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 and participation 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 7%. I also find strong evidence that providers face a large trade-off between reducing expenditure and increasing quality of care. One counterfactual policy experiment shows that when ACOs are required to pay money back to Medicare when they spend too much, the cost-savings of the Medicare Shared Savings Program increases by a factor of 3.5, though quality scores decrease significantly. Another counterfactual experiment finds that cost-savings is maximized when 44% of savings are paid back to ACOs, which is close to current policy (50%). The final counterfactual shows that over $1 billion per year in program savings is lost to non-cooperative behavior in ACOs.

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

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1 Introduction

Health care spending in the United States reached an all-time high at $3.5 trillion in 2017. The federal government accounts for 28 percent of that spending at $1 trillion, with $700 billion spent on Medicare alone. Finding a way to curtail health care spending in the United States, without sacrificing quality of care, has been the goal of policy makers and economists for decades. The Medicare Shared Savings Program (MSSP) and its Accountable Care Organizations (ACOs) are popular and promising potential solutions to this massive problem.

Welcomed with the enactment of the Patient Protection and Affordable Care Act of 2010 (ACA), Medicare’s ACOs are groups of Medicare providers that receive incentive pay for spending less on their beneficiaries while providing high quality of care. Since the beginning of the MSSP in 2012, 10.5 million Medicare beneficiaries have been assigned to ACOs, and over $3 billion in performance payments have been paid by Medicare to ACOs.\(^1\) With the proper incentives, ACOs have the potential to finally spur integrated care delivery and significant reductions in expenditure throughout Medicare, and possibly throughout the entire health care industry.

This paper answers several questions about the nature of participation and performance in ACOs. Broadly, 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 of care? Is there a large trade off between these goals? I also examine the outcome of several counterfactual scenarios: How does altering the incentive scheme of the MSSP change participation and ACO performance? What payment formula maximizes the money saved by the program? How much is lost to non-cooperative behavior and misaligned incentives within ACOs?

To answer these questions, I write and estimate a two-stage structural model of Medicare

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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 rate and quality score to maximize their payoff. These actions 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.

I find that increasing an ACO’s net income by $100,000 increases participation by at least 7% (2-3 participants), and the elasticity of participation with respect to net income is 0.5. The leadership structure of an ACO plays a significant role in a provider’s decision to join. Performance is influenced by both beneficiary demographics and provider behavior. 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 marginal cost of quality of care by nearly $67,000 per participating 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 44%, where Medicare increases the savings of the program by about $16.6 million per year, or 14%. I predict that when ACOs must pay money if they spend too much (facing what’s known as a two-sided risk model), savings rates are four times higher, and this amounts to a 352% increase in savings to Medicare. Quality scores, on the other hand, decrease under this incentive structure, since ACOs incur significantly higher costs of increasing quality when saving more. When weighting program savings by ACO quality scores, neither risk model strictly dominates the other.

Finally, I find that under perfect participant coordination, program savings would increase by over $1 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 marginal 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 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 the MSSP in 2012 and continue to operate today. Nearly any Medicare provider can start an ACO (typically as an LLC) and recruit other Medicare providers to participate in their ACO. A participant can be nearly any health care provider that accepts and bills Medicare, including individual physicians, group practices, and hospitals.\(^2\) 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). Medicare fee-for-service (FFS) beneficiaries are assigned to ACOs by CMS: if a given Medicare beneficiary receives the plurality of primary care services from a primary care provider who is (or is employed by) an ACO participant, that beneficiary is

\(^2\)Participants are legally defined by their Tax ID Number (TIN) or CMS Certification number (CCN).
assigned to that participant’s ACO.³

There are two separate components of assessing ACO performance, and both determine the amount ACOs are paid. The first is an overall quality score, which is a composite score between 0 and 1 of 30 to 40 sub-measures of care quality. These sub-measures fall 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”).⁴

The second component is ACO savings. CMS first establishes an ACO’s benchmark expenditure by forecasting per-beneficiary Medicare expenditure 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 the actual expenditure on assigned beneficiaries divided by its benchmark expenditure.

Until June 2019, ACOs have a choice of three risk models called Tracks, and each vary in power and exposure to downside risk. Track 1, available to ACOs only in their first and second three-year agreement periods, is lowered powered and requires no loss sharing with CMS (i.e. it’s one-sided). Accordingly, each performance year the shared savings paid by CMS to an ACO on Track 1 is

\[
\frac{1}{2} \cdot (\text{Benchmark Expenditure} - \text{Expenditure}) \cdot \text{Quality Score}
\]  

³When a Medicare beneficiary receives the plurality of primary care services from a primary care provider not associated with an ACO, they are not assigned to an ACO. This assignment methodology results in roughly one fifth to one third of all FFS beneficiaries assigned to ACOs each year. An ACO must be assigned at least 5000 beneficiaries to operate and earn shared savings payments.

⁴See https://go.cms.gov/2xHy7Uo for a full list of ACO quality scores for every performance year.
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 $186 million (the average over 2012-2017) and minimum savings rate of 0.02. If that ACO has an expenditure of $160 million with a quality score of 0.90, it would earn

$$\frac{1}{2} \cdot (\$186 \text{ million} - \$160 \text{ million}) \cdot 0.90 = \$11.7 \text{ million}$$

in shared savings. Its savings rate is $(18.6 - 16)/16 = 0.1625$, and hence the minimum savings rate is exceeded. Though paying a subsidy, Medicare saves money as well: on net, it saves $14.3 million, as it paid $11.7 million to save $26 million.

Track 2 and Track 3 ACOs face higher powered incentives and downside risk. Instead of a savings fraction of $\frac{1}{2}$, Track 2 and Track 3 offer savings fractions of $\frac{3}{5}$ and $\frac{3}{4}$. Furthermore, payment is two-sided, and if expenditure is much larger than benchmark expenditure, these ACOs must pay money back to Medicare. Track 2 or Track 3 ACOs are discussed in more detail in Section 7.

### 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 health care 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 CMS as principle to examine the size-variance trade-off in group payment mechanisms like the MSSP. 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 MSSP, 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. The 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.5

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.

In an purely empirical analysis, Frech et al. (2015) studies county-level entry of private and public ACOs. The authors find small markets generally discourage ACO entry, and that public ACO entry is largely predicted by higher Medicare spending, higher population, and lower physician site concentration.

More generally, this paper aligns with the literature that studies the supply-side of health

5 The baseline model estimated in this paper does not contain a size-variance trade-off. However, in Section 8 I estimate a separate model that is a generalization of the Frandsen & Rebitzer (2015) model, and my results do not change.
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 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, a participant first chooses a type of ACO to join, or none at all. If they do
choose a type, they then choose an ACO to join among that type. This framework allows correlation of utilities of participants in ACOs in the same type, accounting for when ACOs 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.

In the model’s first stage, the decision makers in this model are Medicare providers that qualify as a participant in the MSSP. Medicare providers that are participants in an ACO are the decision makers in the model’s second stage. This is a heterogeneous group: examples include individual providers, group practices, and hospitals. The set of potential participants $I$ and set of all ACOs $J$ are exogenous.

### 3.1 Participation

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

$$
    u_{ij} = \alpha_i y_j + \beta' X_{j}^{part} + \xi_j + \zeta_{id}(\rho) + (1 - \rho) \epsilon_{ij}.
$$

The variable $y_j$ is the net income of an ACO and $X_{j}^{part}$ is a vector of observed ACO characteristics. The variable $\xi_j$ is unobserved ACO heterogeneity, $\zeta_{id}(\rho)$ is $i$’s specific preference for participating.

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in an ACO in the nest $d$ (allowing correlation of utility of providers within groups of ACOs), and $\epsilon_{ij}$ is an idiosyncratic utility shock. Following Berry (1994) and Cardell (1997), I assume $\epsilon_{ij}$ 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 $\alpha_i$, individual $i$’s return to ACO net income; $\beta$, 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 $\rho$ 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 $\alpha_i$. 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 $X_{j,\text{part}}^j$ are likely correlated with unobserved ACO heterogeneity $\xi_j$, getting unbiased estimates of $\alpha_i$ and
\( \beta \) requires an instrumental variables (IV) technique, outlined in Section 5.

I normalize the utility of the outside option, \( j = 0 \), to 
\[
u_{i0} = \zeta_0(\rho) + (1 - \rho)\epsilon_{i0}
\]
where \( \zeta_0(\rho) \) and \( \epsilon_{i0} \) have distributions described above.

Formally, this model falls into the class of Random Coefficient Nested Logit (RCNL) models.\(^6\) 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 \( \alpha_i \) 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 quality scores, and so actual, observable values don’t exist. However, participants act as if they chose these values, and these values map to ACO performance measures that are observed.\(^7\) Participant savings and quality contributions are chosen strategically to maximize a participant’s profit from participating in an ACO.

Formally, suppose \( n_j \) participants decide to join ACO \( j \). All participants \( i \in j \) simultaneously choose savings and quality contributions 
\[
s_{ij} \in [s, \overline{s}] \quad \text{and} \quad q_{ij} \in [0, 1],
\]
and these choices determine

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\(^6\) For a discussion of RCNL models and the pattern of substitution they imply, see Grigolon & Verboven (2014).
\(^7\) Analogously, 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.
ACO savings rate \( S_j \) and overall quality score \( Q_j \) through the weighted sums

\[
S_j = \sum_{i \in j} w_{ij} s_{ij} \quad \quad \quad Q_j = \sum_{i \in j} w_{ij} q_{ij}.
\] (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.\(^8\)

Each participant \( i \in j \) solves the profit maximization problem

\[
\max_{s_{ij},q_{ij}} R_{ij}(S_j, Q_j) - c_{ij}(s_{ij}, q_{ij})
\] (5)

where \( R_{ij}(S_j, Q_j) \) is provider \( i \)'s portion of shared savings earned by an ACO with savings \( S_j \) and quality score \( Q_j \), \( c_{ij} \) is the strictly convex and twice-continuously differentiable per-provider cost function. Specifically, \( c_{ij}(s_{ij}, q_{ij}) \) is the explicit and implicit costs incurred by \( i \in j \) when choosing \( s_{ij} \) and \( q_{ij} \). For example, a physician that chooses very large values of \( s_{ij} \) and \( q_{ij} \) would incur significant cost—both in operational expenses as well as opportunity cost from forgone services to patients not assigned to \( i \)'s ACO. Conceptually, \( c_{ij}(\cdot) \) can be viewed 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, \( c_{ij} \) places a natural restriction on how well participants, and hence ACOs, can perform.

\(^8\)For 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 \( \pi_j = 0.03 \). 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. See Appendix B for more details.
The shared savings earned by ACO \( j \) takes the known and exogenous form

\[
R_j(S_j, Q_j) = \begin{cases} 
0.5 \cdot B_j S_j Q_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
0 & \text{otherwise}
\end{cases}
\]

(6)

where \( B_j \) is the benchmark expenditure of ACO \( j \), \( S_j \) is the minimum savings rate for ACO \( j \), and \( Q \) is the quality reporting standard.\(^9\) Assuming shared savings is distributed to participants according to influence weights \( w_{ij} \), \( R_{ij}(S_j, Q_j) = w_{ij} R_j(S_j, Q_j) \), and the two first order conditions for participant \( i \) are then

\[
\frac{\partial c_{ij}}{\partial s_{ij}} (s_{ij}, q_{ij}) = \begin{cases} 
0.5 \cdot B_j w_{ij}^2 Q_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
0 & \text{otherwise}
\end{cases}
\]

(8)

\[
\frac{\partial c_{ij}}{\partial q_{ij}} (s_{ij}, q_{ij}) = \begin{cases} 
0.5 \cdot B_j w_{ij}^2 S_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
0 & \text{otherwise}
\end{cases}
\]

(9)

I’ve assumed with the specification of \( R_{ij} \) that ACOs split their earned shared savings with their participants according to influence weights \( w_{ij} \), and not evenly between participants. Actual contracts between ACOs and ACO participants (known as “ACO Participant Agreements”) are generally not publicly available. However, splitting shared savings according to influence on ACO outcomes is a good approximation of how ACOs actually split earnings.\(^10\)

\(^9\)ACOs in their first performance year are “paid to report”, and so shared savings takes the form

\[
R_j(S_j, Q_j) = \begin{cases} 
0.5 \cdot B_j S_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
0 & \text{otherwise}
\end{cases}
\]

(7)

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

\(^{10}\)See [https://go.cms.gov/2HiHgus](https://go.cms.gov/2HiHgus) for more detail.
3.2.1 Strategic Complementarity and Existence of Equilibrium

The shared savings function $R_j$ is written in a way such that it may generate a simultaneous move game with strategic complementarity. 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. $\frac{\partial R_{ij}}{\partial s_{ij}}$ is weakly increasing in $q_{i'j}$ and constant in $s_{i'j}$.

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

*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 $BR_s^i$ and $BR_q^i$ be the best response functions of the savings and quality contributions, respectively, of participant $i$. Then, for all $i \in j$,

1. $BR_s^i$ and $BR_q^i$ are weakly increasing in $q_{i'j}$ and $s_{i'j}$, respectively, for all $i' \neq i$.

2. If $\frac{\partial^2 c_{ij}}{\partial s_{ij} \partial q_{ij}} \leq \frac{w_{ij}^3}{2} B_j$, then $BR_s^i$ and $BR_q^i$ 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

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11For an in-depth discussion, see the seminal papers Bulow et al. (1985) and Milgrom & Roberts (1990).
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 \( \frac{\partial R_{ij}}{\partial q_{ij}} \left( \frac{\partial R_{ij}}{\partial s_{ij}} \right) \) is increasing in \( s_{ij} (q_{ij}) \). Since \( i \)'s marginal revenue of quality (savings) is higher, \( i \) chooses a higher quality (savings) contribution.

The presence of strict strategic complementarity comes only when the ACO's savings rate and overall quality score meet or exceed the minimum savings rate and quality reporting standard. 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 \( S_j = \sum_{i \in j} w_{ij} s_{ij} = s_j \) or \( Q_j = \sum_{i \in j} w_{ij} q_{ij} = Q_j \). For supermodularity, the following assumptions are required: 1) \( \frac{\partial^2 c_{ij}}{\partial s_{ij} \partial q_{ij}} \leq \frac{w_{ij}^3}{2} B_j \), 2) \( S_j \neq s_j \), and 3) \( Q_j \neq Q_j \). Since 1) is not usually satisfied, I prove existence of equilibrium without relying on the presence of a supermodular game. Let \( \mathbf{s}_j = [s_{1j}, \ldots, s_{nj}]' \) and \( \mathbf{q}_j = [q_{1j}, \ldots, q_{nj}]' \) and define participant \( i \)'s profit as

\[
\pi_{ij} \left( \mathbf{s}_j, \mathbf{q}_j \right) = R_{ij} (S_j, Q_j) - c_{ij} (s_{ij}, q_{ij})
\]  

(10)
and its profit when qualifying as

\[ \pi_{ij}^Q(s_j, q_j) = 0.5 \cdot w_{ij}B_jS_jQ_j - c_{ij}(s_{ij}, q_{ij}) \]  

(11)

**Proposition 3.3.** Let the Hessian matrix \( D^2\pi_{ij}^Q \) 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 \( (s_{ij}^*, q_{ij}^*) \) and a Nash equilibrium of the game as \( (s_j^*, q_j^*) \). Accordingly, the ACO’s saving rate and overall quality score resulting from the set of Nash equilibrium strategies are denoted \( S_j^* \) and \( Q_j^* \). Generally, there is not a unique equilibrium. In the proof of Proposition 3.3, I show that there can be up to two equilibria—one where the ACO qualifies or shared savings, and one where it does not. In any case, this is not an issue for estimation, since the equilibrium being played is observed in data.

### 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 the 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.
Let $y_j$ be net income. Define

$$ (\tilde{s}_{ij}, \tilde{q}_{ij}) = \arg \min_{s_{ij}, q_{ij}} c_{ij}(s_{ij}, q_{ij}) . $$

(12)

Then,

$$ y_j = \sum_{i \in j} \left[ \pi_{ij} \left( s^*_{ij}, q^*_{ij} \right) + c_{ij}(\tilde{s}_{ij}, \tilde{q}_{ij}) \right] $$

(13)

When the equilibrium profile of ACO $j$ is such that ACO participants minimize cost, net income is equivalently zero, and otherwise strictly positive for all ACOs. The computation 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.\(^\text{12}\) 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. Little information is available on the characteristics of specific ACO participants or providers.

I use data from performance years 2014, 2015, 2016, and 2017.\(^\text{13}\) 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.

\(^{12}\)Available at data.cms.gov.

\(^{13}\)Performance year data is typically released the in late summer or early fall of the following year.
Table 1: Summary Statistics of ACO Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min.</th>
<th>Med.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of states where beneficiaries reside</td>
<td>1.5</td>
<td>0.99</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Number of assigned beneficiaries</td>
<td>18,095</td>
<td>17,889</td>
<td>152</td>
<td>12,104</td>
<td>149,633</td>
</tr>
<tr>
<td>Average risk score (aged, non-dual)</td>
<td>1.1</td>
<td>0.11</td>
<td>0.81</td>
<td>1</td>
<td>2.1</td>
</tr>
<tr>
<td>Percent of beneficiaries over 75</td>
<td>39</td>
<td>6</td>
<td>35</td>
<td>43</td>
<td>58</td>
</tr>
<tr>
<td>Percent of beneficiaries male</td>
<td>43</td>
<td>2.1</td>
<td>43</td>
<td>58</td>
<td>95</td>
</tr>
<tr>
<td>Percent of beneficiaries nonwhite</td>
<td>17</td>
<td>15</td>
<td>1.5</td>
<td>12</td>
<td>95</td>
</tr>
<tr>
<td>Number of participants</td>
<td>38</td>
<td>58</td>
<td>1</td>
<td>20</td>
<td>840</td>
</tr>
<tr>
<td>Total number of providers</td>
<td>603</td>
<td>862</td>
<td>0</td>
<td>284</td>
<td>7,285</td>
</tr>
<tr>
<td>Proportion of providers that are PCPs</td>
<td>.4</td>
<td>.18</td>
<td>.03</td>
<td>.36</td>
<td>1</td>
</tr>
<tr>
<td>Proportion of providers that are Specialists</td>
<td>.4</td>
<td>.2</td>
<td>0</td>
<td>.44</td>
<td>.88</td>
</tr>
<tr>
<td>Fraction of expenditure on inpatient services</td>
<td>.31</td>
<td>.028</td>
<td>.22</td>
<td>.31</td>
<td>.43</td>
</tr>
<tr>
<td>Fraction of expenditure on outpatient services</td>
<td>.2</td>
<td>.057</td>
<td>.076</td>
<td>.19</td>
<td>.49</td>
</tr>
<tr>
<td>Number of primary care services</td>
<td>10,287</td>
<td>1,758</td>
<td>5,385</td>
<td>9,973</td>
<td>26,163</td>
</tr>
<tr>
<td>Number of inpatient admissions</td>
<td>331</td>
<td>87</td>
<td>171</td>
<td>318</td>
<td>1,856</td>
</tr>
</tbody>
</table>

Table 1 summarizes some ACO characteristics. 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 is assigned about 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 beneficiaries across ACOs, 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. Figure 1 details the relationship. ACOs with a high proportion of specialists 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. 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 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

---

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>$S^*$</td>
<td>0.006</td>
<td>0.049</td>
<td>-0.134</td>
<td>0.004</td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td>$Q^*$</td>
<td>0.801</td>
<td>0.136</td>
<td>0.071</td>
<td>0.847</td>
<td>0.954</td>
</tr>
<tr>
<td></td>
<td>&quot;qualscore&quot;</td>
<td>0.891</td>
<td>0.161</td>
<td>0.000</td>
<td>0.909</td>
<td>1.000</td>
</tr>
<tr>
<td>2015</td>
<td>$S^*$</td>
<td>0.007</td>
<td>0.058</td>
<td>-0.318</td>
<td>0.001</td>
<td>0.194</td>
</tr>
<tr>
<td></td>
<td>$Q^*$</td>
<td>0.899</td>
<td>0.094</td>
<td>0.154</td>
<td>0.923</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td>&quot;qualscore&quot;</td>
<td>0.934</td>
<td>0.091</td>
<td>0.154</td>
<td>0.951</td>
<td>1.000</td>
</tr>
<tr>
<td>2016</td>
<td>$S^*$</td>
<td>0.009</td>
<td>0.054</td>
<td>-0.232</td>
<td>0.006</td>
<td>0.236</td>
</tr>
<tr>
<td></td>
<td>$Q^*$</td>
<td>0.915</td>
<td>0.077</td>
<td>0.174</td>
<td>0.929</td>
<td>0.997</td>
</tr>
<tr>
<td></td>
<td>&quot;qualscore&quot;</td>
<td>0.946</td>
<td>0.074</td>
<td>0.174</td>
<td>0.961</td>
<td>1.000</td>
</tr>
<tr>
<td>2017</td>
<td>$S^*$</td>
<td>0.013</td>
<td>0.048</td>
<td>-0.285</td>
<td>0.011</td>
<td>0.298</td>
</tr>
<tr>
<td></td>
<td>$Q^*$</td>
<td>0.897</td>
<td>0.069</td>
<td>0.317</td>
<td>0.919</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td>&quot;qualscore&quot;</td>
<td>0.924</td>
<td>0.074</td>
<td>0.317</td>
<td>0.927</td>
<td>1.000</td>
</tr>
<tr>
<td>Total</td>
<td>$S^*$</td>
<td>0.009</td>
<td>0.053</td>
<td>-0.318</td>
<td>0.006</td>
<td>0.298</td>
</tr>
<tr>
<td></td>
<td>$Q^*$</td>
<td>0.883</td>
<td>0.103</td>
<td>0.071</td>
<td>0.908</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td>&quot;qualscore&quot;</td>
<td>0.926</td>
<td>0.103</td>
<td>0.000</td>
<td>0.941</td>
<td>1.000</td>
</tr>
</tbody>
</table>

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. 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 common productive input.\(^{15}\)

### 5 Estimation

In this section, I describe how I use aggregate (i.e. ACO-level) data described in Section 4 to estimate the model described in Section 3. Net income $y_j$ is computed using estimates from the model’s second stage, so I estimate the model backwards. First, I parametrically estimate participant cost functions $c_{ij}$, yielding an estimate of a set of parameters called $\theta_2$. Next, I compute an estimate of $y_j$, and finally I compute an estimate of a set of parameters from the participation equation, $\theta_1$. 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.

\(^{15}\)Ultimately, 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.
5.1 Estimation of Second Stage Parameters

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

$$c_{ij}(s_{ij}, q_{ij}) = c(s_{ij}, q_{ij}; x_{ij}^{perf}, \theta_2) = \frac{\delta_S}{2} s_{ij}^2 + \frac{\delta_Q}{2} q_{ij}^2 + \left(\gamma'_S x_{ij}^{perf}\right) s_{ij} + \left(\gamma'_Q x_{ij}^{perf}\right) q_{ij} + \kappa s_{ij} q_{ij}.$$  \hspace{1cm} (14)

where $\delta_S, \delta_Q, \kappa \in \mathbb{R}$ and $\gamma_S, \gamma_Q \in \mathbb{R}^k$ are parameters to be estimated and $x_{ij}^{perf} \in \mathbb{R}^k$ is a vector of characteristics. The assumption that $c$ is quadratic in $s_{ij}$ and $q_{ij}$ is not problematic or too restricting. This simply means 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 $i \in j$ yields

$$MR^S_j = \delta_S S_j^* + \gamma'_S X_j^{perf} + \kappa Q_j^* + \nu_j^S$$ \hspace{1cm} (15)

$$MR^Q_j = \delta_Q Q_j^* + \gamma'_Q X_j^{perf} + \kappa S_j^* + \nu_j^Q$$ \hspace{1cm} (16)

where

$$MR^S_j = \begin{cases} 0.5 \cdot W_j^{(3)} B_j Q_j^* & \text{if } S_j^* \geq S_j \text{ and } Q_j^* \geq Q_j^* \\ 0 & \text{otherwise} \end{cases}$$ \hspace{1cm} (17)

$$MR^Q_j = \begin{cases} 0.5 \cdot W_j^{(3)} B_j S_j^* & \text{if } S_j^* \geq S_j \text{ and } Q_j^* \geq Q_j^* \\ 0 & \text{otherwise} \end{cases}$$ \hspace{1cm} (18)
and
\[ W_j^{(3)} = \sum_{i \in j} w_{ij}^3 \quad X_j^{perf} = \sum_{i \in j} w_{ij} x_{ij}^{perf}. \] (19)

The variables \( \nu_j^S \) and \( \nu_j^Q \) are i.i.d. error terms, coming from unobserved changes in ACO marginal costs. \( X_j^{perf} \) is observed in data, and \( W_j^{(3)} \), which is a measure of influence concentration within an ACO (similar to a Herfindahl-Hirschman index \([\text{HHI}]\)), is computed from data as the sum of cubed shares of expenditure for each type of provider within an ACO. \( W_j^{(3)} \) is discussed in detail in Appendix B.

Accordingly, I assume the moment conditions
\[ \mathbb{E} \left[ \begin{bmatrix} \nu_j^S \\ \nu_j^Q \end{bmatrix} \mid S_j^*, Q_j^*, X_j^{perf} \right] = 0 \] (20)
and use GMM to obtain estimates of parameters, \( \hat{\theta}_2 \).

### 5.2 Computation of Net Income

Using \( \hat{\theta}_2 \), I compute an estimate of additional income \( y_j \) called \( \hat{y}_j \). Recall Equations 12 and 13. These have the equivalent expression:
\[ y_j = \text{Earned Shared Savings of ACO } j - \sum_{i \in j} \left[ c \left( s_{ij}^*, q_{ij}^*; x_{ij}^{perf}, \theta_2 \right) - c \left( \tilde{s}_{ij}, \tilde{q}_{ij}; x_{ij}^{perf}, \theta_2 \right) \right]. \] (21)

The first term in Equation 21 is observed directly in data. The summation over \( i \in j \) requires computing values of \( \left( s_j^*, q_j^* \right) \) and \( \left( \tilde{s}_j, \tilde{q}_j \right) \). Unfortunately, this is not possible since only \( X_j^{perf} \) and not \( x_{ij}^{perf} \) is observed. In the results that follow, I approximate the second term in Equation 21 using participant choices coming from a symmetric equilibrium. See Appendix C for more details.
Let $\hat{y}_j$ be the predicted value of $y_j$.

### 5.3 Estimation of First Stage Parameters

Recall the utility specification for participating in ACO $j$:

$$u_{ij} = \alpha_i y_j + \beta' X_{j_{part}} + \xi_j + \zeta_{id}(\rho) + (1 - \rho) \epsilon_{ij} \quad (22)$$

The estimating equation for mean utility in such a framework with the aforementioned assumptions on unobserved error terms is

$$\ln\left(\frac{a_j}{a_0}\right) = \alpha_0 y_j + \beta' X_{j_{part}} + \rho \ln\left(\frac{a_j}{a_d}\right) + \xi_j. \quad (23)$$

The values $a_j$, $a_0$, and $a_d$ are the shares of Medicare providers choosing ACO $j$, choosing the outside option, and choosing an ACO $j \in d$, respectively.

For the nested logit specification, I divide choices $j \in J$ into groups based on the composition of participants in that nest. I use four nests: the outside option, ACOs that are physician led, ACOs that are hospital led, and ACOs with mixed leadership. Leadership derived from the MSSP ACO Participant List datasets. This way, the first stage of the model accounts for provider’s specific preference for being a part of the MSSP, and I obtain an estimate 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
Table 3: Elements of $X_{perf}^j$

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$nstates_j$</td>
<td>Number of states where beneficiaries assigned to the ACO reside</td>
</tr>
<tr>
<td>$nab_j$</td>
<td>Number of beneficiaries assigned to the ACO in thousands</td>
</tr>
</tbody>
</table>
| $risk_j$        | 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 individual providers in an ACO in thousands.                |
| $fracpcp_j$     | Proportion of individual providers that are primary care physicians         |
| $fracexpint_a$  | Proportion of expenditures that are inpatient expenditures (includes short term, long term, rehabilitation, and psychiatric) |
| $fracexpout_a$  | Proportion of expenditures that are outpatient expenditures                 |
| $pcserv_a$      | Total number of primary care services in thousands                          |
| $inpadm_a$      | Total number of inpatient hospital discharges in thousands                 |
| $fracpcservpc_a$| Proportion of primary care services provided by primary care physician     |
| $allgroup_a$    | Indicates every participant in ACO is a group practice or hospital          |

Not listed: Constant term, year and census division fixed effects. The superscript $^a$ denotes the variable is in $X_{perf}^j$ but not $X_{part}^j$.

the exogenous variables in $X_{part}^j$ as $Z_{part}^j$.\footnote{All elements of $X_{perf}^j$ and $Z_{part}^j$ as well as exclusion restrictions for identification are discussed in detail in Section 5.4.} The moment condition for estimation is

$$E \left[ \hat{\xi}_j \mid Z_{part}^j \right] = 0$$ \tag{24}

where $\hat{\xi}_j$ is the same as Equation 23, but with $\hat{y}_j$ instead of $y_j$.\footnote{In 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 when the estimated component of $\hat{y}_j$ is small and the parameter estimates in $\hat{\theta}_2$ are precise. See Ho (2006) and Domurat (2017).} The random coefficient on income is specified as $\alpha_i = \alpha_0 + \alpha_\eta \eta_i$ with $\eta_i \sim N(0, 1)$. The parameter $\alpha_\eta$ is uniquely determined and estimated via contraction mapping à la Berry (1994), Berry et al. (1995), and Nevo (2000).

5.4 Control Variables and Instruments

The elements of $X_{perf}^j$ and $X_{part}^j$ along with their descriptions are included in Table 3. Six variables...
Table 4: Participation Equation Controls and IVs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>$\hat{y}_j$</td>
<td>Exogenous element in $X_j^{\text{perf}}$</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$n\text{states}_j$</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$nab_j$</td>
<td>Total Medicare beneficiary person-years in ACO area</td>
</tr>
<tr>
<td></td>
<td>$\text{risk}_j$</td>
<td>Lagged risk scores</td>
</tr>
<tr>
<td></td>
<td>$\text{pctover75}_j$</td>
<td>Percent of population over 75 in ACO area</td>
</tr>
<tr>
<td></td>
<td>$\text{pctmale}_j$</td>
<td>Percent of male population with Medicare in ACO area</td>
</tr>
<tr>
<td></td>
<td>$\text{pctnonwhite}_j$</td>
<td>Percent of population black in ACO area</td>
</tr>
<tr>
<td></td>
<td>$\text{totprov}_j$</td>
<td>Exogenous element in $X_j^{\text{perf}}$</td>
</tr>
<tr>
<td></td>
<td>$\frac{\text{fracpcp}_j}{a}$</td>
<td>Exogenous element in $X_j^{\text{perf}}$</td>
</tr>
<tr>
<td>$\rho$</td>
<td>$\ln(a_j/a_d)$</td>
<td>Relative HMO enrollment in ACO area</td>
</tr>
</tbody>
</table>

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

GMM with the moment conditions described in Equation 20 offer an estimate $\hat{\theta}_2$. In a separate estimation, I allow $\kappa$ 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 24 to estimate $\alpha_0$, $\beta$, and $\rho$. Table 4 shows the parameters, variables, and IVs used. Descriptions of all variables are in Table 3. 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 $\hat{y}_j$, $\text{totprov}_j$, and $\text{fracpcp}_j$, I use cost shifters in $X_j^{\text{perf}}$ (but excluded in $X_j^{\text{part}}$) — these values are determined simultaneously with performance, but are realized after participation, and hence can only impact participation though correlation with $\hat{y}_j$, $\text{totprov}_j$, and $\text{fracpcp}_j$. Exogenous variation in $nab_j$, $\text{pctover75}_j$, $\text{pctmale}_j$, $\text{pctnonwhite}_j$ 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 $\text{risk}_{jit}$, 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 group payment system. 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 Table 5. 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. The parameter \( \kappa \), which is 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 nearly $67,000 per participant. Increasing quality contribution by one standard deviation increases marginal cost of savings by more than $150,000 per participant. This means 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. Figures 2 and 3 plot the marginal cost of savings and quality, each showing the inwards shift of marginal cost when savings or quality increase.

Parameter estimates in Table 5 also indicate several determinants of the marginal cost of savings and quality. Participants in ACOs with beneficiaries in many states and with high risk scores face larger marginal costs of savings. Furthermore, participants in ACOs comprised entirely of group practices or hospitals have a harder time producing savings, following the results of McWilliams et
Table 5: Cost Function Parameter Estimates

\[ c(s, q) = \frac{\delta_s}{2} s^2 + \frac{\delta_q}{2} q^2 + \gamma_s s + \gamma_q q + \kappa sq \]

<table>
<thead>
<tr>
<th>Coef.</th>
<th>Variable</th>
<th>Estimate</th>
<th>Std. Err.</th>
<th>P-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\delta_s)</td>
<td>271.130</td>
<td>37.115</td>
<td>0.000</td>
<td>216.230</td>
<td>337.640</td>
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<tr>
<td>(\delta_q)</td>
<td>1.693</td>
<td>0.417</td>
<td>0.000</td>
<td>0.997</td>
<td>2.373</td>
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<tr>
<td>(\kappa)</td>
<td>15.533</td>
<td>6.049</td>
<td>0.010</td>
<td>3.620</td>
<td>23.680</td>
</tr>
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<td>(\gamma_s)</td>
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<td>2.067</td>
<td>0.031</td>
<td>0.811</td>
</tr>
<tr>
<td></td>
<td>nab</td>
<td>0.210</td>
<td>0.143</td>
<td>0.142</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>risk</td>
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<td>38.847</td>
<td>0.003</td>
<td>36.326</td>
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<tr>
<td></td>
<td>petover75</td>
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<td>0.242</td>
<td>0.587</td>
<td>-0.283</td>
</tr>
<tr>
<td></td>
<td>petnonwhile</td>
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<td>0.061</td>
<td>0.041</td>
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<tr>
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<td>pctmale</td>
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<td>1.082</td>
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<td>totprov</td>
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<td>2.017</td>
<td>0.276</td>
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<td>0.458</td>
<td>-6.010</td>
</tr>
<tr>
<td></td>
<td>fracexpinp</td>
<td>-134.000</td>
<td>60.540</td>
<td>0.027</td>
<td>-232.780</td>
</tr>
<tr>
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<td>fracexpout</td>
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<td>30.472</td>
<td>0.000</td>
<td>-163.880</td>
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<td>0.001</td>
<td>-6.241</td>
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<td>impadm</td>
<td>-60.862</td>
<td>27.000</td>
<td>0.024</td>
<td>-101.780</td>
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<td></td>
<td>fracpceservpc</td>
<td>6.711</td>
<td>10.569</td>
<td>0.000</td>
<td>21.085</td>
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<tr>
<td></td>
<td>allgroup</td>
<td>29.339</td>
<td>5.204</td>
<td>0.000</td>
<td>21.085</td>
</tr>
</tbody>
</table>

| \(\gamma_q\) | nstates | -5.031 | 3.003 | 0.094 | -9.514 | 0.024 |
| | nab | 0.327 | 0.198 | 0.099 | -0.021 | 0.641 |
| | risk | 0.011 | 0.011 | 0.318 | -0.004 | 0.032 |
| | petover75 | 8.352 | 3.910 | 0.033 | 1.985 | 14.895 |
| | petnonwhile | 0.009 | 0.017 | 0.594 | -0.020 | 0.037 |
| | pctmale | -0.004 | 0.004 | 0.294 | -0.010 | 0.003 |
| | totprov | 0.055 | 0.081 | 0.497 | -0.067 | 0.192 |
| | fraccecp | -0.152 | 0.153 | 0.320 | -0.429 | 0.057 |
| | fracexpinp | 0.403 | 0.475 | 0.396 | -0.345 | 1.190 |
| | fracexpout | -10.024 | 4.461 | 0.025 | -17.659 | -3.337 |
| | pceserv | -6.613 | 2.015 | 0.001 | -9.979 | -3.533 |
| | impadm | -0.298 | 0.104 | 0.004 | -0.465 | -0.123 |
| | fracpceservpc | -4.148 | 2.426 | 0.087 | -8.299 | -0.201 |
| | allgroup | 0.598 | 0.680 | 0.380 | -0.477 | 1.751 |

| N | 1486 |

Standard errors, p-values, and CIs are from bootstrapping with 1000 rep. Estimates include year and Census Division FE. \(\delta_s\), \(\delta_q\), and \(\kappa\) are scaled estimates.
Figure 2: Marginal Cost vs. Savings Rate

Figure 3: Marginal Cost vs. Quality Score
al. (2013) and Rahman et al. (2016), which discuss the scale of health care providers and margins to improve savings and quality for large providers. 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 viewpoints: the parameter estimates in this paper imply increasing inpatient admissions decreases the marginal cost of savings \textit{ceteris paribus}. Other cost-increasing determinants positively correlated with inpatient admissions are held constant, and savings are now easier to achieve, possibly from economies of scale or less operational complexity. Table 5 also shows providers with older beneficiaries have a higher marginal cost of quality, and that marginal cost of quality is lower when inpatient admissions and number of primary care services offered to ACO beneficiaries is large.

Next, let’s examine and distribution of net income, $\hat{y}_j$, pictured in units of $100,000 in Figure 4. Here we see that correcting ACO income for the increase in cost incurred by its participants
shifting the distribution of money earned slightly to the left. In Figure 5, I show net income $\hat{y}_j$ as a fraction of earned shared savings. There’s are fair amount of heterogeneity in the net income earned by ACOs. The average ACO losses 34% of their earned shared savings to increases in effort cost, with some barely breaking even. Some ACOs require large cost outlays in order to qualify for incentive pay—others, with low marginal costs, earn a lot with giving up little.

Finally, I present the results to estimation of the participation equation in Table 6. The first column of estimates is of the OLS logistic regression without IVs. The Random Coefficients (non-nested) Logit with IVs is in the second column (RC) and the Random Coefficients Nested Logit with IV is in the third column (RCNL). After accounting for endogeneity, 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 the amount of participants in an ACO by over 7%, all else constant. This is an increase in two to three participants for the average ACO. Keep in mind that $100,000 is a small increment relative to overall net-income, which has a mean of $2.8 million when the ACO qualifies for shared savings. The elasticity of participation with respect to net income is 0.5.
Table 6: Participation Equation Estimates

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

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Variable</th>
<th>OLS</th>
<th>RC</th>
<th>RCNL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha_0)</td>
<td>(\hat{y}_j)</td>
<td>-0.007*</td>
<td>0.076**</td>
<td>0.072**</td>
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<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.028)</td>
<td>(0.022)</td>
</tr>
<tr>
<td>(\alpha_\eta)</td>
<td>(\eta_i \hat{y}_j)</td>
<td>0.012***</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.002)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>(\rho)</td>
<td>(\ln(a_j/a_d))</td>
<td></td>
<td>0.544*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.227)</td>
<td></td>
</tr>
<tr>
<td>(\beta)</td>
<td>(nstates)</td>
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<td>0.021</td>
<td>-0.014</td>
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<td>(0.039)</td>
<td>(0.071)</td>
<td>(0.073)</td>
</tr>
<tr>
<td></td>
<td>(nab)</td>
<td>0.026***</td>
<td>0.026†</td>
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<td>(risk)</td>
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<td>(0.567)</td>
<td>(0.866)</td>
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<td>(petover75)</td>
<td>0.027***</td>
<td>0.135***</td>
<td>0.113***</td>
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<tr>
<td></td>
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<td>(0.007)</td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td></td>
<td>(petnonwhite)</td>
<td>0.028***</td>
<td>0.045***</td>
<td>0.034***</td>
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<td>(0.002)</td>
<td>(0.009)</td>
<td>(0.008)</td>
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<tr>
<td></td>
<td>(pctmale)</td>
<td>0.100***</td>
<td>0.275**</td>
<td>0.160***</td>
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<tr>
<td></td>
<td></td>
<td>(0.017)</td>
<td>(0.095)</td>
<td>(0.039)</td>
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<td>(totprov)</td>
<td>0.134*</td>
<td>-0.457</td>
<td>-0.791*</td>
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<td></td>
<td></td>
<td>(0.060)</td>
<td>(0.414)</td>
<td>(0.366)</td>
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<tr>
<td></td>
<td>(fracpcp)</td>
<td>0.249</td>
<td>-2.494</td>
<td>-3.268*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.201)</td>
<td>(1.771)</td>
<td>(1.439)</td>
</tr>
</tbody>
</table>

| \(N\)       | 1486              |

+ \(p < 0.10\); \(* p < 0.05\); \(** p < 0.01\); \(*** p < 0.001\)

Bootstrapped standard errors (1,000 rep.) in parentheses. Estimates include year and Census Division FE. \(\hat{y}_j\) is in units of \$100k.
The parameter $\alpha_\eta$, describing the dispersion of taste for net income, has a precise estimate of 0.012 in the RC model and an imprecise estimate of 0.014 in the RCNL model. Coefficients on control variables $X_j^{perf}$ offer varying evidence that a provider’s decision to participate in an ACO depends on characteristics of an ACO along other than the ACO’s ability to earn shared savings. In the RCNL estimation, the nesting parameter $\rho$ is estimated with some precision at 0.544. 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 model of participation and performance to predict the outcome of changing the MSSP payment design and the outcome of changing the behavioral assumptions of ACOs and ACO participants. Each counterfactual follows the following steps:

1. Predict ACO outcomes $S_j^{CF}$ and $Q_j^{CF}$ using the shared savings function $R_j^{CF}(S_j, Q_j)$, where $CF$ denotes the counterfactual policy or behavioral assumptions.

2. With $S_j^{CF}$ and $Q_j^{CF}$, compute net income $\hat{y}_j^{CF}$ under the counterfactual policy, and use that to compute changes in participation.

3. To account for ACO exit under the the counterfactual, I estimate a logit with dependent variable equal to one if an ACO exits in performance year $t + 1$. Formally, I estimate $\nu_0$, $\nu_1$, $\nu_2$.
\[ \nu_2, \nu_3, \text{and } \psi \text{ in } \\
\begin{align*}
    \text{exit}_{jt+1} = 1 \left\{ \nu_0 + \nu_1 \hat{y}_{jt} + \nu_2 1 \{ \hat{y}_{jt} > 0 \} + \nu_3 \text{age}_{3jt} + \psi' X_{jt}^{perf} + \epsilon_{jt+1} \right\}
\end{align*} \tag{25}
\]

where \( \text{age}_{3jt} \) indicates the ACO is three years old and would start a new agreement with CMS in year \( t + 1 \), and \( \epsilon_{jt+1} \sim \text{Logistic}(0, 1) \). Results for this is in Table 11 in the appendix.\(^{18}\)

4. In the event that two equilibria exist in the second stage counterfactual, I choose the utilitarian equilibrium (where net income is larger).

While participation change in ACOs and ACO exit are predicted, I do not predict which or how many ACOs would not enter (as opposed to exit) in the face of the counterfactual changes. Nonetheless, if several ACOs exit under counterfactual changes, it’s likely a portion of those exiting ACOs would have never entered in the first place, so the predictions are still informative.

To put counterfactual changes in ACO overall quality score into meaningful terms, I use regularized regressions from Machine Learning. As discussed in Section 4, an ACO’s overall quality score is a composite measure of 30 to 40 sub-measures. The actual method of computing overall quality score from these sub-measures is discontinuous, unintuitive, and presents no method to find the marginal effect of a sub-measure on overall quality score. For this reason I’ll instead estimate a very simple model of overall quality score, where it is merely a linear combination of quality sub-measures. Techniques known as the Least Absolute Shrinkage and Selection Operator (LASSO) and Elastic Net automatically select a subset of sub-measures that explain the most variation in overall quality score. While a simplification, this model still explains over 80% of the variation in overall quality score. Appendix E details the process and results.

\(^{18}\)ACOs with non-negative net income are 15 percentage points less likely to exit. No element in \( X_{jt}^{perf} \) is a significant predictor of ACO exit, consistent with the idea that ACOs are profit maximizing.
ACOs in the MSSP have a choice of three risk models. Under Track 1, an ACO earns shared savings when its savings rate $S_j$ exceeds its minimum savings rate $S_j$. Even if a Track 1 ACO’s savings rate is negative, they are not required to pay shared losses to Medicare, so risk is one-sided. On the other hand, under Track 2 and Track 3, there is two-sided risk, and ACOs are required to repay Medicare if their savings rate is below the minimum loss rate, defined symmetrically as $-S_j$. Track 2 and Track 3 ACOs also earn a larger fraction of the money they save than Track 1 ACOs (for a given quality score), with savings fractions 0.6 and 0.75, respectively.

Figure 6 graphs an ACO’s earned shared savings or losses as a function of its savings rate, $S_j$. Under any risk model, an ACO earns shared savings when $S_j \geq S_j$ and earns nothing when $S_j \in (-S_j, S_j)$. Track 1 ACOs pay nothing back to CMS when $S_j \leq -S_j$, unlike Track 2 and 3 ACOs that pay money back.

The estimation of the cost function and utility from participation uses only Track 1 ACOs,
Table 7: Two-Sided ACO Performance Predictions

<table>
<thead>
<tr>
<th>(F)</th>
<th>(S_j^*)</th>
<th>(Q_j^*)</th>
<th>(PQ)</th>
<th>(PF)</th>
<th>(PS)</th>
<th>(S_j^*)</th>
<th>(Q_j^*)</th>
<th>(PQ)</th>
<th>(PF)</th>
<th>(PS)</th>
<th>(SL)</th>
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<tbody>
<tr>
<td>0.25</td>
<td>-0.0088</td>
<td>0.8843</td>
<td>0.3351</td>
<td>0.3950</td>
<td>-0.1432</td>
<td>0.0117</td>
<td>0.7167</td>
<td>0.3338</td>
<td>0.0168</td>
<td>0.3971</td>
<td>0.0919</td>
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<tr>
<td>0.30</td>
<td>-0.0048</td>
<td>0.8867</td>
<td>0.3526</td>
<td>0.3869</td>
<td>-0.0301</td>
<td>0.0150</td>
<td>0.7211</td>
<td>0.3546</td>
<td>0.0168</td>
<td>0.4883</td>
<td>0.0919</td>
</tr>
<tr>
<td>0.40</td>
<td>0.0023</td>
<td>0.8920</td>
<td>0.3863</td>
<td>0.3769</td>
<td>0.1096</td>
<td>0.0213</td>
<td>0.7293</td>
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<td>0.5837</td>
<td>0.0919</td>
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<tr>
<td>0.50</td>
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<td>0.8953</td>
<td>0.4118</td>
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<td>0.0354</td>
<td>0.0317</td>
<td>0.7660</td>
<td>0.4468</td>
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<td>0.3580</td>
<td>0.0354</td>
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<td>0.4704</td>
<td>0.0511</td>
<td>0.5340</td>
<td>0.1911</td>
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<tr>
<td>0.75</td>
<td>0.0202</td>
<td>0.9046</td>
<td>0.4623</td>
<td>0.3520</td>
<td>-0.2984</td>
<td>0.0375</td>
<td>0.7620</td>
<td>0.4643</td>
<td>0.0289</td>
<td>0.0403</td>
<td>0.1136</td>
</tr>
</tbody>
</table>

In the data, the mean of \(S_j^*\) is 0.0084 and the mean of \(Q_j^*\) is 0.8840. \(PQ\) is the proportion of ACOs with \(S_j^* \geq S_j\), and \(PF\) is the proportion of ACOs with \(S_j^* \leq -S_j\). \(PS\) is total program savings in $ billions, defined in Equation 28. \(SL\) is total shared losses paid to CMS in $ billions.

where the shared savings earned by ACO \(j\) is

\[
R_j(S_j, Q_j) = \begin{cases} 
F \cdot B_j S_j Q_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
0 & \text{otherwise} 
\end{cases} \quad (26)
\]

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

\[
R_j^{TS}(S_j, Q_j) = \begin{cases} 
F Q_j \cdot B_j S_j & \text{if } S_j \geq S_j \text{ and } Q_j \geq Q \\
(1 - F Q_j) \cdot B_j S_j & \text{if } S_j \leq -S_j \\
0 & \text{otherwise} 
\end{cases} \quad (27)
\]

where \(F = 0.6\) for Track 2 ACOs and \(F = 0.75\) for Track 3 ACOs.\(^1\) Table 7 details the simulation results, where \(R_j^{TS}\) is used in the maximization problem for ACO participants. 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. The model’s prediction under current law is in

\(^1\)For Track 3 ACOs, the so-called “final loss rate” \(1 - F Q_j\) is bounded below at 0.4. For Track 2 ACOs, it’s bounded above by 0.6; on Track 3, its bounded above by 0.75.
the middle-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, where payment is two-sided and $F = 0.60$ (Track 2) or $F = 0.75$ (Track 3).

The model predicts very large increases in average savings rates of ACOs under the two-sided model. The increase in savings has two causes. First, marginal revenue of savings is higher in the two-sided model, so ACO participants find it optimal to save more. Second, under Track 1, the equilibrium for some ACOs is to minimize cost at a savings rate below $-S_j$; this is not optimal under Tracks 2 and 3 since they are penalized for doing so. Looking at columns PQ and PF in Table 7, we can see that out of 1486 observations, 609 (41%) qualify for shared savings under Track 1, 698 (47%) under Track 2, and 684 (46%) under Track 3. Moreover, under Tracks 2 and 3, just 74 (5%) and 45 (3%) pay shared losses to CMS, compared to 550 (37%) Track 1 ACOs with a savings fraction less than the minimum loss rate. The large increase in average savings rates under two-sided risk is primarily due to the threat of shared losses, rather than the higher savings fraction.

Under both one-sided and two-sided incentives, quality scores almost always increase as $F$ increases.$^{20}$ 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. According to the Elastic Net results described in Appendix E, these changes in average overall quality score from 0.90 under one-sided risk to between 0.70 and 0.80 under two-sided risk amount to one of the following:

1. The percentile of all ACO providers COPD/Asthma emergency admissions increasing by four to eight percentage points (e.g. from 5th percentile to 9th percentile).

---

$^{20}$The lone exception to this is when $F$ changes from 0.6 to 0.75 under two-sided risk. Quality score decreases here because of the cap on the final loss rate $(1 - FQ_j)$. This is also the reason that the proportion of ACOs with $S^*_j \leq -S_j$ becomes smaller over the same increment.
2. The percentile of all ACO providers Heart Failure emergency admissions increasing by 6.5 to 13 percentage points.

3. The percentile of all ACO providers score on Health Promotion and Education portion of CAHPS decreasing by 25 to 50 percentage points.

The risk model faced by ACOs plays 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. The column SL is the amount paid to CMS from by ACOs failing to perform well enough. Column PS is the total money saved (or lost) over the benchmark expenditure less the amount shared with ACOs. The values indicate we should expect the total revenue to CMS to increase significantly with Track 2 ACOs with over a 352% increase, and decrease by 66% under Track 3. While these changes are very large, they are not unreasonable. Under two-sided risk, simply minimizing cost is no longer an equilibrium for ACO participants. More than a third of ACOs respond by having an equilibrium with a savings rate at least as high as the minimum loss rate, and this adds up to hundreds of millions of additional savings to CMS.

The increase in program savings under two-sided risk is essentially a transfer from ACOs to CMS, and so we must also account for the effect of two-sided incentives on participation in ACOs. Table 8 shows that net income is 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. For a fixed savings fraction, mean net income decreases by less than $100,000$ on average, and mean participation decreases between 3% and 10%. When the savings fraction increases along with the change to a two-sided risk structure, the effect is a net positive. To account for exiting ACOs, I use the results of a logit model of exit (described in Appendix D) to predict the number of ACOs
Table 8: Two-Sided ACO Net Income and Participation

<table>
<thead>
<tr>
<th>$F$</th>
<th>One-Sided Risk Model (Track 1)</th>
<th>Two-Sided Risk Model (Tracks 2 and 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Net Income</td>
<td># of Participants</td>
</tr>
<tr>
<td>0.25</td>
<td>1.891</td>
<td>21.017</td>
</tr>
<tr>
<td>0.30</td>
<td>2.579</td>
<td>22.146</td>
</tr>
<tr>
<td>0.40</td>
<td>4.204</td>
<td>25.059</td>
</tr>
<tr>
<td>0.50</td>
<td>6.117</td>
<td>28.982</td>
</tr>
<tr>
<td>0.60</td>
<td>8.313</td>
<td>34.248</td>
</tr>
<tr>
<td>0.75</td>
<td>11.892</td>
<td>44.962</td>
</tr>
</tbody>
</table>

In the data, the mean number of participants is 34. Net income is in $100k.

that would exit in the next performance year under the counterfactual payment scheme.

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 savings-optimal savings fraction $F$ by solving the problem

$$
\max_{F \in [0,1]} \sum_{j \in J} \left\{ \frac{\text{\$ saved by ACO } j}{B_j S_j^*(F)} - F \cdot B_j S_j^*(F) Q_j^*(F) \mathbf{1}\{S_j^*(F) \geq S_j\} \mathbf{1}\{Q_j^*(F) \geq Q\} \right\}
$$

s.t. \( (s_{ij}^*(F), q_{ij}^*(F)) = \arg \max_{s_{ij}, q_{ij}} \pi_{ij}(s_{ij}, q_{ij}) \) for all \( i \in j \) and \( j \in J \).

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 7 plots the objective function of CMS when maximizing total savings with one-sided ACOs (Equation 28) and the objective function of CMS with two-sided ACOs (which is slightly different than Equation 28). CMS saves the most
money under a one-sided incentive scheme at $F^* = 0.44$. The amount saved is approximately $16.6 million higher than under current law, where $F = 0.5$. If payment is two-sided, the optimal saving fraction is nearly the same at $F^* = 0.47$. This is far lower than ACOs on Tracks 2 and 3, where $F$ is 0.60 and 0.75. Compared to Track 2 and Track 3 ACOs, the amount saved at $F^* = 0.47$ is $236 million and $730 million higher, respectively.\textsuperscript{21}

The difference between one-sided and two-sided program savings comes overwhelmingly from the \textit{threat} of shared losses. Figure 8 plots the shared losses paid by ACOs as a percent of the difference in program savings between one-sided and two-sided incentives. As $F$ increases, shared losses increase in its share of the difference between one-sided and two-sided program savings. This is because the final loss rate $(1 - FQ_j)$ is decreasing in $F$. Shared losses comprise 40% of the difference at most.

We can also examine the effect on participation that occurs when changing $F$. Figure 9 plots savings fraction vs. mean number of participants per ACO. Since net income isn’t very different

\textsuperscript{21}The 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.
Figure 8: Shared Losses

Figure 9: Participation vs. Savings Fraction
for one-sided and two-sided ACOs, participation isn’t very different either.

The objective function in Equation 28 is written such that the solution maximizes total program savings—in other words, it’s savings-optimal. Importantly, that objective is decreasing in the quality score of ACOs, since a higher quality score increases the amount paid to ACOs. To examine how this impacts the optimal savings fraction, I also compute the savings-quality-optimal savings fraction, where the objective is to maximize savings weighted by quality score. Formally, the problem is

$$
\max_{F \in [0,1]} \sum_{j \in J} \left\{ \frac{\text{saved by ACO } j}{B_j S_j^*(F)} - F \cdot B_j S_j^*(F)Q_j^*(F)1 \left\{ S_j^*(F) \geq S_j \right\} 1 \left\{ Q_j^*(F) \geq Q \right\} \right\} Q_j^*(F) \quad (29)
$$

s.t. \( \left( s_{ij}^*(F), q_{ij}^*(F) \right) = \arg \max_{s_{ij}, q_{ij}} \pi_{ij}(s_{ij}, q_{ij}) \) for all \( i \in j \) and \( j \in J \).

Figure 10 plots the objective function of CMS when maximizing total savings weighted by quality score with one-sided ACOs (Equation 29) and the objective function of CMS with two-sided ACOs (which is slightly different than Equation 29). The apparent dominance of the two-sided risk model disappears once we weight program savings by quality scores. In fact, outside of the interval
[0.44, 0.70], the one-sided risk model has higher quality weighted savings than the two-sided risk model at a fixed $F$. The maximum value occurs at $F = 0.40$ for the one-sided risk model and $F = 0.50$ for the two-sided risk model. The two-sided risk model has an objective value just 7.6% higher at its maximum.

These counterfactual exercises offer strong evidence that the optimal savings fraction for the MSSP is between 0.4 and 0.5—very close to current law. The push to two-sided incentive structures is well-founded if maximizing program savings is the objective, however, these savings come at the cost of quality of care.

### 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

$$\max_{s_j, q_j} R_j (S_j, Q_j) - \sum_{i \in j} c_{ij} (s_{ij}, q_{ij}).$$

(30)

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 9. Under perfect cooperation, average ACO savings rate increases by nearly four percentage points, or about one standard deviation. Quality scores increase by just 0.02, or 0.22 standard deviations. This amounts to more than $1 billion per year in additional program savings to CMS.

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 $R_j(S_j, Q_j)$, marginal revenue of savings and quality
Table 9: Performance Loss from Non-Cooperative Behavior

<table>
<thead>
<tr>
<th>$F$</th>
<th>$S^*_j$</th>
<th>$Q^*_j$</th>
<th>PS</th>
<th>Net Income</th>
<th># Part.</th>
<th>$S^*_j$</th>
<th>$Q^*_j$</th>
<th>PS</th>
<th>Net Income</th>
<th># Part.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>-0.0088</td>
<td>0.8843</td>
<td>-0.1432</td>
<td>1.891</td>
<td>21.017</td>
<td>-0.0088</td>
<td>0.8843</td>
<td>-0.1432</td>
<td>2.216</td>
<td>21.542</td>
</tr>
<tr>
<td>0.30</td>
<td>-0.0048</td>
<td>0.8867</td>
<td>-0.0301</td>
<td>2.579</td>
<td>22.146</td>
<td>0.0299</td>
<td>0.9098</td>
<td>1.6643</td>
<td>3.117</td>
<td>23.070</td>
</tr>
<tr>
<td>0.40</td>
<td>0.0023</td>
<td>0.8920</td>
<td>0.1096</td>
<td>4.204</td>
<td>25.059</td>
<td>0.0392</td>
<td>0.9168</td>
<td>1.6687</td>
<td>5.208</td>
<td>27.047</td>
</tr>
<tr>
<td>0.50</td>
<td>0.0078</td>
<td>0.8953</td>
<td>0.1182</td>
<td>6.117</td>
<td>28.982</td>
<td>0.0466</td>
<td>0.9239</td>
<td>1.4698</td>
<td>7.605</td>
<td>32.454</td>
</tr>
<tr>
<td>0.60</td>
<td>0.0137</td>
<td>0.8998</td>
<td>0.0354</td>
<td>8.313</td>
<td>34.248</td>
<td>0.0540</td>
<td>0.9286</td>
<td>1.2576</td>
<td>10.200</td>
<td>39.533</td>
</tr>
<tr>
<td>0.75</td>
<td>0.0202</td>
<td>0.9046</td>
<td>-0.2984</td>
<td>11.892</td>
<td>44.962</td>
<td>0.0623</td>
<td>0.9360</td>
<td>0.6744</td>
<td>14.583</td>
<td>55.172</td>
</tr>
</tbody>
</table>

PS is total program savings in $ billions, defined in Equation 28. Net Income is in $ 100k.

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

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. This model is generalization of Frandsen & Rebitzer (2015), since I allow for heterogeneous participants and payment functions that depend on quality score.

Define $s_{ij}$, $q_{ij}$, $S_j$, and $Q_j$ as before, except that realized contributions of participants are i.i.d. random variables

\[ \hat{s}_{ij} \sim N(s_{ij}, \sigma_S^2) \]
\[ \hat{q}_{ij} \sim N(q_{ij}, \sigma_Q^2) \]

(31)
where $\mathcal{N}(\cdot)$ is the normal distribution. Defining $\hat{S}_j = \sum_{i \in j} w_{ij} \hat{s}_{ij}$ and $\hat{Q}_j = \sum_{i \in j} w_{ij} \hat{q}_{ij}$, each participant $i \in j$ solves the expected profit maximization problem

$$
\max_{s_{ij}, q_{ij}} \mathbb{E} \left[ R_{ij} (\hat{S}_j, \hat{Q}_j) \right] - c (s_{ij}, q_{ij}; x_{ij}, \theta_2)
$$

(32)

where $R_{ij}(\hat{S}_j, \hat{Q}_j)$ is the per-participant shared savings earned by an ACO with savings $\hat{S}_j$ and quality score $\hat{Q}_j$ (defined in Section 3.2). The objective function in Equation 32 becomes

$$
E^j_i (s_{ij}, q_{ij}, S_j, Q_j) = 0.5 \cdot w_{ij} B_j \cdot E_S(S_j) \cdot E_Q(Q_j) - c_{ij} (s_{ij}, q_{ij})
$$

(33)

where

$$
E_S(S_j) = \mathbb{E} \left[ \hat{S}_j \mathbf{1} \{ \hat{S}_j \geq S_j \} \right] = S_j \Phi \left( \frac{S_j - S_j}{\sqrt{W_j^{(2)} \sigma_S}} \right) + \sqrt{W_j^{(2)} \sigma_S} \phi \left( \frac{S_j - S_j}{\sqrt{W_j^{(2)} \sigma_S}} \right)
$$

(34)

and

$$
E_Q(Q_j) = \mathbb{E} \left[ \hat{Q}_j \mathbf{1} \{ \hat{Q}_j \geq Q_j \} \right] = Q_j \Phi \left( \frac{Q_j - Q_j}{\sqrt{W_j^{(2)} \sigma_Q}} \right) + \sqrt{W_j^{(2)} \sigma_Q} \phi \left( \frac{Q_j - Q_j}{\sqrt{W_j^{(2)} \sigma_Q}} \right).
$$

(35)

and $W_j^{(2)} = \sum_{i \in j} w_{ij}^2$ (see Appendix B). The functions $\phi$ and $\Phi$ 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.

$$
E^j_R(S_j, Q_j) = 0.5 \cdot B_j \cdot E_S(S_j) \cdot E_Q(Q_j).
$$

(36)

**Proposition 8.1.** Let $i' \neq i$. Marginal expected revenue $\frac{\partial E^j_R}{\partial s_{ij}} (S_j, Q_j)$ is increasing in $s_{ij}$ and
Proposition 8.1 states that the marginal payoff to a participant in an ACO is strictly increasing in the savings and quality of other participants for large regions of the domains of savings and quality.

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

\[
\frac{\partial E^i_j}{\partial s_{ij}q_{ij}} (S_j, Q_j) > \frac{\partial c_{ij}}{\partial s_{ij}q_{ij}} (s_{ij}, q_{ij})
\]

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 \( E^i_j \) to achieve existence in the following proposition.

**Proposition 8.2.** Consider the simultaneous move game played by participants \( i \) in ACO \( j \). If \( D^2 E^i_j \) is negative semidefinite, then there exists a Nash equilibrium in pure strategies. This equilibrium is unique.

**Proof.** See Appendix A.5. \( \square \)

### 8.1.2 Identification and Estimation

Identification and estimation of \( \theta_2 \) and \( \theta_1 \) in this model (with uncertainty) is nearly identical to their identification and estimation outlined in Section 5 for the model without uncertainty. There
Table 10: **Cost Function Parameter Estimates (Uncertainty Model)**

\[
c(s, q) = \delta S^2 s^2 + \delta Q^2 q^2 + \gamma S s + \gamma Q q + \kappa s q
\]

<table>
<thead>
<tr>
<th>Model</th>
<th>Coef.</th>
<th>Estimate</th>
<th>Std. Err.</th>
<th>P-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>(\delta_S)</td>
<td>271.130</td>
<td>37.115</td>
<td>0.000</td>
<td>216.230 337.640</td>
</tr>
<tr>
<td></td>
<td>(\delta_Q)</td>
<td>1.693</td>
<td>0.417</td>
<td>0.000</td>
<td>0.997  2.373</td>
</tr>
<tr>
<td></td>
<td>(\kappa)</td>
<td>15.533</td>
<td>6.049</td>
<td>0.010</td>
<td>3.620  23.680</td>
</tr>
<tr>
<td>w/ Uncertainty</td>
<td>(\delta_S)</td>
<td>353.940</td>
<td>47.718</td>
<td>0.000</td>
<td>260.910 418.170</td>
</tr>
<tr>
<td></td>
<td>(\delta_Q)</td>
<td>1.591</td>
<td>0.565</td>
<td>0.005</td>
<td>0.970  2.324</td>
</tr>
<tr>
<td></td>
<td>(\sigma_S)</td>
<td>0.011</td>
<td>0.013</td>
<td>0.370</td>
<td>0.000  0.021</td>
</tr>
<tr>
<td></td>
<td>(\sigma_Q)</td>
<td>0.010</td>
<td>0.004</td>
<td>0.023</td>
<td>0.002  0.014</td>
</tr>
<tr>
<td>(N)</td>
<td></td>
<td>1486</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard errors, p-values, and CIs are from bootstrapping with 1000 rep. Estimates include year and Census Division FE. \(\delta_S\), \(\delta_Q\), and \(\kappa\) are scaled estimates.

are two additional parameters to estimate, \(\sigma_S\) and \(\sigma_Q\), which are identified from variation in \(W_j^{(2)}\) without additional assumptions if \(c\) has linear marginal cost in savings and quality.

### 8.1.3 Results

Table 10 shows the estimates of parameters in \(\theta_2\) that describe the shape of the cost function as well as \(\hat{\sigma}_S\) and \(\hat{\sigma}_Q\). The parameters estimated from the model with uncertainty are well within a reasonable range of the parameters estimated from the model without uncertainty, albeit some with less precision. The estimate of \(\sigma_S\) is very imprecise, while \(\sigma_Q\) is estimated with some precision.

### 9 Conclusion

In this paper, I take a close look at the incentives faced by participants 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 provider face a large trade-off between increasing savings and increasing quality of care. Counterfactual policy analysis shows Track 2 and Track 3
ACOs will save far more Track 1 ACOs, and that the optimal savings fraction (with and without weighting by quality score) falls between 0.4 and 0.5. Another counterfactual shows performance improves significantly were ACOs able to perfectly coordinate. Over $1 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 health care. It’s not clear as of now if group-payment arrangements are the next great hope for health care 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 $S_j < S_j' \text{ or } Q_j < Q_j'$, $\frac{\partial R}{\partial s_{ij}}$ is identically zero, so the proof is trivial. Otherwise, we have

$$\frac{\partial^2 R}{\partial s_{ij} \partial s_{ij'}} = 0 \tag{38}$$

$$\frac{\partial^2 R}{\partial s_{ij} \partial q_{ij'}} = 0.5 \cdot B_j w^2_{ij} w_{ij'} \geq 0 \tag{39}$$

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

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 $\frac{\partial^2 c}{\partial s_{ij} q_{ij}} \leq \frac{w^2_{ij}}{2} B_j$. 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

$$\frac{\partial R}{\partial s_{ij}}(q_{ij}') = \frac{\partial c}{\partial s_{ij}}(s_{ij}', q_{ij}') \tag{40}$$

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 $\frac{\partial^2 R}{\partial s_{ij} q_{ij}} < \frac{\partial^2 c}{\partial s_{ij} q_{ij}}$. The latter violates the assumption of this proposition, and so $s_{ij}' > s_{ij}$. An similar argument applies when increasing $q_{ij}'$. \hfill \Box
A.3 Proof of Proposition 3.3

Proof. First, the assumption that $D^2 \pi_{ij}^Q$ is negative semidefinite and that $c_{ij}$ is strictly convex guarantees that there's a unique solution to both of the problems (fixing $s_{-ij}$ and $q_{-ij}$)

$$
\begin{align*}
\max_{s_{ij} \in [\underline{s}, \bar{s}]} & \quad \pi_{ij}^Q(s_j, q_j) \\
\min_{s_{ij} \in [\underline{s}, \bar{s}]} & \quad c_{ij}(s_{ij}, q_{ij})
\end{align*}
$$

Problem A

$$
\begin{align*}
\max_{q_{ij} \in [0, 1]} & \quad \pi_{ij}^Q(s_j, q_j) \\
\min_{q_{ij} \in [0, 1]} & \quad c_{ij}(s_{ij}, q_{ij})
\end{align*}
$$

Problem B

for all $i \in j$. In any equilibrium, every participant is solving Problem A, or every participant is solving Problem B. Otherwise, there would be at least one participant not maximizing $\pi_{ij}$. Let $(s_j^B, q_j^B)$ be the a tuple of vectors such that the elements of the vectors solve Problem B for all $i \in j$, and similarly define $(s_j^A, q_j^A)$. I will show that equilibrium exists, and it is always one of these tuples.

$(s_j^B, q_j^B)$ is an equilibrium when there is no $i \in j$ such that $i$ is better off choosing $(s_{ij}^A, q_{ij}^A)$ while others choose $(s_{-ij}^B, q_{-ij}^B)$. In other words, the cost-minimizing equilibrium exists when no participant is so influential (high $w_{ij}$) with low enough marginal costs such that it’s still optimal for that participant to push the entire ACO to earn shared savings.

Suppose there is a participant with such characteristics, and $(s_j^B, q_j^B)$ is not an equilibrium. What’s left to establish is that there is at least one such $(s_j^A, q_j^A)$ that is an equilibrium. To see this, consider the first order conditions to Problem A for all agents:

$$
\begin{align*}
\frac{w_{ij}^2 B_j Q_j^A}{2} & = c_{ij,1}(s_{ij}^A, q_{ij}^A) \\
\frac{w_{ij}^2 B_j S_j^A}{2} & = c_{ij,2}(s_{ij}^A, q_{ij}^A)
\end{align*}
$$

where $c_{ij,1}$ reflects differentiation with respect to the first element. Note that since $c_{ij}$ is strictly
convex, $c_{ij,1}$ and $c_{ij,2}$ are strictly increasing and so inverse functions in a given argument exist:

$$c_{ij,1}^{-1} \left( \frac{w_{ij}^2 B_j Q_j^A}{2}, q_{ij}^A \right) = s_{ij}^A$$  \hspace{1cm} (43)

$$c_{ij,2}^{-1} \left( \frac{w_{ij}^2 B_j S_j^A}{2}, s_{ij}^A \right) = q_{ij}^A$$  \hspace{1cm} (44)

First, note that if $c_{ij}$ is quadratic, $c_{ij,1}^{-1}$ and $c_{ij,2}^{-1}$ are linear, and so a unique equilibrium exists. If $c_{ij,1}^{-1}$ and $c_{ij,2}^{-1}$ are otherwise non-linear, consider the mapping $\Psi_j : \mathbb{R}^{n_j} \times [0,1]^{n_j} \rightarrow \mathbb{R}^{2n_j}$

$$\Psi_j \left( s_{j}^A, q_{j}^A \right) = \begin{bmatrix} c_{ij,1}^{-1} \left( \frac{w_{ij}^2 B_j Q_j^A}{2}, q_{ij}^A \right) - s_{ij}^A \\ c_{ij,2}^{-1} \left( \frac{w_{ij}^2 B_j S_j^A}{2}, s_{ij}^A \right) - q_{ij}^A \end{bmatrix}_{i \in j}$$  \hspace{1cm} (45)

Clearly, zeros to the function $\Psi_j$ are equilibria. To show that a unique zero exists, I’ll use the inverse function theorem and show the Jacobian of $\Psi_j$ has full rank at $\left( s_{j}^A, q_{j}^A \right)$. First, note in the diagonal entries of $D\Psi_j$ are all $-1$. Next, if the $i$th row of $D\Psi_j$ is odd, then any odd column’s element in that row is zero. If the $i$th row is even, then any even column’s element in that row is zero. Therefore, no row is a linear combination of the others, and $D\Psi_j$ has full rank. \hfill \Box

A.4 Proof of Proposition 8.1

Proof. First, consider the second order derivative of $E_R$,

$$\frac{\partial^2 E_R}{\partial s_{ij} s_{ij}'} (S_j, Q_j) = -w_{ij}^2 w_{ij} B_j E_Q(Q_j) \left[ \frac{1}{\sqrt{W_j^{(2)}} \sigma_S} + \frac{S_j (S_j - \xi)}{W_j^{(2)}} \frac{s_j^A}{\sigma_S} \phi \left( \frac{S_j - \xi}{\sqrt{W_j^{(2)}} \sigma_S} \right) \right].$$  \hspace{1cm} (46)
The sign of this equation depends entirely on the term in the square brackets. Rearranging terms, we have

\[ S_j \left( S_j - S_j \right) < \sigma S \sqrt{W_j^{(2)}} \Rightarrow \frac{\partial^2 E_R}{\partial s_{ij} \partial s_{ij'}} (S_j, Q_j) > 0 \]

Since \( S_j > 0 \), 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 \( \sigma S \sqrt{W_j^{(2)}} / S_j \). 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 \( \{(s^*_{ij}, q^*_{ij})\}_{i \in j} \) 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. \( \square \)

### B Influence weights \( w_{ij} \)

I’ve defined influence weights \( \{w_{ij}\}_{i \in j} \) such that

\[
\sum_{i \in j} w_{ij} s_{ij} = S_j \quad \sum_{i \in j} w_{ij} q_{ij} = Q_j \quad (47)
\]
where $\sum_{i \in j} w_{ij} = 1$. Note that for participant savings contributions $s_{ij}$ have to have a definition analogous to that of $S_j$, we would have

$$S_j = \frac{BE_j - E_j}{BE_j} = \frac{\sum_{i \in j} BE_{ij} - \sum_{i \in j} E_{ij}}{\sum_{i \in j} BE_{ij}} = \sum_{i \in j} w_{ij} \frac{BE_{ij} - E_{ij}}{BE_{ij}} = \sum_{i \in j} w_{ij} s_{ij}$$  \hspace{1cm} (48)$$

where $BE_j$ and $E_j$ are the benchmark expenditure and expenditure of ACO $j$ (both real quantities observed in data) and $BE_{ij}$ and $E_{ij}$ are the benchmark expenditure and expenditure of participant $i$ in ACO $j$ (both theoretical quantities). Thus, a definition of $w_{ij}$ consistent with the above is $w_{ij} = \frac{BE_{ij}}{BE_j}$, or simply participant $i$’s share of ACO benchmark expenditure. Intuitively, this means that a very influential participant $i$ in ACO $j$ will have a relatively large share of expected expenditure on assigned beneficiaries.

In data, I measure $w_{ij}$ as shares of expenditure for each type of provider within an ACO. To be specific, suppose provider $i$ has type $t$. Then,

$$w_{ij} = \frac{\text{Total Spending by type } t}{\text{(Total # of } i \text{ with type } t) \times (\sum_t \text{Total Spending by type } t)}$$  \hspace{1cm} (49)$$

The numerator and both terms in the denominator are observed for the general types $t \in \{\text{Individual Provider, Non-Individual Provider}\}$.

This measure of $w_{ij}$ has two important requirements. First, it requires that providers of the same type have similar shares of overall expenditure within an ACO. This is likely the case, since ACOs tend to be predominantly hospital based or group practice based. Second, this measure requires that the ratio $BE_{ij}/BE_j$ is close to the ratio $E_{ij}/E_j$, since $w_{ij}$ as defined in Equation 49 is the latter ratio.
C Computation of Equilibrium and Net Income

To compute predicted values of $S_j^*$ and $Q_j^*$, I solve the system of equations in Equations 15 and 16 given an estimate of $\theta_2$. Since equilibrium is symmetric, this means $s_{ij}^* \equiv S_j^*$ and $q_{ij}^* \equiv Q_j^*$ for all $i \in j$. Systems analogous to Equations 15 and 16 are solved to find symmetric equilibria in the counterfactual exercises. In the event two equilibria exist, I assume the equilibria played is one where the sum of profit across participants is greater. There are no cases where profit is equal for two equilibria (though it’s theoretically possible).

My estimate of net income is then

$$\hat{y}_j = \text{Earned Shared Savings of ACO } j - n_j \left[ c \left( s_{ij}^*, q_{ij}^*; X_{j}^{\text{perf}}, \hat{\theta}_2 \right) - c \left( \bar{s}_{ij}, \bar{q}_{ij}; X_{j}^{\text{perf}}, \hat{\theta}_2 \right) \right].$$

(50)

D Exit Logit

Columns (3) and (4) of Table 11 show raw coefficient estimates and marginal effects for the logit model

$$\text{exit}_{jt+1} = 1 \left\{ \nu_0 + \nu_1 \hat{y}_{jt} + \nu_2 1 \{ \hat{y}_{jt} > 0 \} + \nu_3 \text{age}_{jt} + \psi' X_{jt}^{\text{perf}} + \varepsilon_{jt+1} \right\}$$

(51)

None of the elements in $\psi$ are significant, so they are suppressed from output. I also show the result when net income $\hat{y}_j$ is replaced with an ACO’s Earned Shared Savings, which is just income as opposed to net income. Note that when ACOs fail to earn shared savings, they have a 0.15 higher probability of exiting. Otherwise, dollar increases in earnings don’t significantly impact exiting decisions. ACOs in their final agreement period have a 0.13 higher probability of exiting.
Table 11: Logit of ACO Exit

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned Shared Savings</td>
<td>-0.00334</td>
<td>-0.000288</td>
<td>(0.0115)</td>
<td>(0.000986)</td>
</tr>
<tr>
<td>$1{\text{Earned Shared Savings} &gt; 0}$</td>
<td>-1.430**</td>
<td>-0.123**</td>
<td>(0.501)</td>
<td>(0.0441)</td>
</tr>
<tr>
<td>$\hat{y}_{jt}$</td>
<td>-0.00703</td>
<td>-0.000614</td>
<td>(0.0141)</td>
<td>(0.00123)</td>
</tr>
<tr>
<td>$1{\hat{y}_{jt} &gt; 0}$</td>
<td>-1.712**</td>
<td>-0.150**</td>
<td>(0.565)</td>
<td>(0.0498)</td>
</tr>
<tr>
<td>age3</td>
<td>1.557***</td>
<td>0.134***</td>
<td>1.475***</td>
<td>0.129***</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
\(\hat{y}_{jt}\) and Earned Shared Savings are in units of $100,000.

\[p < 0.10, \quad * p < 0.05, \quad ** p < 0.01, \quad *** p < 0.001\]

E LASSO and Elastic Net for Overall Quality Score

I use both the Least Absolute Shrinkage and Selection Operator (LASSO) and Elastic Net method to compute which sub-measures of the overall quality score explain changes in the overall quality score. Formally, this takes the following steps:

1. Let ACO quality score take the form: \(Q_j = \chi_0 + \sum_{m=1}^M \chi_m Q_{jm}\), where \(Q_{jm}\) is the \(m\)th sub-measure and \(\{\chi_m\}_{m=0}^M\) are parameters to be estimated.

2. Elastic Net coefficients are given by

\[
\{\hat{\chi}_m\}_{m=0}^M = \arg \min_{\{\chi_m\}_{m=0}^M} \sum_{j=1}^J \left( Q_j - \chi_0 - \sum_{m=1}^M \chi_m Q_{jm} \right)^2 + \lambda \left[ \frac{1 - \alpha}{2} \sum_{m=0}^M \chi_m^2 + \alpha \sum_{m=0}^M |\chi_m| \right]
\]

where \(\lambda > 0\) is a regularization parameter and \(\alpha \in [0,1]\) weights regularization on the \(L^1\)-norm of coefficients (relative to the \(L^2\)-norm). LASSO coefficients are given in the special case
when this problem is solved with $\alpha = 1$. Selection of $\alpha$ and $\lambda$ are done by cross-validation. This is a method where for a given $\lambda$ (or $\alpha$), coefficients are computed for a subsample of the data, and then out-of-sample fit is computed for the complement of the subsample. See Abadie & Kasy (2017) and Burlig et al. (2019) for more details. Elastic Net is favorable to LASSO when regressors are highly correlated. Since this is clearly the case here, Elastic Net will be my specification of choice, but I present the results to both.

Table 12 presents the results of both specifications.
Table 12: **Regularized Regressions of Overall Quality Score on Quality Sub-Measures**

<table>
<thead>
<tr>
<th>Sub-measure (Percentile 0-100)</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACO-2. CAHPS: How Well Your Providers Communicate</td>
<td>0.0310</td>
<td></td>
</tr>
<tr>
<td>ACO-5. CAHPS: Health Promotion and Education</td>
<td>0.314</td>
<td>0.337</td>
</tr>
<tr>
<td>ACO-6. CAHPS: Shared Decision Making</td>
<td>0.391</td>
<td>0.382</td>
</tr>
<tr>
<td>ACO-9. Ambulatory Sensitive Conditions Admissions: Chronic Obstructive Pulmonary Disease or Asthma in Older Adults (AHRQ Prevention Quality Indicator (PQI) #5)</td>
<td>-1.259</td>
<td>-1.142</td>
</tr>
<tr>
<td>ACO-10. Ambulatory Sensitive Conditions Admissions: Heart Failure (AHRQ Prevention Quality Indicator (PQI) #8)</td>
<td>-2.422</td>
<td>-2.560</td>
</tr>
<tr>
<td>ACO-11. Percent of PCPs who Successfully Meet Meaningful Use Requirements 0.134</td>
<td>0.141</td>
<td></td>
</tr>
<tr>
<td>ACO-13. Falls: Screening for Future Fall Risk</td>
<td>0.0256</td>
<td>0.0243</td>
</tr>
<tr>
<td>ACO-14. Preventative Care and Screening: Influenza Immunization</td>
<td>0.0312</td>
<td>0.0288</td>
</tr>
<tr>
<td>ACO-15. Pneumonia Vaccination Status for Older Adults</td>
<td>0.0280</td>
<td>0.0244</td>
</tr>
<tr>
<td>ACO-16. Preventive Care and Screening: Body Mass Index (BMI) Screening and Follow Up</td>
<td>0.0852</td>
<td>0.0883</td>
</tr>
<tr>
<td>ACO-17. Preventive Care and Screening: Tobacco Use: Screening and Cessation Intervention</td>
<td>0.0236</td>
<td>0.0195</td>
</tr>
<tr>
<td>ACO-18. Preventive Care and Screening: Screening for Clinical Depression and Follow-up Plan</td>
<td>0.0476</td>
<td>0.0487</td>
</tr>
<tr>
<td>ACO-27. Diabetes Mellitus: Hemoglobin A1c Poor Control</td>
<td></td>
<td>-0.171</td>
</tr>
<tr>
<td>ACO-30. Ischemic Vascular Disease (IVD): Use of Aspirin or Another Antithrombotic</td>
<td></td>
<td>0.103</td>
</tr>
<tr>
<td>ACO-33. Angiotensin-Converting Enzyme (ACE) Inhibitor or Angiotensin Receptor Blocker (ARB) Therapy – for patients with CAD and Diabetes or Left Ventricular Systolic Dysfunction (LVEF&lt;40[1em] ACO-12. Medication Reconciliation Post-Discharge</td>
<td></td>
<td>0.0401</td>
</tr>
<tr>
<td>Constant</td>
<td>6.160</td>
<td>8.456</td>
</tr>
</tbody>
</table>

| $R^2$                                                | 0.840  | 0.841  |
| $\alpha$                                            | 0.6842 | 1      |
| $\lambda$                                           | 0.1517 | 0.1159 |

The parameter $\lambda$ is found via cross validation in (1) and (2).

The parameter $\alpha$ is found via cross validation in (1) and set equal to 1 in (2).
References


Frandsen, B., Powell, M., & Rebitzer, J. B. 2017. Sticking points: Common-agency problems and contracting in the u.s. healthcare system..


