>
</tr>
<tr>
<td>$K \times \bar{\sigma}$</td>
<td>-176.99** (28.08)</td>
<td>-176.99** (28.08)</td>
<td>-13.49** (0.84)</td>
<td>-13.49** (0.84)</td>
</tr>
<tr>
<td>$n$</td>
<td>658.85** (15.06)</td>
<td>2274.21** (70.49)</td>
<td>-13.49** (0.84)</td>
<td>-13.49** (0.84)</td>
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<tr>
<td>$n^2$</td>
<td>-131.72** (4.80)</td>
<td>-131.72** (4.80)</td>
<td>-131.72** (4.80)</td>
<td>-131.72** (4.80)</td>
</tr>
<tr>
<td>$w_{ER}$</td>
<td>0.16** (0.005)</td>
<td>0.36** (0.008)</td>
<td>8.38e-05 (7.14e-05)</td>
<td>0.16** (0.005)</td>
</tr>
<tr>
<td>$m_1$</td>
<td>0.01 (0.008)</td>
<td>6.58e-05 (0.007)</td>
<td>-1.78e-04 (1.20e-04)</td>
<td>-1.78e-04 (1.20e-04)</td>
</tr>
<tr>
<td>$m_2$</td>
<td>0.03** (0.002)</td>
<td>0.04** (0.002)</td>
<td>6.44e-05 (3.44e-05)</td>
<td>6.44e-05 (3.44e-05)</td>
</tr>
<tr>
<td>$D$</td>
<td>-927.93** (354.21)</td>
<td>-795.43** (340.41)</td>
<td>8.69 (5.56)</td>
<td>8.69 (5.56)</td>
</tr>
<tr>
<td>$H_1$</td>
<td>491.77** (23.14)</td>
<td>497.85** (22.23)</td>
<td>-0.05 (0.36)</td>
<td>-0.05 (0.36)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>18698.31** (122.26)</td>
<td>19057.53** (483.11)</td>
<td>1.11 (1.92)</td>
<td>1.11 (1.92)</td>
</tr>
<tr>
<td>$\beta^2$</td>
<td>5326.53** (431.09)</td>
<td>5326.53** (431.09)</td>
<td>-9.45 (6.67)</td>
<td>-9.45 (6.67)</td>
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<tr>
<td>$\beta \times w_{ER}$</td>
<td>-0.43** (0.014)</td>
<td>-0.43** (0.014)</td>
<td>-1.02e-04 (2.22e-04)</td>
<td>-1.02e-04 (2.22e-04)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.549 (0.005)</td>
<td>0.584 (0.005)</td>
<td>0.675 (0.005)</td>
<td>0.709 (0.005)</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are the differences in savings between respective payment mechanisms. All regressions are simple OLS. Regressions in columns 2 and 4 include key parameter interaction terms. Significance at the 5% level is indicated by **.