

Participation and Performance in Accountable Care Organizations

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Abstract

This paper studies provider participation and performance in Medicare's Accountable Care Organizations (ACOs). I build and estimate a two-stage structural model in which potential ACO participants first choose which, if any, ACO to join based on the characteristics of an ACO and the net income they expect to earn from participating in that ACO. In the second stage, participants in an ACO act strategically, choosing their contribution to ACO savings and quality to maximize their payoff, hence determining overall ACO performance and the net income from participating. The model is estimated with public ACO-level performance data. Estimation provides strong evidence that Medicare providers are more likely to participate in ACOs that earn more, with an additional \$100,000 in ACO income increasing participation in that ACO by over 1%. I also find that primary care physicians have a much higher cost of improving quality of care and increasing savings than specialists, and all providers face a strong trade-off between these two objectives. One counterfactual policy experiment shows that two-sided ACOs could increase the cost-savings of the Medicare Shared Savings Program by \$50 million per year, or 9%. Another counterfactual experiment finds that cost-savings is maximized when 53% of savings are paid back to ACOs, which is strikingly close to current policy. Under perfect coordination of ACO participants, program savings would increase by \$1.26 billion.

Keywords: Accountable Care Organization (ACO), Medicare, Medicare Shared Savings Program (MSSP)

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1 Introduction

The Medicare Shared Savings Program (MSSP) and its Accountable Care Organizations (ACOs) are among the most recent and important attempts to curtail healthcare expenditure and improve healthcare quality in the United States. Welcomed with the enactment of the Patient Protection and Affordable Care Act of 2010 (ACA), these ACOs are groups of Medicare providers that receive incentive pay for spending less on their beneficiaries while providing high quality of care. Early indicators are favorable: since the beginning of the MSSP in 2012, 10.5 million Medicare beneficiaries have been assigned to ACOs, over \$3 billion in performance payments have been paid by Medicare to ACOs, and over \$7 billion has been saved.¹ ACOs have the potential to finally spur integrated care delivery and significant reductions in expenditure throughout Medicare—and possibly throughout the entire \$3 trillion healthcare industry.

This paper answers several questions surrounding participation and performance in ACOs: Which characteristics of ACOs are important to providers thinking about joining? How important is incentive pay? Which characteristics are conducive to spending less and improving quality? Is there a large trade off between these goals? Furthermore, I examine the outcome of several counterfactual scenarios: How will performance change as two-sided incentive schemes take precedence? What payment formula maximizes the money saved by the Medicare program? How much is lost to non-cooperative behavior and misaligned incentives within ACOs?

In order to answer these questions, I write and estimate a two-stage structural model of Medicare providers' decisions regarding ACOs. In the first stage, potential ACO participants choose which, if any, ACO to join, taking into account an ACO's characteristics (including information about other participants and the ACO's assigned beneficiaries) and the net income (that is, earned incentive pay minus explicit and implicit costs) from joining an ACO. In the second stage, ACO participants act strategically and choose their contribution to the organization's overall savings and quality to maximize their payoff. These actions

¹“Medicare Shared Savings Program Fast Facts.” CMS. Published January 2018. <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/Downloads/SSP-2018-Fast-Facts.pdf>.

determine an ACO's performance, and hence the net income from participating. I estimate structural parameters that describe utility from participation and supply curves for Medicare savings and quality of care.

The results are novel and robust. I find that increasing an ACO's net income by \$100,000 increases participation by at least 1%, and the leadership structure of an ACO plays a significant role in a provider's decision to join. Performance is largely determined by the type of providers comprising an ACO, as primary care physicians have far higher marginal costs of performance than specialists. There is a strong trade-off between Medicare savings and quality of care: a standard deviation increase in an ACO's savings rate increases the the marginal cost of quality of care by nearly \$4,000 per provider.

Counterfactual experiments offer several insights to policymakers. Under the current scheme, ACOs can earn up to 50% of the money they save as incentive pay. I compute that the optimal savings fraction is 53%, where Medicare increases the savings of the program by about \$17 million per year, or 1.55%. I predict that two-sided ACOs will have five times the savings rate of one-sided ACOs, and this amounts to nearly a 9% increase in savings to Medicare. Quality scores, on the other hand, decrease under the two-sided incentive structure, since ACOs incur significantly higher costs of increasing quality when savings increases.

Finally, I find that under perfect participant coordination, program savings would increase by about \$1.26 billion per year. While massive, this could be even higher, as the payment structure of the MSSP exhibits strategic complementary: when a participant in an ACO increases their contributions to savings and quality, the benefit to other participants for doing the same increases. Were the payment structure of a different form, the increase in savings under perfect coordination would be even higher.

This paper continues in the following manner: Section 2.1 describes the legal specifics of participation and incentive pay in the MSSP, and Section 2.2 describes literature related to this paper. I outline my model of participation and performance in Section 3, and the data used for estimation is discussed in Section 4. I describe identification and estimation in Section 5, and results in Section 6. I present counterfactual analysis in Section 7, robustness checks in Section 8, and Section 9 concludes.

2 Background and Related Literature

2.1 ACO Participation, Performance, and Payment

ACOs began operating in 2012 and continue to operate today. Nearly any Medicare provider can start an ACO (typically as an LLC) and recruit other Medicare providers, referred to as participants, to join their venture. A participant can be nearly any healthcare provider that accepts and bills Medicare, including individual physicians, group practices, and hospitals. Once an ACO shows they have established a governing board that oversees clinical and administrative aspects of operation and shows the presence of formal contracts between itself and its member participants (including the distribution of shared savings payments), it then enters into a three year agreement with the Center for Medicare and Medicaid Services (CMS). Provided the ACO is assigned at least 5,000 beneficiaries, they are officially part of the MSSP, and will pursue shared savings payment in the following performance year.

There are two separate components of assessing ACO performance, and both determine the resulting shared savings payment amount. First, an ACO's overall quality score is a composite score between 0 and 1 of 30 to 40 sub-measures of care quality falling into the domains of "Patient/Caregiver Experience," "Care Coordination/Patient Safety," "Preventative Health," and "At-Risk Population." Some sub-measures are survey responses (e.g. "ACO2: How Well Your Doctors Communicate"), while others are computed from Medicare Claims and aggregated to the ACO-level (e.g. "ACO21: Proportion of Adults who had blood pressure screened in past 2 years").²

The second component is ACO savings. CMS first establishes an ACO's benchmark expenditure by forecasting per-beneficiary Medicare expenditure of the ACO's participants for beneficiaries that would have been assigned to the ACO in the three years prior to the agreement period. For performance years after the first, the benchmark is updated based on projected growth of per-beneficiary Medicare expenditure. The savings rate of an ACO in a performance year is then the difference between its benchmark expenditure and actual expenditure divided by its benchmark expenditure.

ACOs have a choice of three Tracks—Track 1 is only available to newer ACOs (which is

²See <https://go.cms.gov/2xHy7Uo> for a full list of ACO quality scores for every performance year.

almost all ACOs right now), and is one-sided insofar as there is no loss sharing with CMS (only shared savings). In each year, to qualify for shared savings, the ACO's savings rate must be greater than the minimum savings rate, which is determined by CMS according to the number of beneficiaries assigned to the ACO.

Accordingly, the shared savings offered by CMS to an ACO on Track 1 is

$$0.5 \cdot (\text{Benchmark Expenditure} - \text{Expenditure}) \cdot \text{Quality Score} \quad (1)$$

when an ACO's savings rate meets or exceeds its minimum savings rate and its quality score meets or exceeds quality reporting standards. Otherwise, an ACO earns \$0 in shared savings. For example, consider an ACO with benchmark expenditure of \$18.6 million (the average over 2012-2017) and minimum savings rate of 0.02. If that ACO has an expenditure of \$16 million with a quality score of 0.90, it would earn

$$0.5 \cdot (\$18.6 \text{ million} - \$16 \text{ million}) \cdot 0.90 = \$1.17 \text{ million} \quad (2)$$

in shared savings. Its savings rate is $(18.6 - 16)/16 = 0.14$, and hence the minimum savings rate is exceeded. Though paying a subsidy, the government saves money as well: they are \$1.43 million richer, as it paid \$1.17 million to save \$2.6 million.

Unlike Track 1 ACOs, Track 2 and Track 3 ACOs face losing money, as their payment structure is two-sided. Track 2 or Track 3 ACOs are discussed in more detail in Section 7.1.

2.2 Related Literature in Economics and Health

This paper falls neatly into several areas of academic research. It contributes to the health economics literature concerning healthcare provider payment systems and their behavior in organizations (Gaynor et al., 2004; Encinosa et al., 2007; Rebitzer & Votruba, 2011; Ho & Pakes, 2014; Frandsen & Rebitzer, 2015; Frandsen et al., 2017). Medicare's Accountable Care Organizations are a fascinating and popular example of such an environment, and this paper is the first to estimate a structural model of ACOs and conduct predictive counterfactual policy analysis of the Medicare Shared Savings Program.

Frandsen & Rebitzer (2015) is perhaps the paper related closest to this one. The authors calibrate a simple moral-hazard model with the Center for Medicare and Medicaid Services as principle to distinguish the effect of ACO size on performance. They find a pertinent free-riding problem, and argue that ACOs will be unable to self-finance—that is, the cost of moral hazard will overwhelm any bonus paid by CMS. The authors conclude with a skeptical look at the Medicare Shared Savings Program, and mention the untenability of integrated organizations in the now very fractioned US health care market. These conclusions differ vastly from my own—I argue in Sections 3 and 6 that an ACO’s performance loss due to free-riding (or more generally, non-cooperative behavior) is largely mitigated by strategic complementarity imposed by the shared savings formula.³

In a theoretical framework, Frandsen et al. (2017) discusses the MSSP’s impact on health-care in the United States in the context of common agency, where several payers motivate the same agent to improve care delivery and integration. The authors find that unique equilibrium contracts from payers are lower powered in the presence of shared savings payments, and ACO entry can possibly inspire other shared savings contracts in the private sector if they don’t already exist. Frandsen et al. (2017) differs from the present paper in that it opts to model an additional payer’s impact on providers, as opposed to within-ACO incentives and decision making.

More generally, this paper aligns with the literature that studies the supply side of health-care, and examines the incentives faced and decisions made by physicians, hospitals, and insurers (Gaynor, 2006; Chandra et al., 2011; Gaynor et al., 2015; Ho & Lee, 2017; Foo et al., 2017). Several articles point to ACOs as a policy worth looking at closely, and this paper fills that void. This paper also joins literature that estimates static games and discrete choice models with aggregate data (Berry, 1994; Berry et al., 1995; Cardell, 1997; Nevo, 2000; Rysman, 2004; Gowrisankaran et al., 2015; Hoberg & Phillips, 2016).

Recent empirical findings suggest physicians and other Medicare providers respond strongly to financial incentives imposed by Medicare. For example, Eliason et al. (2016) and Einav et al. (2017) show the large jump in Medicare payments to long-term care hospitals after a long

³The model calibrated in Frandsen & Rebitzer (2015) focuses on a shared savings formula for ACOs in their first performance year where strategic complementarity is not present.

stay of a beneficiary impacts discharge decision significantly. Early evidence of the performance of ACOs is discussed in McWilliams et al. (2016), where a differences-in-differences design compares ACO providers and a control group before and after the start of the MSSP. The authors find ACO and non-ACO providers had similar spending trends prior to the start of the program, but spending decreased for ACO providers in the first year of the program.

3 Model

I model participation and performance in ACOs as a two-stage decision process. All decisions are made by participants (i.e. Medicare providers), and occur in a static framework. I intentionally avoid modeling an ACO's management level decisions—while ACOs do have influence over their members, it's ultimately the participants that see and treat its assigned beneficiaries, so I assume these are the relevant decision-makers. Any ACO influence is unobserved heterogeneity, and I identify underlying structural parameters accordingly.

In the first stage, a potential participant chooses which ACO to join. This stage is in a general nested logit form, where there are essentially two sub-decisions. First, a participant chooses a type of ACO to join, or none at all. If they do choose a type, they then choose among that type which ACO to join. This accounts for the possibility that some participants are ex-ante more likely to join an ACO of a given type, and are, in other words, selected into participating.

In the second stage, participation is taken as given, and each member chooses their savings and quality contributions to the overall ACO savings and quality score in order to maximize their own payoff. Formally, each member in an ACO is playing a simultaneous move game, and an ACO's savings and quality score is the outcome of the Nash equilibrium strategies chosen by its participants. Though this model is written in a way such that decisions are made by individual participants, underlying structural parameters can be identified and estimated with aggregate, ACO level data. Section 5 details this process.

The decision makers in this model are Medicare providers that qualify as a participant in the MSSP in the model's first stage and Medicare providers that are participants in an Accountable Care Organization in the model's second stage. This is a heterogeneous group:

examples include individual providers, group practices, and hospitals. The set of potential participants \mathcal{I} and set of all ACOs \mathcal{J} are exogenous.

3.1 Participation

The model starts with a provider i choosing to participate in ACO $j \in \{1, \dots, J\}$ or not to participate where $j = 0$. The potential participant i has utility from joining ACO $j \neq 0$ in nest d is

$$u_{ij} = \alpha_i y_j + \beta' X_j^{part} + \xi_j + \zeta_{id}(\rho) + (1 - \rho)\epsilon_{ij} \quad (3)$$

where y_j is the net income of an ACO and X_j^{part} is a vector of observed ACO characteristics. The variable ξ_j is unobserved ACO heterogeneity, $\zeta_{id}(\rho)$ is i 's specific preference for participating in an ACO in the nest d (allowing correlation of utility of providers within groups of ACOs), and ϵ_{ij} is an idiosyncratic utility shock. Following Berry (1994) and Cardell (1997), I assume ϵ_{ij} is distributed Type I Extreme Value, and $\zeta_{id}(\rho)$ has the unique distribution such that $\zeta_{id}(\rho) + (1 - \rho)\epsilon_{ij}$ is distributed Type I Extreme Value.

The variable y_j is meant to capture the potential pecuniary benefit to a participant for participating in an ACO. Note, this is defined as the *net income* of an ACO, and not merely the shared savings earned by the ACO. This is an important distinction: participants in an ACO incur costs (both explicit and implicit) in order to spend less on Medicare beneficiaries and provide high quality of care. Were this not accounted for in the model, an attempt to capture the pecuniary benefit of participation in ACO j with only the earned shared savings of ACO j would necessarily be an overstatement. In order to measure y_j , I estimate the marginal cost function of ACOs and subtract the increase in cost incurred by operating in an ACO from the earned shared savings of an ACO. This procedure is outlined in detail in Section 3.3.

The parameters in the first stage of this model are α_i , individual i 's return to ACO net income; β , a vector describing mean preferences over ACO characteristics; and the nesting parameter $\rho \in [0, 1]$, which measures the correlation of utilities of members in the same nest. As ρ increases, the influence an ACO's nest has over a participant's decision increases. The

set of parameters in the first stage of this model is denoted $\theta_1 = \{\alpha_i, \beta, \rho\}$.

The parameter of paramount interest in this first stage is α_i . If positive, then Medicare providers are more likely to join ACOs with higher net income. Though plausible (if not obvious), this fact has not been established in health or economics literature. (For reference, Ryan et al. (2015), Yasaitis et al. (2016), and Mansour et al. (2017) discuss physician income and ACO participation, though participation in response to income is inconclusive.) Since y_j and several elements of X_j^{part} are likely correlated with unobserved ACO heterogeneity ξ_j , getting unbiased estimates of α_i and β requires an instrumental variables (IV) technique, outlined in Section 5.

I normalize the utility of the outside option, $j = 0$, to $u_{i0} = \zeta_{i0}(\rho) + (1 - \rho)\epsilon_{i0}$ where $\zeta_{i0}(\rho)$ and ϵ_{i0} have distributions described above.

Formally, this model falls into the class of Random Coefficient Nested Logit (RCNL) models.⁴ This specification is natural in this context. A nested logit form is equivalent to modeling participation in two stages: first, a decision of which nest to join, and second, a decision of which ACO within that nest to join. The random coefficient α_i conveniently allows provider preferences for additional income to vary. In Section 6, I present coefficient estimates for the full RCNL model, as well the restricted version with $\rho \equiv 0$.

3.2 Performance

In the second stage of this model, participating Medicare providers in ACOs choose their own savings and quality contributions, which in turn determines each ACO's overall savings and quality. Note that these participant-level contributions are *theoretical quantities*—that is, ACO participants aren't assigned a benchmark expenditure, and aren't given overall quality scores, and so actual, observable values don't exist and cannot be computed. However, participants act *as if* they chose these values, and these values map to ACO performance measures that are observed.⁵ Participant savings and quality contributions are chosen strate-

⁴For a discussion of RCNL models and the pattern of substitution they imply, see Grigolon & Verboven (2014).

⁵Analogously, principle agent models assume agents choose effort, a theoretical quantity, which maps to an observed outcome (such as firm performance). This model could be written equivalently with effort choices of each, though I opt for choices of participant savings and quality for clarity.

gically to maximize a participant’s per-provider profit of participating in an ACO.

Formally, all participants $i \in j$ simultaneously choose savings and quality contributions $s_{ij} \in [-1, 1]$ and $q_{ij} \in [0, 1]$, and these choices determine ACO savings rate S_j and overall quality score Q_j through the weighted sums

$$S_j = \sum_{i \in j} w_{ij} s_{ij} \qquad Q_j = \sum_{i \in j} w_{ij} q_{ij}. \qquad (4)$$

Here, $\{w_{ij}\}_{i \in j}$ are exogenous influence weights such that $w_{ij} \geq 0$ for all $i \in j$ and $\sum_{i \in j} w_{ij} \equiv 1$. These weights account for heterogeneous influence of participants contributions on ACO performance.⁶

Each participant $i \in j$ solves the profit maximization problem

$$\max_{s_{ij}, q_{ij}} R(S_j, Q_j) - c(s_{ij}, q_{ij}; x_{ij}, \boldsymbol{\theta}_2) \qquad (5)$$

where $R(S_j, Q_j)$ is the per-provider shared savings earned by an ACO with savings S_j and quality score Q_j , c is the strictly convex and twice-continuously differentiable per-provider cost function, mapping participant savings and quality choices to the cost it incurs, x_{ij} is a vector of participant and ACO specific characteristics, and $\boldsymbol{\theta}_2$ is a set of parameters.

The per-provider cost $c(s_{ij}, q_{ij}; x_{ij}, \boldsymbol{\theta}_2)$ is the explicit and implicit costs of saving s_{ij} and providing quality q_{ij} . Were a physician to choose $s_{ij} = 1$ and $q_{ij} = 1$, we would expect them to incur significant cost—both in operational expenses as well as opportunity cost (for example, due to time, forgone services to patients not assigned to i ’s ACO). Conceptually, we can think of $c(\cdot)$ as the function being minimized by Medicare providers outside of the ACO program, where their actions imply savings and quality contributions, and they incur an effort cost of doing so. Ultimately, c places a natural restriction on how well participants, and hence ACOs, can perform.

⁶For example, consider an ACO with $n_j = 2$ participants: a hospital with savings rate 2%, and an individual provider with savings rate 4%. This means $s_{1j} = 0.02$, $s_{2j} = 0.04$, and $\bar{s}_j = 0.03$. The ACO’s savings rate, however, would be far closer to $S_j \approx 0.02$ since the hospital has a larger share of overall expenditure.

Conveniently, shared savings takes the known and exogenous form

$$R(S_j, Q_j) = \begin{cases} 0.5 \cdot B_j S_j Q_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

where B_j is the per-provider benchmark expenditure of ACO j , \underline{S}_j is the benchmark savings rate for ACO j , and \underline{Q} is the quality reporting standard.⁷ The two first order conditions for participant i are then

$$\frac{\partial c}{\partial s_{ij}}(s_{ij}, q_{ij}) = \begin{cases} 0.5 \cdot B_j w_{ij} Q_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ 0 & \text{otherwise} \end{cases} \quad (8)$$

$$\frac{\partial c}{\partial q_{ij}}(s_{ij}, q_{ij}) = \begin{cases} 0.5 \cdot B_j w_{ij} S_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ 0 & \text{otherwise} \end{cases} . \quad (9)$$

3.2.1 Strategic Complementarity and Existence of Equilibrium

The shared savings function R is written in a way such that it generates a simultaneous move game with strategic complementarity.⁸ These games have the property that the best response function of a player is increasing in the strategies of the other players. In this context, this means that the marginal payoffs of the savings and quality contributions of ACO participant i are higher when a different participant i' chooses higher savings and quality contributions. I establish this formally in the following propositions.

Proposition 3.1. *Consider the simultaneous game played by participants in ACO j , and let $i, i' \in j$ with $i \neq i'$.*

1. $\frac{\partial R}{\partial s_{ij}}$ is weakly increasing in $q_{i'j}$ and constant in $s_{i'j}$.
2. $\frac{\partial R}{\partial q_{ij}}$ is weakly increasing in $s_{i'j}$ and constant in $q_{i'j}$.

⁷ACOs in their first performance year are “paid to report”, and so shared savings takes the form

$$R(S_j, Q_j) = \begin{cases} 0.5 \cdot B_j S_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

—in other words, Q_j is equivalently 1 when an ACO meets quality reporting standards in the first performance year.

⁸For an in-depth discussion, see Bulow et al. (1985) and Milgrom & Roberts (1990).

Proof. See Appendix A.1. □

Proposition 3.2. *Consider the simultaneous game played by participants in ACO j , and let $i, i' \in j$ with $i \neq i'$. Let $BR_s(s_{-ij}, q_{-ij})$ and $BR_q(s_{-ij}, q_{-ij})$ be the best response functions of the savings and quality contributions, respectively, of participant i . Then,*

1. BR_s and BR_q are weakly increasing in $q_{i'j}$ and $s_{i'j}$, respectively, for all $i' \neq i$.
2. If $\frac{\partial^2 c}{\partial s_{ij} \partial q_{ij}} \leq \frac{w_{ij}^2}{2} B_j$, then BR_s and BR_q are also increasing in $s_{i'j}$ and $q_{i'j}$, respectively, for all $i' \neq i$.

Proof. See Appendix A.2. □

The intuition behind Proposition 3.2 is as follows. First, since i 's marginal revenue of savings (quality) is increasing in the quality (savings) contribution of i' , i will always choose a higher savings (quality) contribution when i' chooses a higher quality (savings) contribution. Second, since i chooses a higher savings (quality) contribution in response to a higher quality (savings) contribution of i' , i 's marginal revenue of quality (savings) *also* increases, since $\frac{\partial R}{\partial q_{ij}}$ ($\frac{\partial R}{\partial s_{ij}}$) is increasing in s_{ij} (q_{ij}). Since i 's marginal revenue of quality (savings) is higher, i chooses a higher quality (savings) contribution.

Note that the presence of strict strategic complementarity comes only when the ACO's savings rate and overall quality score meet or exceed the benchmarks. Otherwise, all participants have best response functions that are constant in the strategies of their peers. In essence, ACOs benefit from strategic complementarity when participants are all operating at a high-level of savings and quality, and when there is a relatively small trade-off between savings and quality for the individual provider. Ultimately, the shared savings formula (defined by law) has the property that ACOs with underachieving participants obtain no advantage from strategic complementarity, but those with participants with high contributions do. This incentive effect drives several ACO-level outcomes (discussed in Section 6) as well as the counterfactuals of interest (Section 7).

In general, the game played by ACO participants is *not* supermodular. The objective function of the maximization problem solved by participants is not twice-continuously differentiable since there's a discontinuity in revenue when $S_j = \sum_{i \in j} w_{ij} s_{ij} = \underline{S}_j$ or $Q_j =$

$\sum_{i \in j} w_{ij} q_{ij} = \underline{Q}_j$. For supermodularity, the following assumptions are required: 1) $\frac{\partial^2 c}{\partial s_{ij} \partial q_{ij}} \leq \frac{w_{ij}^2}{2} B_j$, 2) $S_j \neq \underline{S}_j$, and 3) $Q_j \neq \underline{Q}_j$. Since 1) is not usually satisfied, I prove existence of equilibrium without relying on the presence of a supermodular game. First, define

$$\pi_{ij}(s_{ij}, q_{ij}) = R(S_j, Q_j) - c(s_{ij}, q_{ij}; x_{ij}, \theta_2) \quad (10)$$

for all $i \in j$.

Proposition 3.3. *Let the Hessian matrix $D^2\pi_{ij}$ be negative semidefinite. Then, there is a Nash equilibrium in pure strategies.*

Proof. See Appendix A.3. □

Denote a Nash equilibrium strategy of participant i in ACO j as (s_{ij}^*, q_{ij}^*) . Accordingly, the ACO's saving rate and overall quality score resulting from the set of Nash equilibrium strategies are denoted S_j^* and Q_j^* . These equilibriums are not unique—in general, there can be up to two Nash equilibrium profiles for a given ACO j —one where every participant maximizes π_{ij} with $S_j^* \geq \underline{S}_j$ and $Q_j^* \geq \underline{Q}_j$, and one where every participant minimizes their cost and the benchmarks are not met. Figure 1 details the possible equilibria. Dollars are on the y -axis and the savings contribution of i are on the x -axis (the figure is for a fixed $\{q_{ij}, s_{-ij}, q_{-ij}\}$). MR_j^s is the right hand side of Equation 8, c_1 , c_2 , and c_3 are cost functions (each with a different marginal cost), and all satisfy the assumption in Proposition 3.3.

[Figure 1 about here.]

Given the choices of other participants, \tilde{s}_{ij} is the choice of a participant with marginal costs too high to achieve shared savings. If other participants choose a higher quality score, MR_j^s could increase to a value high enough such that $\frac{\partial c_1}{\partial s_{ij}}$ intersects with it. Similarly, s_{ij}^* is the choice of a participant when cost is sufficiently low. The values \tilde{s}'_{ij} and $s_{ij}^{* \prime}$ are both possible choices of a participant in the rare case the participant can increase their contribution and bring the entire ACO's performance above the savings and quality benchmarks. For this last case to occur, w_{ij} must be very large relative to $\frac{\partial c_2}{\partial s_{ij}}$.

3.3 Net Income

An ACO's *net income* is the realized increase in money earned by all members of an ACO in a given performance year by participating in the MSSP. If the ACO does not qualify for shared savings, additional income is defined as zero—participants choose savings and quality contributions in the same way they would were they not participating in an ACO. If an ACO does qualify for shared savings, then net income is the total earned shared subsidy of the ACO, minus the increase in cost incurred by participants for having savings and quality contributions higher than they would otherwise be. By joining an ACO and attempting to earn shared savings, a participant acts differently than they otherwise would, which carries explicit and implicit costs. For example, a participating hospital may invest in a sophisticated electronic health records system to improve patient outcomes (explicit cost), or a participating physician may spend more time researching effective treatments for the same end (implicit cost).

Let y_j be net income. Define

$$(\tilde{s}_{ij}, \tilde{q}_{ij}) = \arg \min_{s_{ij}, q_{ij}} c(s_{ij}, q_{ij}; x_{ij}, \boldsymbol{\theta}_2). \quad (11)$$

Then,

$$y_j = \sum_{i \in j} \left[\pi_{ij} \left(s_{ij}^*, q_{ij}^* \right) + c \left(\tilde{s}_{ij}, \tilde{q}_{ij}; x_{ij}, \boldsymbol{\theta}_2 \right) \right] \quad (12)$$

When the equilibrium profile of ACO j $\{(s_{ij}, q_{ij})\}_{i \in j}$ is such that ACO participants minimize cost, $y_j \equiv 0$. Furthermore, y_j will necessarily be positive for all ACOs. The estimation and implementation of y_j is discussed in Section 5.

4 Data

This paper primarily uses data from MSSP ACO Public Use Files, MSSP Participant Lists, MSSP ACO Performance Year Results, and Number of ACO Assigned Beneficiaries by

County Public Use Files.⁹ All data has yearly observations at the ACO level and without any finer observations. In short, the data consists of ACO expenditures, benchmark expenditures, quality scores (along with every quality sub-measure), various assigned beneficiary demographics, and various participant and provider statistics. No public information is available on the characteristics of specific ACO participants or providers.

I use data from performance years 2014, 2015, 2016, and 2017. In the first performance year, 2012-2013, ACO pay does not vary by quality score, and thus provides little variation useful within the scope of this paper.¹⁰

Table 1 summarizes some ACO characteristics.

[Table 1 about here.]

The the number of ACOs operating each year increases over time: 220 in 2012-2013, 333 in 2014, 392 in 2015, 432 in 2016, and 472 in 2017. Attrition is not uncommon, with roughly 15% of ACOs leaving the MSSP each year. Most ACOs operate with beneficiaries in just one or two states. The median ACO has approximately 12,000 beneficiaries, though larger ACOs (with up to 150,000) beneficiaries skew the distribution, which has a mean near 18,000. There is significant variation in the risk scores and ethnicity of ACO beneficiaries, and little in age and gender.

The provider distribution within ACOs is a rich source of information. There are roughly 50 Medicare providers per ACO participant, suggesting most participants are at least group practices, if not hospitals. Furthermore, the standard deviation of providers per participant is quite high, implying ACOs range from small groups of large participants to large groups of small participants. The providers in an ACO are often overwhelmingly primary care physicians or overwhelmingly specialists. Figures 2 and 3 detail the relationship.

[Figure 2 about here.]

[Figure 3 about here.]

⁹Available at data.cms.gov.

¹⁰Performance year data is typically released the in late summer or early fall of the following year.

Figure 3 shows that ACOs that are primarily specialist are also nearly exclusively specialist. ACOs with mostly primary care physicians, on the other hand, may be composed of a collection of primary care physicians, nurse practitioners, physician assistants, and certified nurse specialists. One explanation, also relating to the large amount of variation in providers per participant in ACOs, is the distinction between “physician led” and “hospital led” ACOs. Physician led ACOs are groups of independent physicians, integrated horizontally; hospital led ACOs are groups of providers integrated vertically within a hospital. For a discussion, see McWilliams et al. (2016), which finds the independent, primary care physician led ACOs in the first year of the MSSP have significantly more savings than other ACO types and other years.

Table 2 presents observed ACO savings (S_j^*), *computed* quality score (Q_j^*), and *reported* quality score (“qualscore”). I compute Q_j^* from quality sub-measures included with each year’s performance data following CMS guidelines.¹¹ This is necessary since the reported quality score is coded as “P4R” or “1” for ACOs in their first performance year in public data.

[Table 2 about here.]

Table 2 shows that there is a large amount of variation in ACO savings rate, where ACOs differ by about 5 percentage points on average. Mean ACO savings rate is between one half and one and one half percent on average—a comfortably unremarkable range. The extremes are interesting, however, with one ACO spending 30% less than its benchmark, and another spending 32% more. From 2014 to 2017, ACOs had \$184.2 million in average expenditure versus a \$185.7 million average benchmark. The most profitable ACO saved \$89.1 million and earned \$41.9 million in shared subsidy. Average subsidy pay is \$1.5 million, but among ACOs that qualify, average pay is \$5.0 million. Per provider, this is roughly \$3,000 and \$10,000 respectively; per participant, it’s \$42,000 and \$139,000 respectively.

Finally, the savings rate and quality score of ACOs have a correlation of 0.0589. It’s unclear if this correlation is due to underlying incentives in the payment mechanism, or a

¹¹See, for example: Center for Medicare and Medicaid Services. “Medicare Shared Savings Program Quality Measure Benchmarks for the 2014 Reporting Year.” February 2015.

common productive input.¹² Diving further into this relationship, Table 3 displays estimates from a regression of S_j^* and Q_j^* on each other, with and without additional controls.¹³

[Table 3 about here.]

5 Identification and Estimation

In this section, I describe how I use aggregate (i.e. ACO-level) data to estimate the structural parameters in θ_1 and θ_2 . Since y_j is predicted from a latter model stage, I estimate the model backwards, first uncovering an estimate of θ_2 , then computing an estimate of y_j , and finally computing an estimate of θ_1 . This section follows the same order. I assume I observe S_j^* and Q_j^* , which are mean ACO savings and quality score from a Nash equilibrium. Equilibrium selection is not required since the equilibrium played (qualified or not qualified for shared savings) is observed.

5.1 Estimation of Second Stage Parameters

Let $\theta_2 = \{\delta_S, \delta_Q, \gamma_S, \gamma_Q, \kappa\}$. I specify the cost function

$$c(s_{ij}, q_{ij}; x_{ij}, \theta_2) = \frac{\delta_S}{2} s_{ij}^2 + \frac{\delta_Q}{2} q_{ij}^2 + (\gamma'_S x_{ij}) s_{ij} + (\gamma'_Q x_{ij}) q_{ij} + \kappa s_{ij} q_{ij} . \quad (13)$$

The assumption that c is quadratic is not problematic or too restricting. In fact, it's probably realistic, since it requires that at extreme values of s_{ij} and q_{ij} , high or low, explicit and implicit costs are increasing.

Consider the first order conditions for the objective function in Equations 8 and 9. With the cost function above, pre-multiplying the first order conditions by w_{ij} and summing over

¹²Ultimately, I'll argue that this positive correlation is from the payment mechanism, and there is a strong trade off between savings and quality in Section 6.

¹³See Table 4 for a description of control variables.

$i \in j$ yields

$$MR_j^S = \delta_S S_j^* + \gamma'_S X_j^{perf} + \kappa Q_j^* + \nu_j^S \quad (14)$$

$$MR_j^Q = \delta_Q Q_j^* + \gamma'_Q X_j^{perf} + \kappa S_j^* + \nu_j^Q \quad (15)$$

where

$$MR_j^S = \begin{cases} 0.5 \cdot W_j B_j Q_j^* & \text{if } S_j^* \geq \underline{S}_j \text{ and } Q_j^* \geq \underline{Q}_j \\ 0 & \text{otherwise} \end{cases}, \quad (16)$$

$$MR_j^Q = \begin{cases} 0.5 \cdot W_j B_j S_j^* & \text{if } S_j^* \geq \underline{S}_j \text{ and } Q_j^* \geq \underline{Q}_j \\ 0 & \text{otherwise} \end{cases}, \quad (17)$$

and

$$W_j \equiv \sum_{i \in j} w_{ij}^2 \quad X_j^{perf} \equiv \sum_{i \in j} w_{ij} x_{ij}. \quad (18)$$

The variables ν_j^S and ν_j^Q are unobserved, i.i.d. error terms. X_j^{perf} is observed approximately in data, and W_j , which is a measure of influence concentration within an ACO (similar to a Herfindahl-Hirschman index [HHI]), is computed from data as the sum of squared shares of expenditure for each type of provider within an ACO.

Accordingly, I assume the moment conditions

$$\mathbb{E} \begin{bmatrix} \nu_j^S \\ \nu_j^Q \end{bmatrix} \Bigg| S_j^*, Q_j^*, X_j^{perf} = 0. \quad (19)$$

Using the estimate of θ_2 called $\hat{\theta}_2$, I compute an estimate of additional income y_j called \hat{y}_j . Recall Equations 11 and 12. The estimate additional income \hat{y}_j has the formula

$$\hat{y}_j = n_j \hat{\pi}_{ij} (S_j^*, Q_j^*) + n_j c (\tilde{S}_j, \tilde{Q}_j; X_j^{perf}, \hat{\theta}_2) \quad (20)$$

where S_j^* and Q_j^* are observed equilibrium values and

$$\left(\tilde{S}_j, \tilde{Q}_j\right) = \arg \min_{S, Q} c\left(S, Q; X_j^{perf}, \hat{\theta}_2\right).$$

The computation of $\left(\tilde{S}_j, \tilde{Q}_j\right)$ is done numerically.

5.2 Estimation of First Stage Parameters

Recall the utility specification for participating in ACO j :

$$u_{ij} = \alpha_i y_j + \beta' X_j^{part} + \xi_j + \zeta_{id}(\rho) + (1 - \rho)\epsilon_{ij} \quad (21)$$

Berry (1994), Berry et al. (1995), and Nevo (2000), show the estimating equation for mean utility in such a framework with the aforementioned assumptions on unobserved error terms is

$$\ln(a_j/a_0) = \alpha_0 y_j + \beta' X_j^{part} + \rho \ln(a_j/a_d) + \xi_j \quad (22)$$

where I specify $\alpha_i = \alpha_0 + \alpha_\eta \eta_i$ for a known distribution of η_i . The values a_j , a_0 , and a_d are the shares of participants choosing ACO j , choosing the outside option, and choosing an ACO $j \in d$, respectively. In the results that follow, I specify $\ln \eta_i \sim N(12.25, 0.40^2)$ to approximate an income distribution of participants—a possible dimension of heterogeneity. I use four nests: the outside option, ACOs that are physician led, ACOs that are hospital led, and ACOs with mixed leadership. This way, the first stage of the model accounts for provider’s specific preference for being a part of the MSSP, and I can obtain a measure of the correlation of utilities of participants in the same nest.

Note that y_j , some elements of X_j^{part} , and $\ln(a_j/a_d)$ are endogenous, and so instrumental variables will be required to estimate their coefficients without bias. Denote these instruments and the exogenous variables in X_j^{part} as Z_j^{part} .¹⁴ The moment condition for estimation

¹⁴All elements of X_j^{part} and Z_j^{part} as well as exclusion restrictions for identification are discussed in detail in Section 5.3.

is

$$\mathbb{E} \left[\hat{\xi}_j \mid Z_j^{part} \right] = 0 \tag{23}$$

where $\hat{\xi}_j$ is the same as Equation 22, but with \hat{y}_j instead of y_j .¹⁵ The parameter α_η is uniquely determined via contraction mapping à la BLP.

5.3 Control Variables and Instruments

The elements of X_j^{perf} and X_j^{part} along with their descriptions are included in Table 4.

[Table 4 about here.]

Five variables in X_j^{perf} are omitted from X_j^{part} since they are not determined at the time participation decisions are made.

GMM with the moment conditions described in Equation 19 offer an estimate $\hat{\theta}_2$. In a separate estimation, I allow κ to differ in each equation when I estimate the second stage parameters. The resulting parameter estimates are not significantly different, which is consistent with the mathematical underpinnings of the moment conditions.

I use GMM with the moment condition described by Equation 23 to estimate α_0 , β , and ρ . Table 5 shows the parameters, variables, and IVs used.

[Table 5 about here.]

Descriptions of all variables are in Table 4. My exclusion restrictions are simple: first, I assume the number of states occupied by an ACO’s assigned beneficiaries is exogenous. To obtain exogenous variation in \hat{y}_j , $totprov_j$, and $fracpcp_j$, I use cost shifters in X_j^{perf} (but excluded in X_j^{part})— these values are determined simultaneously with performance, but are realized after participation, and hence can only impact participation though correlation with \hat{y}_j , $totprov_j$, and $fracpcp_j$. Exogenous variation in nab_j , $pctover75_j$, $pctmale_j$, $pctnonwhite_j$

¹⁵In order to account for uncertainty introduced by using estimates from the second stage, the standard errors of the parameters estimated in the first stage must be adjusted. I achieve this via bootstrapping. Nonetheless, this issue is small, since the estimated component of \hat{y}_j is small (see Figure 7) and the parameter estimates in $\hat{\theta}_2$ are precise. See Ho (2006) and Domurat (2017).

is obtained from Medicare beneficiary demographics of the area an ACO covers. Hence, I assume the characteristics of the Medicare beneficiaries in an ACOs area doesn't affect participation in a particular ACO, except through the ACO's assigned beneficiaries. I use three periods of lagged risk scores for $risk_{jt}$, under the assumption that a previous year's patient's risk score effects this years ACO participation only through this year's patient risk score. Finally, obtaining exogenous variation in an ACO's share of participation *relative to ACOs in a specific nest* is tricky—clearly, $\ln(a_j/a_d)$ is very highly correlated with $\ln(a_j/a_0)$, and exogenous variation has to come from physician tastes in the first place. With that in mind, I use the relative enrollment in HMOs in an ACO's area as an IV for $\ln(a_j/a_d)$. They are correlated due to physician preferences for joining a healthcare *organization*. It's exogenous since any correlation the relative enrollment in HMOs has with the overall participation in ACOs must be through relative participation in ACOs.

6 Results

The estimated cost function parameters, $\hat{\theta}_2$, are presented in Tables 6 and 7.

[Table 6 about here.]

[Table 7 about here.]

The three parameters controlling the shape of the cost function are estimated precisely, and the resulting cost function satisfies the properties required for an equilibrium to exist in the game played by ACO participants in every ACO.

κ , the cross partial of cost with respect to savings rate and quality, has a considerably high estimate. Increasing savings contribution by one standard deviation increases the marginal cost of quality by \$3,832. Increasing quality contribution by one standard deviation increases marginal cost by \$7,551. Since these are second order changes, doubling in absolute costs occurs with just slight increases in each. Ultimately, there is a significant trade-off between producing ACO savings and increasing quality of care. Were a trade-off not present, there would be a measurably higher correlation of S_j^* and Q_j^* , and also better ACO performance.

To further examine the shape of the cost function, Figures 4 and 5 plot cost versus savings and quality over their respective domains.

[Figure 4 about here.]

[Figure 5 about here.]

Salient from these figures, and from the parameter estimates in Table 7, is large differences in marginal costs of both savings and quality between primary care physicians (PCPs) and specialists. It's far less costly for a specialist to improve its performance, especially for quality. In fact, specialists have economies of scale in providing quality for up to very large quality scores. Operational complexity and economies of scope and scale are possible causes: primary care physicians evaluate and refer thousands of patients, with little substitutability across treatments, and therefore little margin to alter services in order to decrease expenditure or improve quality. Specialists, on the other hand, have a larger menu of options for a given patient relative to that patient's needs, and benefit from this in the MSSP. McWilliams et al. (2013) and Rahman et al. (2016) discuss the scale of healthcare providers and margins to improve savings and quality for large providers.

Table 7 also shows providers with older and more male beneficiaries have a higher marginal cost of savings and quality. Riskier patients increases marginal costs savings but not quality. Finally, savings is far less costly when the number of inpatient admissions of ACO participants is larger, all else constant. This, at first, seems contrary to current literature (for example, Einav et al. (2017) argues reducing the length of stay of beneficiaries could provide savings without increasing quality), which contends the current strategy of ACOs is to minimize services per patient and keep beneficiaries out of hospital beds. However, these are not opposing view points: the parameter estimates in this paper imply increasing inpatient admissions decreases the marginal cost of savings *ceteris paribus*. Other cost-increasing determinants positively correlated with inpatient admissions are held constant, and savings are now easier to achieve for the reasons (economies of scale and operational complexity) discussed in the previous paragraph.

Next, let's examine and distribution of net income, \hat{y}_j , pictured in units of \$100,000 in Figure 6.

[Figure 6 about here.]

Here we see that correcting ACO income for the increase in cost incurred by its participants shifts the distribution of money earned slightly to the left. In Figure 7, I show net income \hat{y}_j as a fraction of earned shared savings.

[Figure 7 about here.]

There's a fair amount of heterogeneity in the net income earned by ACOs. The average ACO loses 40% of their earned shared savings to increases in effort cost, with some barely breaking even. These require large cost outputs in order to qualify for government pay—other ACOs, with low marginal costs, earn a lot with giving up little.

Finally, I present the results to estimation of the participation equation in Table 8.

[Table 8 about here.]

The first column of estimates is of the Random Coefficients (non-nested) Logit with IVs, and the second column is the Random Coefficients Nested Logit with IVs. Both models estimate a significant response of ACO participants to ACO net income. The magnitude is large: a \$100,000 increase in ACO net income increases an ACO's share of participants by over 1%, all else constant. This is an increase in one participant for the average ACO. Keep in mind that \$100,000 is a small increment relative to overall net-income, which has a mean of \$3 million when the ACO qualifies for shared savings.

The parameter α_η , describing roughly the relationship between participant salary and participation, has a precise estimate of 0.0018 in the RC model and 0.0034 in the RCNL model. This means for every \$100,000 increase in their own salary, a participant's response to an additional \$100,000 in net income of an ACO increases by 0.2% and 0.3%, respectively. In other words, higher-income providers may be slightly more responsive to changes in net income from ACOs. Coefficients on control variables X_j^{perf} offer little evidence that a provider's decision to participate in ACOs depends on characteristics of an ACO, other than the ACO's ability to earn shared savings. In the RCNL estimation, the nesting parameter ρ is estimated with some precision at 0.4487. Given the definition of nests d as leadership

types of ACOs (hospital, physician, or mixed), this means the correlation of utilities of participants in ACOs under similar leadership is fairly high. Management structure of an ACO plays an important role in a participant’s utility. In a related study, McWilliams et al. (2016) discusses the role ACO leadership with regards to ACO performance.

7 Counterfactuals

In this section, I use the estimated parameters in sets $\hat{\theta}_1$ and $\hat{\theta}_2$ to predict the outcome of changing the MSSP payment design and the outcome of changing the behavioral assumptions of ACOs and ACO participants. The estimated parameters are invariant to simulated changes since the changes impact only the revenue function of participants in the MSSP.

While participation change in ACOs is accounted for, ACO entry and attrition is not. Nonetheless, these are short-run predictions of the immediate ACO responses to changes in policy or circumstance.

7.1 Performance and Participation with Two-Sided Risk

The estimation of the cost function and utility from participation uses only Track 1 ACOs, where the shared savings formula is

$$R(S_j, Q_j) = \begin{cases} F \cdot B_j S_j Q_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ 0 & \text{otherwise} \end{cases} \quad (24)$$

where $F = 0.5$. Track 2 and 3 ACOs are omitted from the estimation sample, but we can predict their behavior by altering the revenue function and assuming the same cost function. For the following predictions, Track 2 and 3 ACOs have the shared savings formula

$$R^{TS}(S_j, Q_j) = \begin{cases} F \cdot B_j S_j Q_j & \text{if } S_j \geq \underline{S}_j \text{ and } Q_j \geq \underline{Q} \\ F \cdot B_j S_j & \text{if } \hat{S}_j \leq -\underline{S}_j \\ 0 & \text{otherwise} \end{cases} \quad (25)$$

where $F = 0.6$ for Track 2 ACOs and $F = 0.75$ for Track 3 ACOs. With two-sided risk, the game now exhibits strategic complementarity for very negative values of S_j . Table 9 details the simulation results, where R^{TS} is used in the maximization problem for ACO participants.

[Table 9 about here.]

The table contains predictions of average ACO savings and quality scores S_j^* and Q_j^* for one-sided and two-sided incentive structures over varying savings fractions. My model's prediction under current law is in the top-left cells, where $F = 0.50$ and payment is one-sided (italicized font). The counterfactual predictions of interest are in the cells in bold font.

The model predicts moderate *decreases* in quality scores, but very large increases in savings for the two-sided model. The increase in savings has two causes. First, marginal revenue is higher in the two-sided model, increasing the choice of savings. Second, some ACOs find it optimal to minimize cost at a savings rate below $-\underline{S}_j$ under Track 1, but this is not optimal under Tracks 2 and 3 since they are penalized for doing so. Out of 1615 observations, 503 (31%) qualify for shared savings under Track 1, 601 (37%) under Track 2, and 638 (40%) under Track 3. Moreover, under Track 2 and Track 3, just 4 (0.25%) and 3 (0.18%) pay shared losses to CMS. According to the simulation, the ACOs that improve their performance significantly under Tracks 2 and 3 are those with many (but not the most) primary care physicians, and those with riskier patient populations. These ACOs have a lower than average marginal cost of savings and while under performing with incentives imposed under Track 1, their costs aren't so high that they cannot qualify for shared savings under Track 2 and 3. Those ACOs with nearly all primary care physicians do not shift to earning shared savings, and may pay significant shared losses to CMS.

Under both one-sided and two-sided incentives, quality scores increase as F increases. For a fixed F , however, ACOs facing one-sided incentives have a significantly higher quality score than ACOs facing two-sided incentives. Since there is a large trade-off between savings and quality (i.e. $\hat{\kappa}$ is very large), ACOs must choose a lower quality score to avoid paying shared losses to CMS.

This has a large impact on the Center for Medicare and Medicaid Service's bottom line

as well. Their savings from the program changes since 1) ACOs are saving different amounts, 2) the savings fraction is increasing for Track 2 and 3, and 3) CMS now earns money when ACOs do very poorly. Table 10 details pecuniary benefit to CMS for each track.

[Table 10 about here.]

The column “Shared Losses” is the amount paid to CMS from by ACOs failing to perform well enough. These values are fairly small (around 0.5% of all income earned by CMS). “Total Savings” includes money saved over the benchmark expenditure less the amount shared with ACOs. The values indicate we should expect the total revenue to CMS to increase fairly significantly with Track 2 ACOs with a 8.7% increases, and decrease significantly under Track 3 with a 17.5% decrease.

Finally, we must also account for the effect of two-sided incentives on ACOs and ACO participants. Though ACOs save more and earn more shared savings on average, their net income is only slightly lower under two-sided payment. The cost of increasing savings rate is, on average, larger than the additional subsidy earned. As it turns out, ACOs fortunately have higher net income under Tracks 2 and 3, but *only because the savings fraction F is larger*. Table 11 details this.

[Table 11 about here.]

For a fixed savings fraction, net income decreases by just a few thousand dollars on average, and median participation remains nearly the same. When the savings fraction increases along with the change to a two-sided risk structure, the effect is a net positive, increasing net income by over \$20,000 and participation by two.

7.2 Computing the Optimal Savings Fraction

The savings fraction F plays a large role in determining the success of the Medicare Shared Savings Program as a whole. It’s set to 0.5, 0.6, and 0.75 for Track 1, 2, and 3 ACOs, but these aren’t necessarily the values that maximize total program savings. To this end, I

compute the ACO’s *income-optimal* savings fraction F by solving the problem

$$\begin{aligned} & \max_{F \in (0,1)} \sum_{j \in \mathcal{J}} [B_j S_j^*(F) - F \cdot B_j S_j^*(F) Q_j^*(F)] \\ & \text{s.t. } (s_{ij}^*(F), q_{ij}^*(F)) = \arg \max_{S,Q} \pi_{ij}(s_{ij}, q_{ij}) \text{ for all } i \in j \text{ and } j \in \mathcal{J}. \end{aligned} \tag{26}$$

The objective function is the total amount of money saved by the Medicare Shared Savings Program. Note that an ACO’s savings rate S_j^* and quality score Q_j^* are written as a function of the savings fraction F , since ACOs save more when F is higher. The trade off, of course, is that CMS only receives a fraction of what’s saved from the benchmark. Figure 8 plots the objective function of CMS when maximizing total savings with one-sided ACOs (Equation 26) and the objective function of CMS with two-sided ACOs (which is slightly different than Equation 26).

[Figure 8 about here.]

CMS saves the most money, under a one-sided incentive scheme, at $F^* = 0.53$. The amount saved is approximately 1.55% higher than under current law, where $F = 0.5$. If payment is two-sided, the optimal saving fraction is nearly the same at $F^* = 0.54$. This is just slightly lower than ACOs on Track 2, where $F = 0.60$. Compared to Track 2 and Track 3 ($F = 0.75$) ACOs, the amount saved at $F^* = 0.54$ is 2.92% and 35.42% higher, respectively. These changes amount to several hundreds of millions of dollars in potential savings.¹⁶

We can also examine the effect on participation that occurs when changing F . Figure 9 plots savings fraction vs. median number of participants per ACO.

[Figure 9 about here.]

Since net income isn’t very different for one-sided and two-sided ACOs, participation isn’t very different either.

¹⁶The savings fraction is higher for two-sided ACOs under current law in order to encourage ACOs to choose those Tracks—my analysis does not account for this choice. That said, offering a higher savings fraction, especially as high as 0.75, comes at a huge cost.

7.3 Performance Loss due to Non-cooperative Decision Making

In this section, I consider the problem where a governing body with complete control over ACO participant behavior chooses participant savings and quality in order to maximize the total profit of all participants in an ACO. The maximization problem is

$$\max_{\{(s_{ij}, q_{ij})\}_{i \in j}} n_j R(S_j, Q_j) - \sum_{i \in j} c(s_{ij}, q_{ij}; x_{ij}, \theta_2). \quad (27)$$

The difference between this problem and the game played by participants is that cost is now shared between participants: agents with low margins may operate at a loss be compensated by those with high margins. I solve this for every ACO, and present the means in Table 12. Optimal savings and quality are S^o and Q^o , respectively.

[Table 12 about here.]

Under perfect cooperation, average ACO savings rate increases by more than three percentage points, or about 0.60 standard deviations. Quality scores increase by just 0.02, or 0.22 standard deviations. This amounts to an additional \$1.26 billion per year in savings to CMS, or a 112% increase.

While performance loss due to strategic behavior is large in absolute value, it's mitigated to an even larger degree by strategic complementarity in the revenue function. Since S_j and Q_j are multiplicative in the shared savings function $R(S_j, Q_j)$, marginal revenue of savings and quality contributions of participants is higher when other participants choose higher contributions. Were this not the case, and the shared saving formula were something like $F_S B_j S_j + F_Q B_j Q_j$ for some values F_S and F_Q , the marginal revenue of each participant would be constant in the decisions of other participants.

8 Robustness Checks

This section discusses two important checks for robustness: including uncertainty in ACO performance, and checking alternate cost functions.

8.1 Uncertainty in Savings and Quality

In the second stage of this model, participating Medicare providers in ACOs choose their own savings and quality contributions to overall ACO performance, though the mapping from participant choices to overall performance is deterministic. To check the robustness of this paper's results with respect to the assumption of certainty, this section briefly discusses a model and estimation where uncertainty is included.

Define s_{ij} , q_{ij} , S_j , and Q_j as before. *Realized* ACO savings rate and overall quality score are the random variables

$$\hat{S}_j \sim N(S_j, \sigma_S^2) \quad \hat{Q}_j \sim N(Q_j, \sigma_Q^2) \quad (28)$$

where $N(\cdot)$ is the normal distribution.

Each participant $i \in j$ solves the expected profit maximization problem

$$\max_{s_{ij}, q_{ij}} \mathbb{E} \left[R(\hat{S}_j, \hat{Q}_j) \right] - c(s_{ij}, q_{ij}; x_{ij}, \boldsymbol{\theta}_2) \quad (29)$$

where $R(\hat{S}_j, \hat{Q}_j)$ is the per-provider shared savings earned by an ACO with savings \hat{S}_j and quality score \hat{Q}_j .

Assume that $\text{cov}(\hat{S}_j, \hat{Q}_j | S_j, Q_j) = 0$. Then, the objective function in Equation 29 becomes

$$E_{\Pi}(s_{ij}, q_{ij}, S_j, Q_j) = 0.5 \cdot B_j \cdot E_S(S_j) \cdot E_Q(Q_j) - c(s_{ij}, q_{ij}; x_{ij}, \boldsymbol{\theta}_2) \quad (30)$$

where

$$E_S(S_j) = \mathbb{E} \left[\hat{S}_j \mathbf{1} \{ \hat{S}_j \geq \underline{S}_j \} \right] = S_j \Phi \left(\frac{S_j - \underline{S}_j}{\sigma_S} \right) + \sigma_S \phi \left(\frac{S_j - \underline{S}_j}{\sigma_S} \right) \quad (31)$$

and

$$E_Q(Q_j) = \mathbb{E} \left[\hat{Q}_j \mathbf{1} \{ \hat{Q}_j \geq \underline{Q} \} \right] = Q_j \Phi \left(\frac{Q_j - \underline{Q}}{\sigma_Q} \right) + \sigma_Q \phi \left(\frac{Q_j - \underline{Q}}{\sigma_Q} \right). \quad (32)$$

The functions ϕ and Φ are the standard normal probability and cumulative density functions, respectively, and $\mathbf{1}\{\cdot\}$ is the indicator function that takes a value of one if the statement in the brackets is true and zero otherwise.

8.1.1 Strategic Complementarity and Existence of Equilibrium

First define the expected revenue function.

$$E_R(S_j, Q_j) = 0.5 \cdot B_j \cdot E_S(S_j) \cdot E_Q(Q_j) . \quad (33)$$

Proposition 8.1. *Let $i' \neq i$. Marginal expected revenue $\frac{\partial E_R}{\partial s_{ij}}(S_j, Q_j)$ is increasing in s_{ij} and $s_{i'j}$ when $\underline{S}_j (S_j - \underline{S}_j) < \sigma_S$ and is always increasing in $q_{i'j}$. Marginal expected revenue $\frac{\partial E_R}{\partial q_{ij}}(S_j, Q_j)$ is increasing in q_{ij} and $q_{i'j}$ when $\underline{Q}_j (Q_j - \underline{Q}_j) < \sigma_Q$ and is always increasing in $s_{i'j}$.*

Proof. See Appendix A.4. □

The punchline of Proposition 8.1 is that the marginal payoff to a participant in an ACO is often strictly increasing in the savings and quality of other participants.

Note that satisfying these properties alone do not imply that the game played by ACO participants is necessarily supermodular. That requires the additional condition

$$\frac{\partial E_R}{\partial s_{ij} q_{ij}}(S_j, Q_j) > \frac{\partial c}{\partial s_{ij} q_{ij}}(S_j, Q_j; x_{ij}, \theta_2) \quad (34)$$

so that the best response of savings is increasing in own quality and visa versa.

As in Section 3.2.1, since the game played by ACO participants is generally not supermodular, I cannot use that property to prove existence of a pure strategy Nash equilibrium. Instead, I impose a restriction on the expected profit function E_{Π} to achieve existence in the following proposition.

Proposition 8.2. *Consider the simultaneous move game played by participants i in ACO j . If $D^2 E_{\Pi}$ is negative semidefinite, then there exists a Nash equilibrium in pure strategies. This equilibrium is unique.*

Proof. See Appendix A.5. □

8.1.2 Identification, Estimation, and Results

Identification and estimation of θ_2 and θ_1 in this model (with uncertainty) is nearly identical to their identification and estimation outlined in Section 5 for the model without uncertainty. There are two additional parameters to estimate, σ_S and σ_Q , which are identified without additional assumptions if c has linear marginal cost in savings and quality.

8.1.3 Results

Table 13 shows the estimates of parameters in θ_2 that describe the shape of the cost function as well as $\hat{\sigma}_S$ and $\hat{\sigma}_Q$.

[Table 13 about here.]

The parameters estimated from the model with uncertainty are within one standard deviation of the parameters estimated from the model without uncertainty, albeit each has less precision. The estimate of σ_S is quite low and imprecise, while σ_Q is large with a fair degree of precision. Nonetheless, neither are significantly different than zero.

Table 14 contains estimates of the participation equation. Note that the magnitude of $\hat{\alpha}_0$ increases and the estimate becomes more precise in both the RC and RCNL models. The point estimate of ρ close to the estimate from the model without uncertainty, though it's estimated with far less precision.

[Table 14 about here.]

8.2 Cost Function Specification

To show robustness of this paper's results with respect to the specification of the cost function in Section 5, I re-estimate the model with a higher-ordered polynomial cost function such that the right hand sides of Equations 14 and 15 are polynomials of order 2 and 3. I also estimate the model with logged ACO savings rate and quality score in the place of S_j^* and Q_j^* .

[Table 15 about here.]

The second column of estimates in Table 15 is rather close to the baseline model, albeit with second-order term coefficients estimates with far less precision. The third column of estimates all lack precision, though still imply a strictly convex function over a reasonable domain. Ultimately, these estimates don't provide evidence that marginal cost is nonlinear, and I conclude the results are robust to the original cost function specification.

9 Conclusion

In this paper, I take a close look at the incentives faced by participants involved in the Medicare Shared Savings Program and Accountable Care Organizations. I estimate a two-stage structural model of participation and performance in ACOs which yields several results. First, I find Medicare providers *do* respond to the income they expect to earn from an ACO, as participation is increasing in the amount an ACO earns. Second, I find that performance is largely determined by the composition of providers within an ACO—the ACOs with the lowest marginal costs are those made up of almost exclusively specialists. Counterfactual policy analysis shows Track 2 and Track 3 (two-sided) ACOs will perform at an even higher level than current Track 1 ACOs. Another counterfactual shows performance improves significantly were ACOs able to perfectly coordinate. Over \$1.26 billion per year is lost to non-cooperative decision making.

This paper is the first structural applied microeconomics paper on MSSP ACOs, though there promises to be several more. The first step in future work is to use more granular data. For example, ACO provider-level data paired with information on ACO assigned beneficiary claims would permit a far more complicated model of decision making within an ACO, and help answer questions outside the scope of this paper. For example, variation of expenditure by providers within ACOs could address the nature of care coordination within ACOs and the effects thereof. Medicare claims data would also help identify the MSSP's impact on Medicare as a whole, answering questions about common agency, Accountable Care Organizations' relationships with market power and industry concentration, and, over a long enough time span, lasting effects of the program.

Finally, future work includes the assessing the tenability of applying the ACO payment

model to other areas of healthcare. It's not clear as of now if group-payment arrangements are the next great hope for healthcare in the United States, but the continuing expansion and popularity of the MSSP is promising.

A Appendix A: Proofs

A.1 Proof of Proposition 3.1

Proof. Note that if $S_j < \underline{S}_j$ or $Q_j < \underline{Q}$, $\frac{\partial R}{\partial s_{ij}}$ is identically zero, so the proof is trivial. Otherwise, we have

$$\frac{\partial^2 R}{\partial s_{ij} \partial s'_{ij}} = 0 \quad (35)$$

$$\frac{\partial^2 R}{\partial s_{ij} \partial q'_{ij}} = 0.5 \cdot B_j w_{ij} w'_{ij} \geq 0 \quad (36)$$

which proves item 1 of the proposition. Item 2 has a nearly identical proof. \square

A.2 Proof of Proposition 3.2

Proof. Item 1 of Proposition 3.2 follows trivially from Items 1 and 2 of Proposition 3.2.

To prove Item 2, let $\frac{\partial^2 c}{\partial s_{ij} \partial q_{ij}} \leq \frac{w_{ij}^2}{2} B_j$. Suppose s_{ij} increases to s'_{ij} . From Item 1, q_{ij} increases to $q'_{ij} = BR_q(s'_{-ij}, q_{-ij})$ as well. The first order condition for s_{ij} maintains

$$\frac{\partial R}{\partial s_{ij}}(q'_{ij}) = \frac{\partial c}{\partial s_{ij}}(s'_{ij}, q'_{ij}) \quad (37)$$

the left hand side of the above is marginal revenue, which is increasing under Proposition 3.1. Thus, either $s'_{ij} \geq s_{ij}$ or $s'_{ij} < s_{ij}$ and $\frac{\partial^2 R}{\partial s_{ij} \partial q_{ij}} < \frac{\partial^2 c}{\partial s_{ij} \partial q_{ij}}$. The latter violates the assumption of this proposition, and so $s'_{ij} > s_{ij}$. \square

A.3 Proof of Proposition 3.3

Proof. The assumption that $D^2 \pi_{ij}$ is negative semidefinite and that c is strictly convex guarantees that there's a unique interior solution or at least one corner to the problems

$$\max_{s_{ij}, q_{ij}} \pi_{ij}$$

and

$$\max_{s_{ij}, q_{ij}} -c(s_{ij}, q_{ij})$$

each. Since any choice of participants must satisfy their FOCs (or corner solution), given s_{ij}^* and q_{ij}^* are the best responses to S_j^* and Q_j^* , any deviation would suboptimal. Hence, equilibrium exists, and it is unique. \square

A.4 Proof of Proposition 8.1

Proof. First, consider the second derivative of E_R ,

$$\frac{\partial^2 E_R}{\partial s_{ij} \partial s'_{ij}}(S_j, Q_j) = -w_{ij} w'_{ij} B_j E_Q(Q_j) \left[\frac{1}{\sigma_S} + \frac{\underline{S}_j (S_j - \underline{S}_j)}{\sigma_S^2} \right] \cdot \phi \left(\frac{S_j - \underline{S}_j}{\sigma_S} \right). \quad (38)$$

The sign of this equation depends entirely on the term in the square brackets. When $\frac{1}{\sigma_S} + \frac{\underline{S}_j (S_j - \underline{S}_j)}{\sigma_S^2} < 0$, Equation 38 is positive. Rearranging terms, we have

$$\underline{S}_j (S_j - \underline{S}_j) < \sigma_S \implies \frac{\partial^2 E_R}{\partial s_{ij} \partial s'_{ij}}(S_j, Q_j) > 0$$

Since $\underline{S}_j > 0$, this condition implies that expected revenue has increasing differences in savings contributions always when average savings contribution is less than the benchmark. When average savings contribution is larger than the benchmark, there is still increasing differences when the difference is less than $\sigma_S / \underline{S}_j$. A similar argument applies for Q_j . \square

A.5 Proof of Proposition 8.2

Proof. If the Hessian matrix $D^2 E_{\Pi}$ is negative semidefinite, then each participant i has a unique pair (s_{ij}^*, q_{ij}^*) that maximizes $E_{\Pi}(\cdot)$ given values of s_{-ij} and q_{-ij} . Note it is possible that $\left| \frac{\partial c}{\partial q_{ij}} \right|$ is large enough that a corner solution for q_{ij}^* occurs.

What's left to determine is if the values $\left\{ (s_{ij}^*, q_{ij}^*) \right\}_{i \in j}$ constitute a Nash equilibrium. This is obvious—any choice of participants must satisfy their FOCs (or corner solution). Given s_{ij}^* and q_{ij}^* are the best responses to S_j^* and Q_j^* , any deviation would suboptimal.

Hence, equilibrium exists, and it is unique.

□

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Figure 1: Types of Equilibria

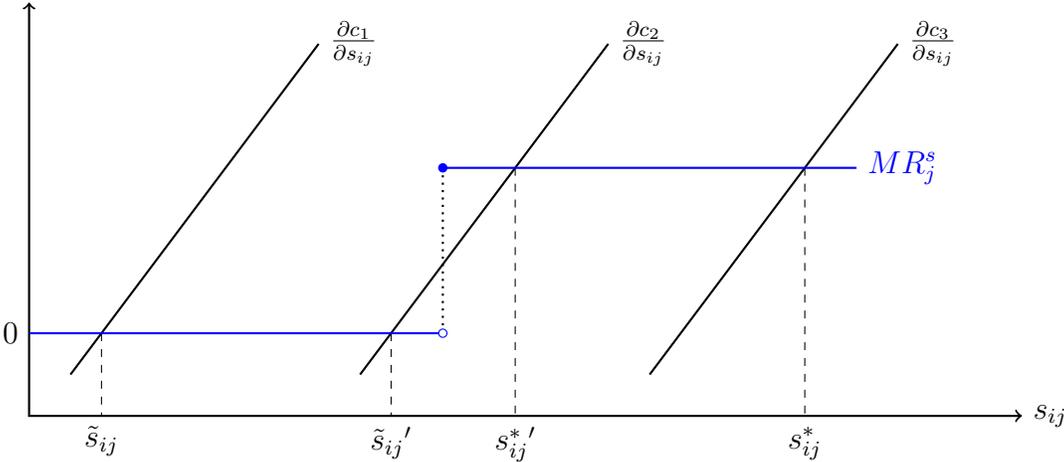


Figure 2: Histogram of Provider Types

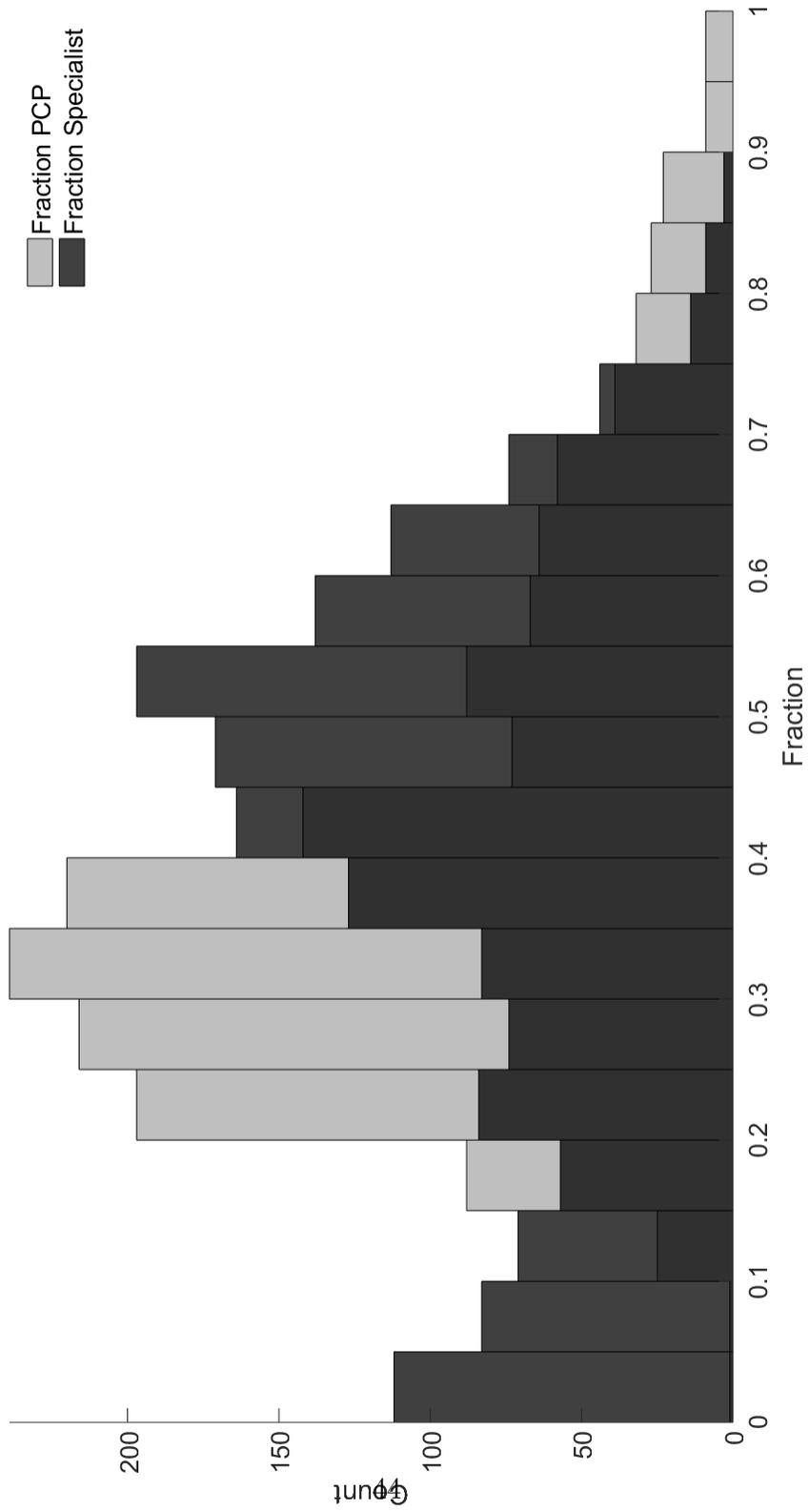


Figure 3: Scatter Plot of Provider Types

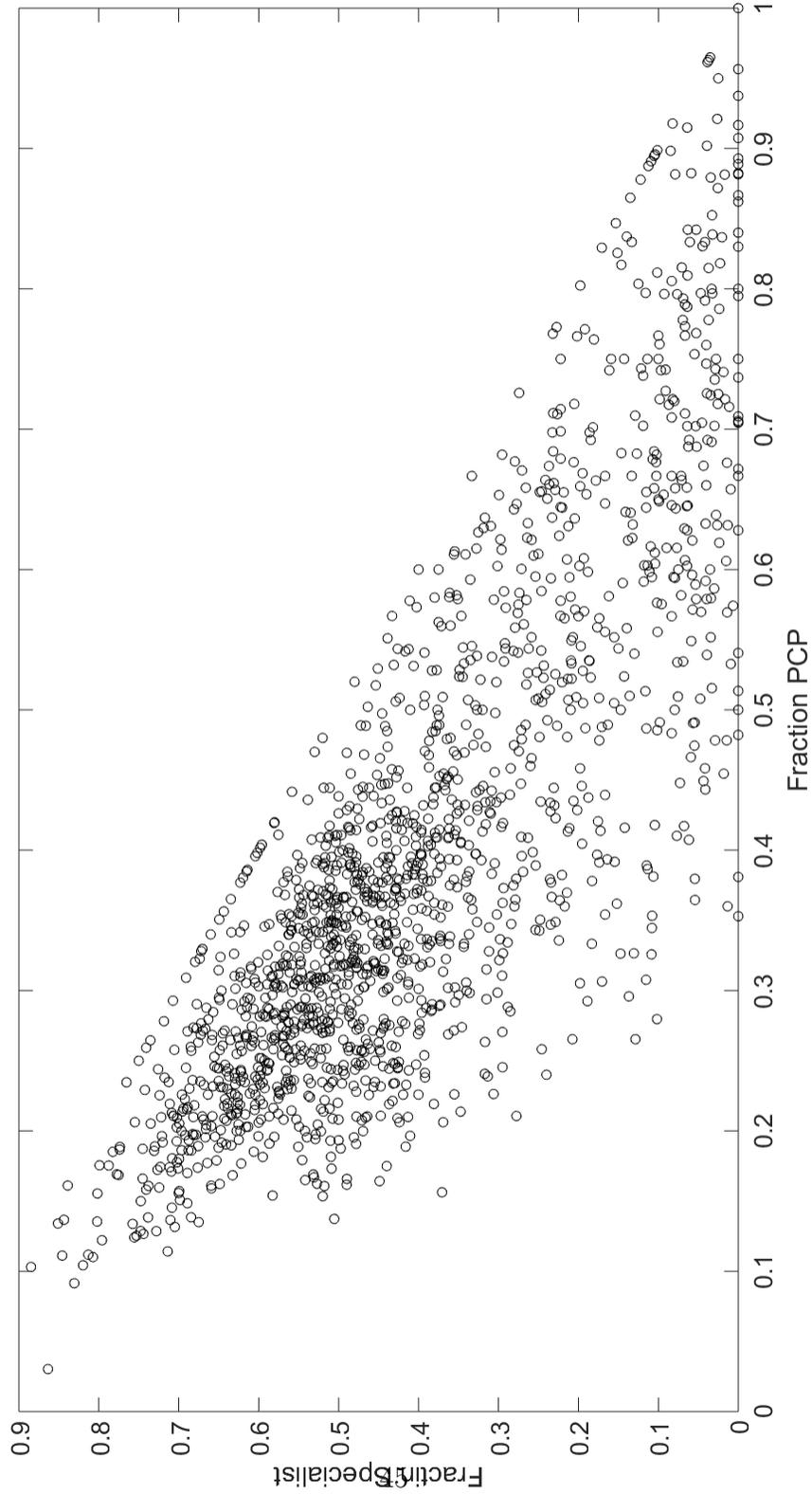


Figure 4: Cost vs. Savings

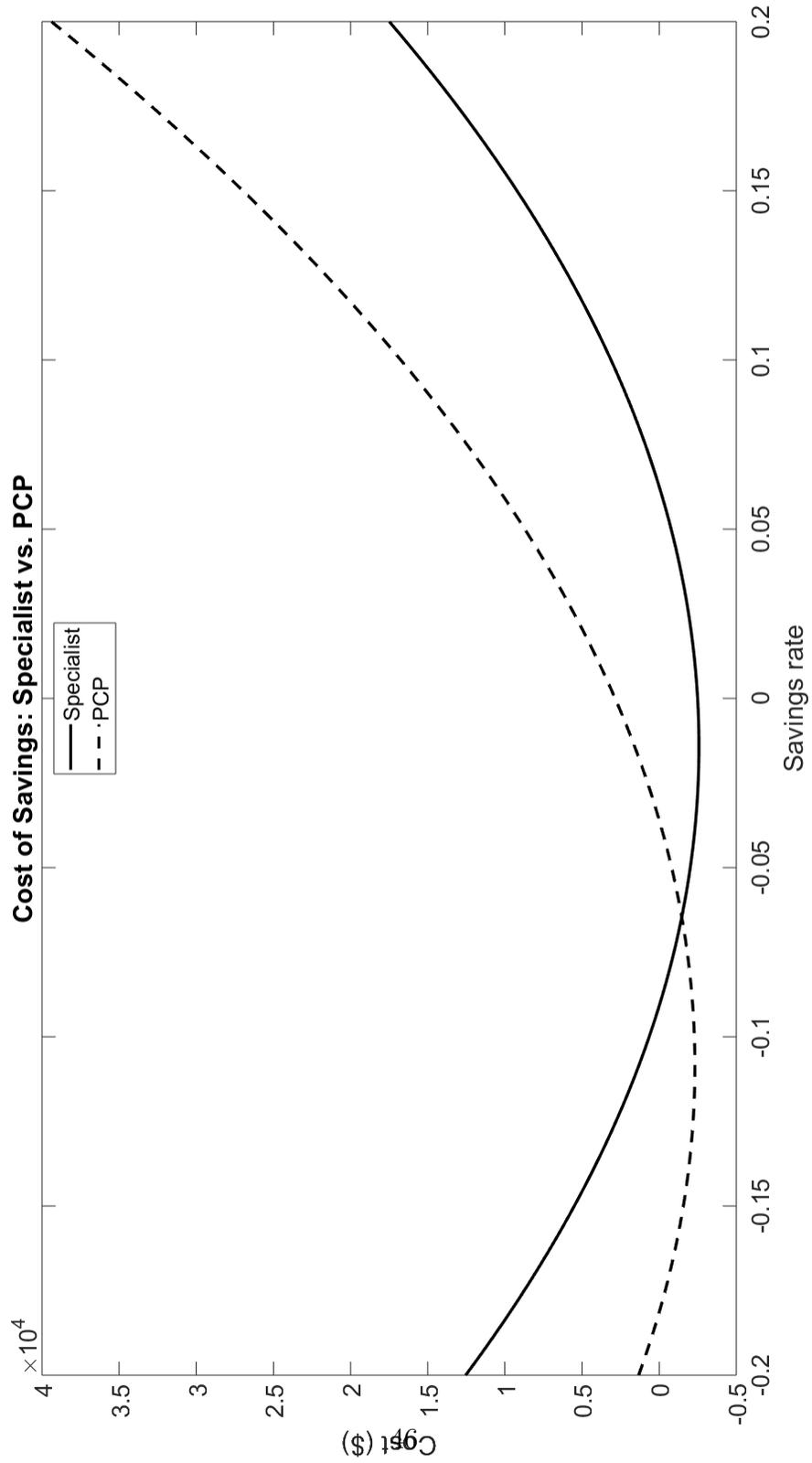


Figure 5: Cost vs. Quality Score

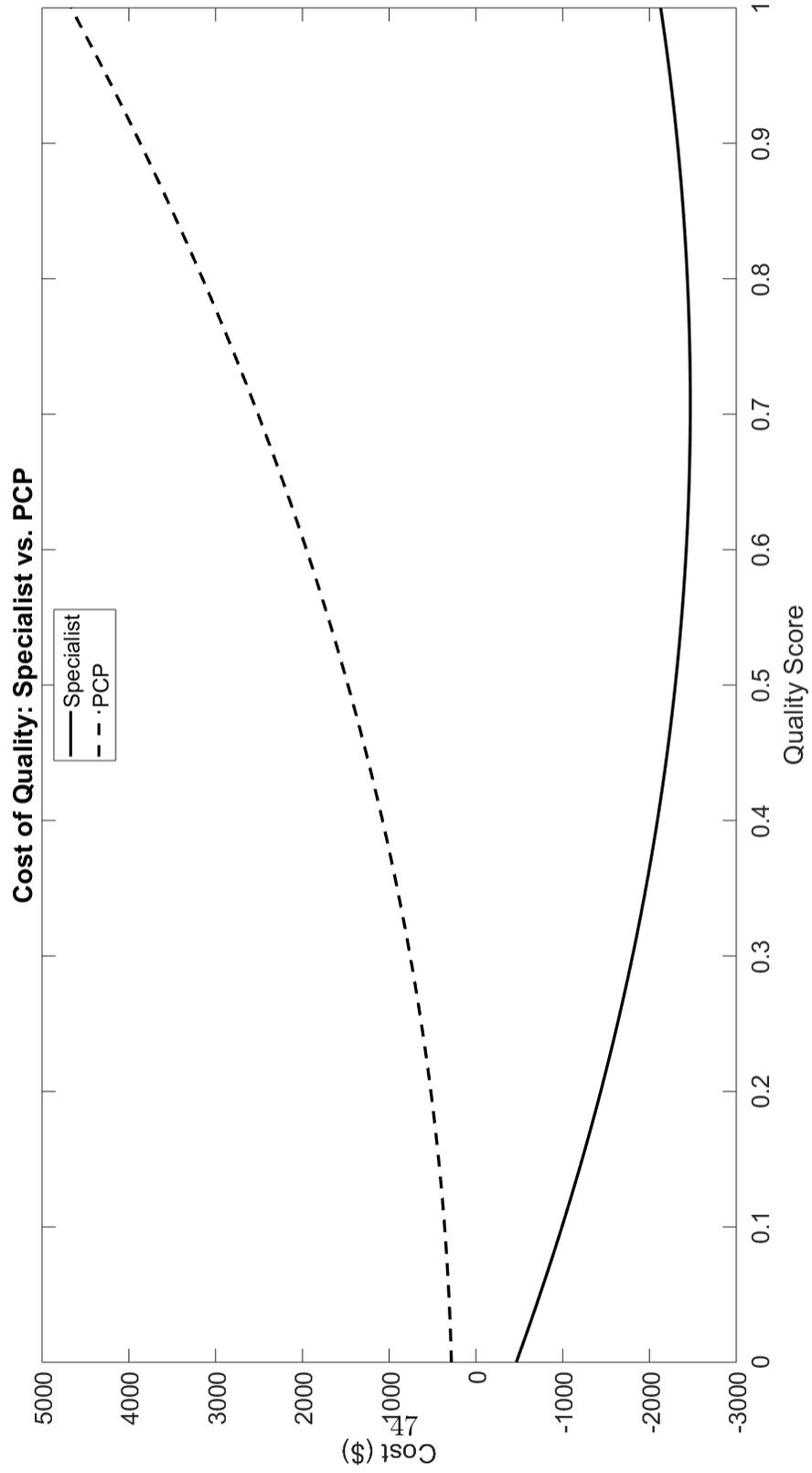


Figure 6: Histogram of Net Income and Earned Shared Savings

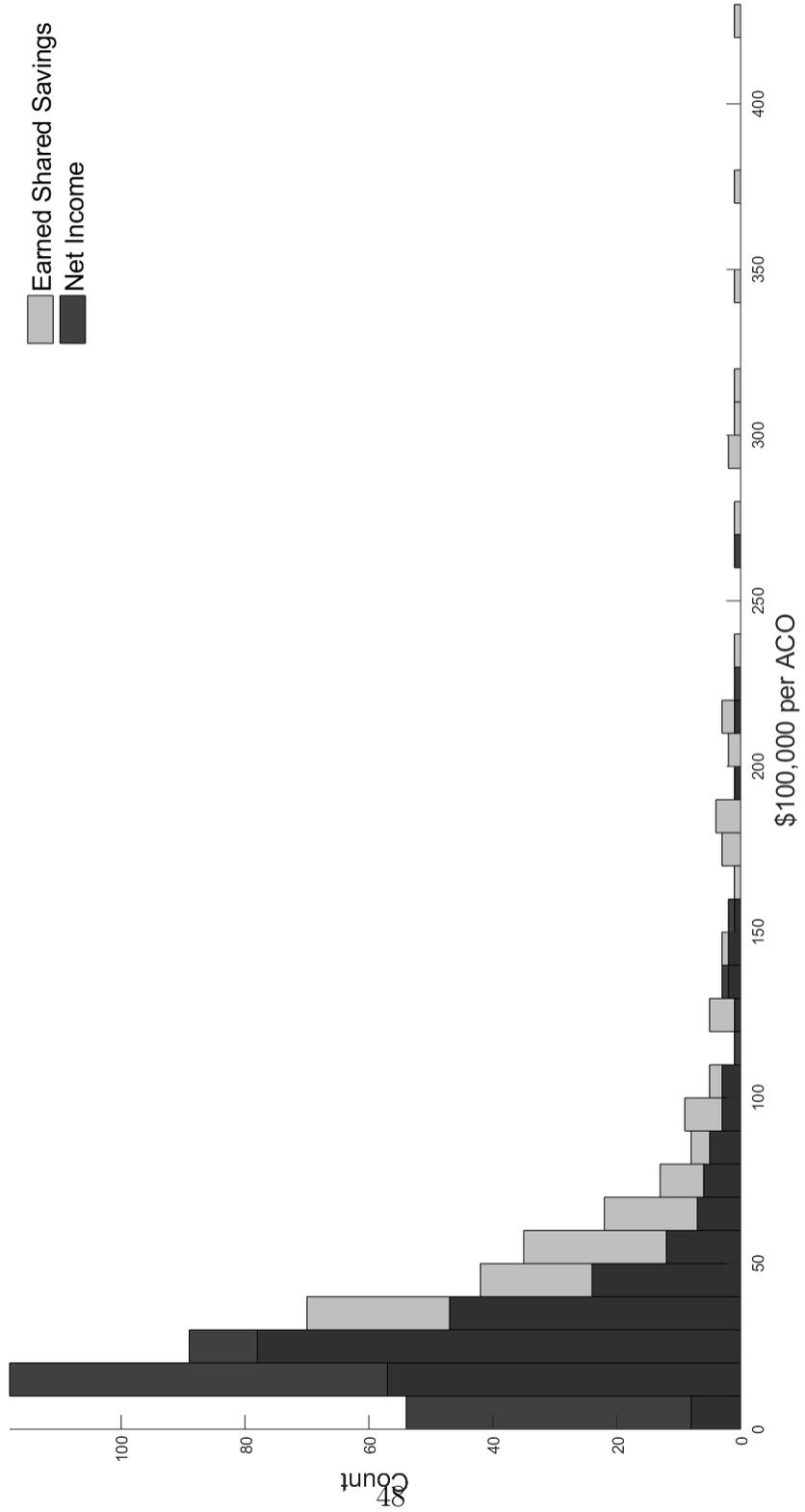


Figure 7: Histogram of Net Income divided by Earned Shared Savings

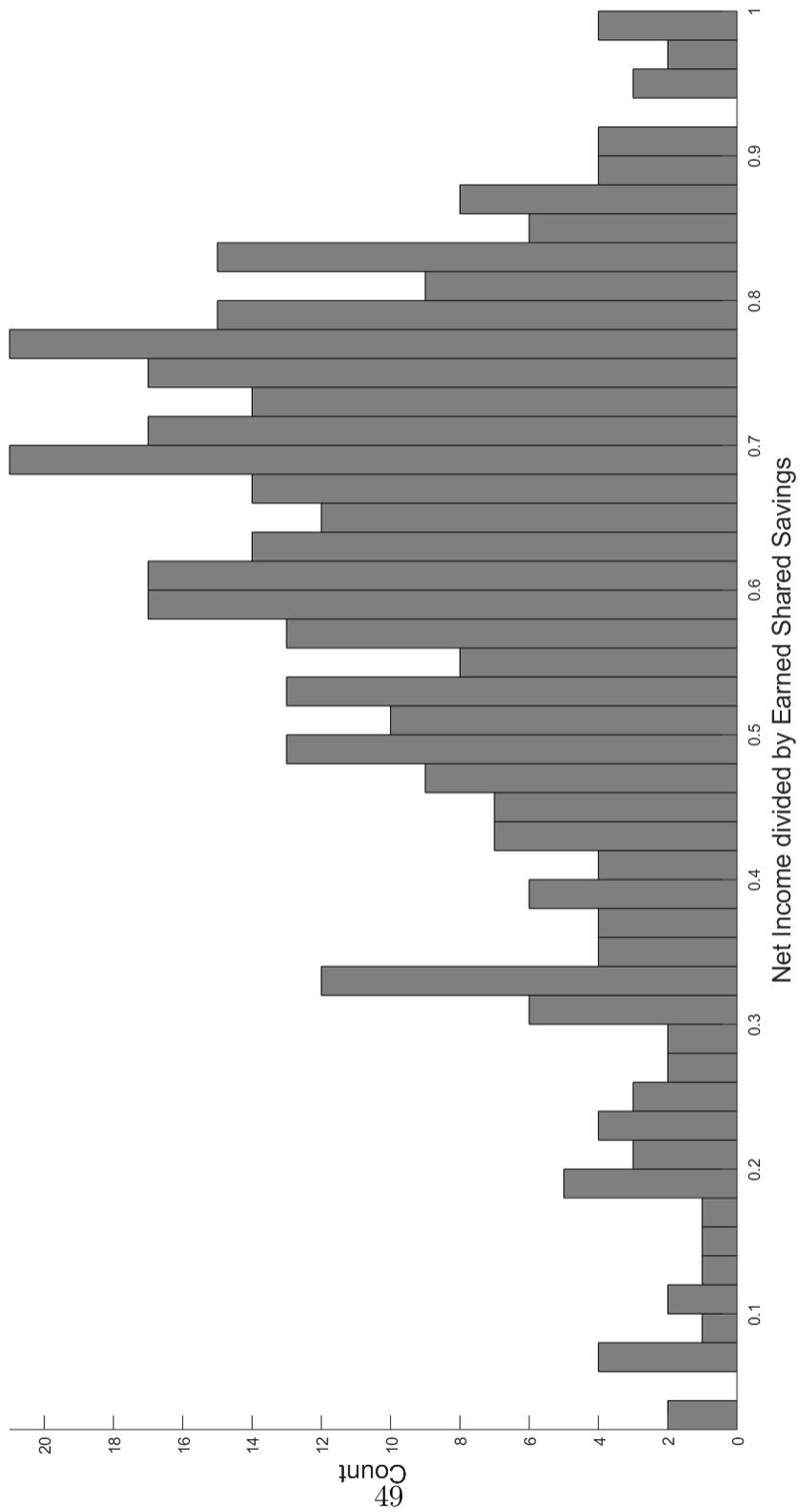


Figure 8: Optimal Savings Fraction

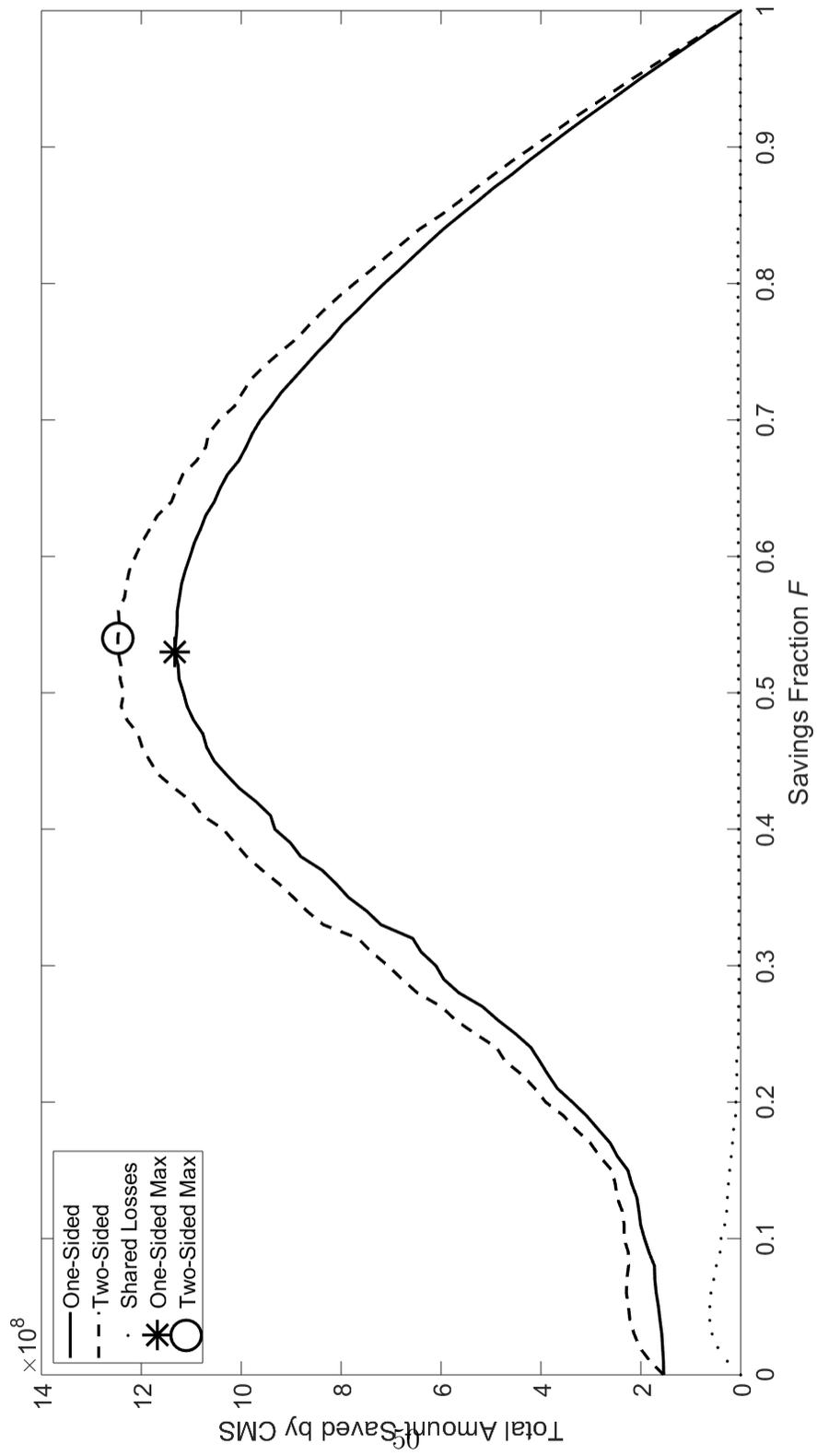
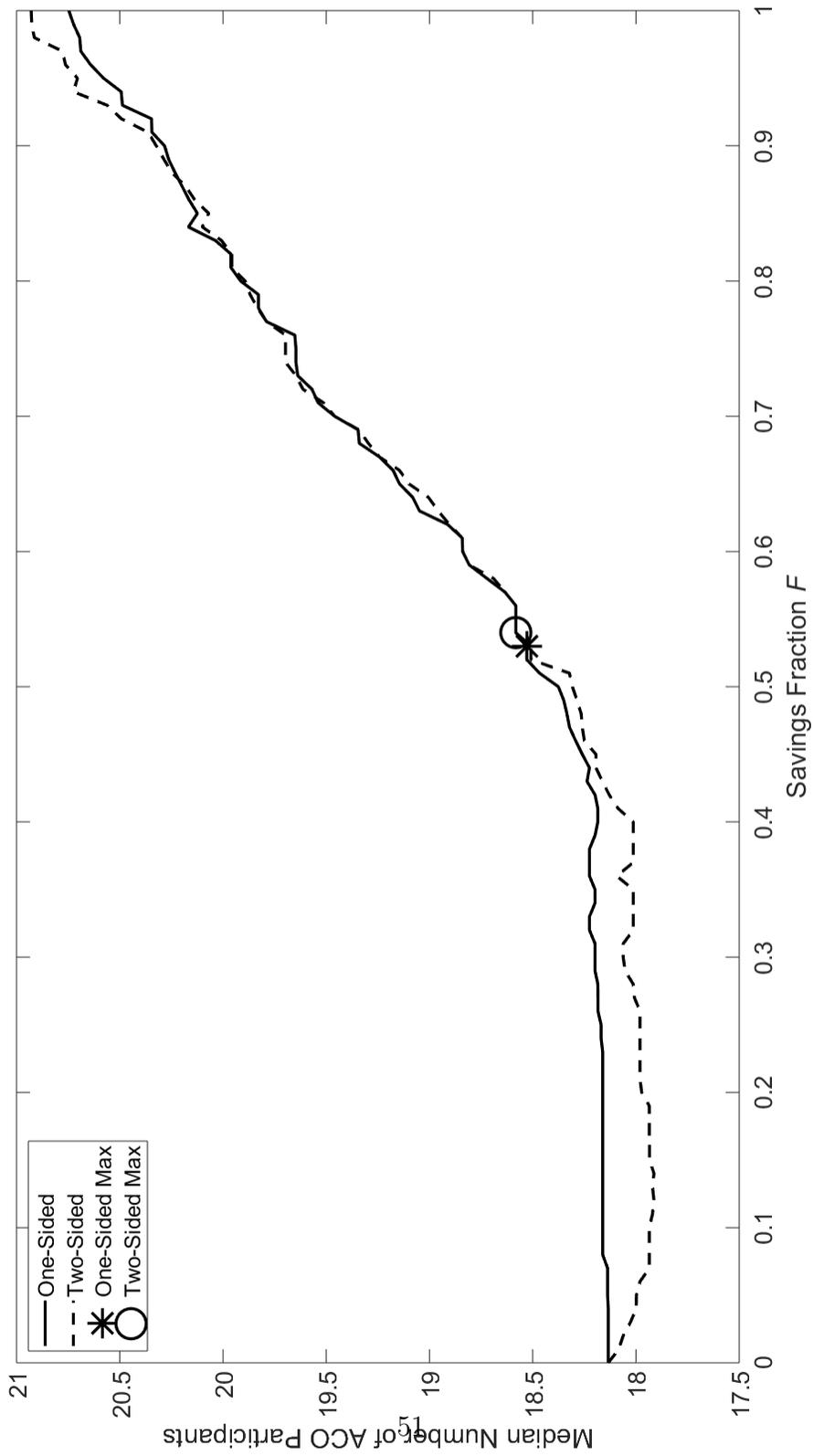


Figure 9: Optimal Savings Fraction



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Table 1: **Summary Statistics of ACO Characteristics**

Var.	Mean	S.D.	Min.	Med.	Max.
# States where ben. reside	1.5	.99	1	1	10
# Assigned ben.	18,095	17,889	152	12,104	149,633
Avg. aged non-dual risk score	1.1	.11	.81	1	2.1
% Ben. over 75	39	6	13	39	66
% Ben. male	43	2.1	35	43	58
% Ben. Nonwhite	17	15	1.5	12	95
# Participants	38	58	1	20	840
Total # of providers	603	862	0	284	7,285
Frac. providers PCP	.4	.18	.03	.36	1
Frac. providers Spec.	.4	.2	0	.44	.88
Frac. expend. inp.	.31	.028	.22	.31	.43
Frac. expend. out.	.2	.057	.076	.19	.49
# Primary care serv.	10,287	1,758	5,385	9,973	26,163
# Inp. adm.	331	87	171	318	1,856

Table 2: Summary Statistics of Savings and Quality Score by Year

year	Var.	Mean	S.D.	Min.	Med.	Max.
2014	S^*	0.006	0.049	-0.134	0.004	0.160
	Q^*	0.801	0.136	0.071	0.847	0.954
	“qualscore”	0.891	0.161	0.000	0.909	1.000
2015	S^*	0.007	0.058	-0.318	0.001	0.194
	Q^*	0.899	0.094	0.154	0.923	0.998
	“qualscore”	0.934	0.091	0.154	0.951	1.000
2016	S^*	0.009	0.054	-0.232	0.006	0.236
	Q^*	0.915	0.077	0.174	0.929	0.997
	“qualscore”	0.946	0.074	0.174	0.961	1.000
2017	S^*	0.013	0.048	-0.285	0.011	0.298
	Q^*	0.897	0.069	0.317	0.919	0.998
	“qualscore”	0.924	0.074	0.317	0.927	1.000
Total	S^*	0.009	0.053	-0.318	0.006	0.298
	Q^*	0.883	0.103	0.071	0.908	0.998
	“qualscore”	0.926	0.103	0.000	0.941	1.000

Table 3: Regressions of Savings and Quality Score

	Dependent Variable: S^*			Dependent Variable: Q^*		
Q^*	0.0290 ⁺ (0.0153)		0.0445 ^{**} (0.0142)			
S^*				0.0961 ⁺ (0.0503)		0.139 ^{**} (0.0454)
<i>nstates</i>	-0.00141 (0.00172)	-0.00140 (0.00172)		-0.000265 (0.00240)	-0.0000681 (0.00240)	
<i>nab</i>	-5.98e-08 (9.25e-08)	-8.51e-08 (9.28e-08)		0.000000569 ^{***} (0.000000141)	0.000000577 ^{***} (0.000000140)	
<i>risk</i>	0.165 ^{***} (0.0294)	0.163 ^{***} (0.0293)		0.0408 (0.0387)	0.0179 (0.0381)	
<i>pctover75</i>	-0.00102 ^{**} (0.000326)	-0.00101 ^{**} (0.000327)		-0.000165 (0.000590)	-0.0000224 (0.000584)	
<i>pctnonwhite</i>	0.000442 ^{***} (0.000133)	0.000501 ^{***} (0.000135)		-0.00133 ^{***} (0.000223)	-0.00139 ^{***} (0.000227)	
<i>pctmale</i>	-0.000842 (0.00103)	-0.000744 (0.00104)		-0.00219 ⁺ (0.00129)	-0.00207 (0.00130)	
<i>totprov</i>	0.000000674 (0.00000213)	0.000000796 (0.00000212)		-0.00000273 (0.00000350)	-0.00000283 (0.00000347)	
<i>fracpcp</i>	0.0147 ⁺ (0.00826)	0.0147 ⁺ (0.00830)		0.00123 (0.0181)	-0.000821 (0.0181)	
<i>fracexpinp</i>	-0.174 [*] (0.0681)	-0.175 ^{**} (0.0678)		0.0357 (0.126)	0.0599 (0.126)	
<i>fracexpout</i>	-0.100 [*] (0.0428)	-0.107 [*] (0.0427)		0.159 ^{**} (0.0508)	0.173 ^{***} (0.0517)	
<i>pcserv</i>	-0.000000598 (0.00000216)	-0.000000911 (0.00000216)		0.00000702 ^{**} (0.00000222)	0.00000711 ^{**} (0.00000226)	
<i>inpadm</i>	-0.000181 ^{***} (0.0000480)	-0.000170 ^{***} (0.0000475)		-0.000258 ^{***} (0.0000599)	-0.000232 ^{***} (0.0000572)	
<i>fracpcservpc</i>	0.0324 ⁺ (0.0169)	0.0317 ⁺ (0.0170)		0.0153 (0.0301)	0.0108 (0.0303)	
<i>N</i>	1626	1615	1615	1626	1615	1615
adj. R^2	0.056	0.159	0.164	0.185	0.251	0.255

Standard errors in parentheses; Year and Census Division FE for all specifications.

⁺ $p < 0.10$, ^{*} $p < 0.05$, ^{**} $p < 0.01$, ^{***} $p < 0.001$

Table 4: **Elements of X_j^{perf}**

Variable Name	Description
$nstates_j$	Number of states where beneficiaries assigned to the ACO reside
nab_j	Number of beneficiaries assigned to the ACO
$risk_j$	Average CMS HCC risk score of aged, non-dual beneficiaries assigned to the ACO. This is well correlated with other risk scores.
$pctover75_j$	Percent of assigned beneficiaries over age 75
$pctmale_j$	Percent of assigned beneficiaries that are male
$pctnonwhite_j$	Percent of assigned beneficiaries that are non-white
$totprov_j$	Total number of providers in an ACO
$pctpcp_j$	Percent of providers that are primary care physicians
$pctexpint_j^a$	Percent of expenditures that are inpatient expenditures (includes short term, long term, rehabilitation, and psychiatric)
$pctexpout_j^a$	Percent of expenditures that are outpatient expenditures
$pcserv_j^a$	Total number of primary care services
$inpadm_j^a$	Total number of inpatient hospital discharges
$pctpcservpc_j^a$	Percent of primary care services provided by primary care physician

Not listed: Constant term, year and census division fixed effects.

The superscript ^a denotes the variable is in X_j^{perf} but not X_j^{part} .

Table 5: **Participation Equation Controls and IVs**

Parameter	Variable	IV
α_0	\hat{y}_j	Exogenous element in X_j^{perf}
	$nstates_j$	N/A
	nab_j	Total Medicare ben. person-years ACO area
	$risk_j$	Lagged risk scores
	$pctover75_j$	% pop. over 75 in ACO state
β	$pctmale_j$	% male pop. with Medicare in ACO state
	$pctnonwhite_j$	% black in ACO state
	$totprov_j$	Exogenous element in X_j^{perf}
	$fracpcp_j$	Exogenous element in X_j^{perf}
ρ	$\ln(a_j/a_d)$	Relative HMO enrollment in ACO area

Table 6: **Cost Function Parameter Estimates (1)**

$$c(s, q) = \frac{\delta_S}{2}s^2 + \frac{\delta_Q}{2}q^2 + \gamma_S s + \gamma_Q q + \kappa sq$$

Parameter	Estimate	Std. Err.	<i>p</i> -value	95% C.I.
δ_S	875,410	67,447	0.000	(743,113, 1,007,707)
δ_Q	8,001	1,750	0.000	(4,567, 11,436)
κ	76,639	18,763	0.000	(39,835, 113,442)
N	1615			

Estimates include year and Census Division FE.

Table 7: **Cost Function Parameter Estimates (2)**

$$c(s, q) = \frac{\delta_S}{2}s^2 + \frac{\delta_Q}{2}q^2 + \gamma_S s + \gamma_Q q + \kappa sq$$

Cost-Shifter	Estimate: γ_S	Estimate: γ_Q
<i>nstates</i>	-2,322.90 (1,970.00)	-302.03 (185.49)
<i>nab</i>	0.04 (0.15)	-0.01 (0.01)
<i>risk</i>	158,450.00** (54,964.00)	12,909.00* (6,749.20)
<i>pctover75</i>	2,030.50*** (585.89)	233.16** (87.41)
<i>pctnonwhite</i>	147.80 (206.53)	34.74 (32.01)
<i>pctmale</i>	4,581.20** (1,489.90)	422.44** (167.74)
<i>totprov</i>	0.23 (3.47)	0.23 (0.30)
<i>fracpcp</i>	165,560.00*** (22,151.00)	12,093.00*** (2,417.10)
<i>fracexpinp</i>	138,100.00 (114,700.00)	21,375.00* (12,610.00)
<i>fracexpout</i>	101,730.00+ (66,681.00)	11,773.00+ (8,502.40)
<i>pcserv</i>	13.65*** (3.25)	1.17*** (0.36)
<i>inpadm</i>	-216.54 (75.98)	-16.71 (7.84)
<i>fracpcservpc</i>	-4,147.00 (30,859.00)	-2,104.50 (4,647.60)
<i>N</i>	1615	

Standard errors in parentheses. Estimates include year and Census Division FE. Example interpretation: increasing *nstates* by one unit decreases the marginal cost of an 0.01 increase in savings by \$23.23.

Table 8: **Participation Equation Estimates**

$$u_{ij} = (\alpha_0 + \alpha_\eta \eta_i) \hat{y}_j + \beta' X_j^{part} + \xi_j + \zeta_{id}(\rho) + (1 - \rho) \epsilon_{ij}$$

Coef.	Variable	RC	RCNL
α_0	\hat{y}_j	0.0168* (0.0073)	0.0115* (0.0063)
α_η	$\eta_i \hat{y}_j$	0.0018* (0.0008)	0.0034*** (0.0010)
ρ	$\ln(a_j/a_d)$		0.4478* (0.2136)
β	<i>nab</i>	0.00004* (0.00002)	0.00003** (0.00001)
	<i>risk</i>	1.2570 (1.0842)	0.9828+ (0.7313)
	<i>pctover75</i>	0.0717+ (0.0519)	0.0458 (0.0407)
	<i>pctnonwhite</i>	0.0181 (0.0185)	0.0093 (0.0146)
	<i>pctmale</i>	-0.1492 (0.2262)	-0.1695 (0.1528)
	<i>totprov</i>	-0.0007 (0.0007)	-0.0006 (0.0004)
	<i>fracpcp</i>	-3.6100 (3.3775)	-2.2581 (1.7388)
	<i>nstates</i>	0.0111 (0.0499)	-0.0156 (0.0439)
	<i>N</i>		1615

Bootstrapped standard errors (1,000 rep.) in parentheses. Estimates include year and Census Division FE. \hat{y}_j and η_i are in units of \$100,000 US 2016 dollars.

Table 9: **Two-Sided ACO Performance Predictions**

	One-Sided		Two-Sided	
Savings fraction F	S_j^*	Q_j^*	S_j^*	Q_j^*
0.50	<i>0.0065</i>	<i>0.8455</i>	0.0272	0.7249
0.60	0.0140	0.8481	0.0345	0.7328
0.75	0.0220	0.8510	0.0422	0.7397

In the data, $S_j = 0.008$ and $Q_j = 0.88$ on average.

Table 10: **Two-Sided ACO CMS Savings**

Savings fraction F	One-Sided		Two-Sided	
	Shared-Losses	Total Savings	Shared-Losses	Total Savings
0.50	<i>N/A</i>	<i>4.46</i>	0.018	4.94
0.60	<i>N/A</i>	4.41	0.020	4.85
0.75	<i>N/A</i>	3.39	0.021	3.68

Values in billions of US 2016 dollars.

Table 11: **Two-Sided ACO Net Income and Participation**

	One-Sided		Two-Sided	
Savings fraction F	Average y_j	Median n_j	Average y_j	Median n_j
0.50	<i>10.42</i>	<i>18</i>	10.09	17
0.60	12.74	19	12.49	19
0.75	15.55	19	15.86	21

y_j in 100,000's of US 2016 dollars. n_j is number of participants.

Table 12: **Performance Loss from Non-Cooperative Behavior**

S^*	S^o	Q^*	Q^o
0.0065	0.0383	0.8455	0.8672
y_j^*	y_j^o	n_j^*	n_j^o
10.43	22.97	18	23

y_j in 100,000's of US 2016 dollars. n_j is number of participants.

Table 13: **Cost Function Parameter Estimates (Uncertainty Model)**

$$c(s, q) = \frac{\delta_S}{2} s^2 + \frac{\delta_Q}{2} q^2 + \gamma_S s + \gamma_Q q + \kappa s q$$

Parameter	Estimate	Std. Err.	<i>p</i> -value	95% C.I.
δ_S	992,520	224,630	0.000	(232,720, 1,108,000)
δ_Q	7,736	6,601	0.121	(4,047, 27,612)
κ	90,102	26,865	0.000	(41,088, 125,050)
σ_S	0.01	0.09	0.472	(0.00,0.31)
σ_Q	0.43	0.16	0.004	(0.00,0.45)
N	1615			

Bootstrapped standard errors (1,000 rep.) in parentheses. Estimates include year and Census Division FE.

Table 14: **Participation Equation Estimates (Uncertainty Model)**

$$u_{ij} = (\alpha_0 + \alpha_\eta \eta_i) \hat{y}_j + \beta' X_j^{part} + \xi_j + \zeta_{id}(\rho) + (1 - \rho) \epsilon_{ij}$$

Coef.	Variable	RC	RCNL
α_0	\hat{y}_j	0.0191** (0.0068)	0.0248** (0.0099)
α_η	$\eta_i \hat{y}_j$	0.0008*** (0.0001)	0.0008*** (0.0002)
ρ	$\ln(a_j/a_d)$		0.3637+ (0.2610)
β	<i>nab</i>	0.00002* (0.00001)	0.00003* (0.00001)
	<i>risk</i>	0.6245 (0.9800)	0.6134 (0.7563)
	<i>pctover75</i>	0.0950* (0.0501)	0.0729+ (0.0470)
	<i>pctnonwhite</i>	0.0321* (0.0168)	0.0200+ (0.0152)
	<i>pctmale</i>	0.0244 (0.2025)	-0.0263 (0.1637)
	<i>totprov</i>	-0.0004 (0.0006)	-0.0005 (0.0004)
	<i>fracpcp</i>	-3.0662 (2.9444)	-2.5973 (1.9068)
	<i>nstates</i>	0.0025 (0.0471)	-0.0143 (0.0445)
	<i>N</i>		1615

Bootstrapped standard errors (1,000 rep.) in parentheses. Estimates include year and Census Division FE. \hat{y}_j and η_i are in units of \$100,000 US 2016 dollars.

Table 15: **Higher-Ordered Polynomial Cost Function Parameter Estimates**

$$c(s, q) = \sum_{p=2}^P \varphi_p^S \frac{s^p}{p} + \sum_{p=2}^P \varphi_p^Q \frac{q^p}{p} + \gamma_S s + \gamma_Q q + \kappa s q$$

Parameter	$P = 2$ (Baseline)	$P = 3$	$P = 4$
κ	76,639 (18,763)	91,264 (19,573)	61,554 (35,123)
φ_2^S	875,410 (67,447)	838,948 (87,600)	638,948 (204,143)
φ_2^Q	8,001 (1,750)	24,225 (19,414)	-14,225 (25,112)
φ_3^S		313,018 (278,084)	2,078,133 (1,745,933)
φ_3^Q		2,371 (8,763)	-189,113 (168,010)
φ_4^S			-6,907,725 (4,378,907)
φ_4^Q			106,053 (35,502)
N		1615	

Standard errors in parentheses. Estimates include year and Census Division FE.