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**Welfare Analysis Incorporating a Structural
Entry-Exit Model: A Case Study of Medicare HMOs**

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Abstract

Should the government subsidize entry to promote competition? In theory, free entry does not guarantee the socially optimum number of entrants. In differentiated product markets, free entry can result either in excessive or insufficient entry. In this paper I propose an empirical framework to address this issue with a case study of the Medicare HMO market for 2003 and 2004. I perform counterfactual welfare simulations with different entry conditions and with different government payment rates to HMOs. The results indicate that uniformly raising the payment rate lowers national welfare, which supports the government's efforts to contain the payment rate in my sample

years. A comparison of the cases with and without entry and/or market power indicates that this welfare loss does not come from additional entry, but instead the oligopolistic market structure and market distortion from the payment rate subsidy. The number of entrants is likely to be insufficient.

1 Introduction

Should the government subsidize entry to promote competition? In theory, free entry can lead to "too many entrants" under general conditions in homogeneous product markets. In differentiated product markets, the direction of bias is unclear. Consider, for example, a price subsidy to attract more entry in order to promote competition in a differentiated product market. New entrants enhance consumer surplus through more intensive competition — lower prices, better product quality, and giving more choices. On the other hand, new entry lowers social welfare by duplicative set-up costs and "business stealing" from incumbents. The price subsidy affects welfare even without entry — producers' profits and consumer surplus increase but there is market distortion. It is an empirical task to quantify these effects and to determine whether the government can achieve higher social welfare by encouraging entry. In this paper I propose an empirical framework with a case study of Medicare HMOs.

The US Medicare program has experienced many reforms and adjustments over the past decade[1]. One of the primary political concerns has been how to capitalize on private health insurance plans in Medicare to address the program's financial condition and to expand

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[1]Medicare is the federal entitlement program that provides comprehensive health insurance coverage to individuals age 65 and older and to certain disabled people.

beneficiary coverage options. Under the current Medicare program, the majority of private health plans are Medicare Health Maintenance Organizations (HMOs), and participating HMOs receive a monthly payment for each enrollee from the federal government. The payment is set by the government for each county, and it affects HMO's entry-exit decisions and, in turn, social welfare.

I perform a welfare analysis of the Medicare HMO program, by taking the following two significant characteristics of this market into consideration. First, this is a differentiated product market. Firms compete not only in price and quantity, but also in the characteristics of their products. This also results in apparent HMO heterogeneity from differentiated services, different cost structures, and various sizes. Second, market competition among the private plans has been designed by the government to address the program's financial condition and to expand beneficiary coverage options. Thus, how the government's expenditures affect private plans' entry-exit decisions and social welfare is a policy concern.

I advance the entry literature by specifying profit functions in more detail than is typical in the literature. I develop my model as follows: (1) firm heterogeneity in product characteristics and cost is explicit, (2) the estimated demand is embedded in profit functions, and (3) the price setting game is specified as the second stage in the entry-exit game and both stages are estimated together. This structural estimation strategy is advantageous in dealing with the HMO heterogeneity. More importantly, this structural specification allows me to perform counterfactual simulations in differentiated product markets, which is beyond the scope of previous models. For example, a change in payment rates first affects the cost

structure of HMOs. The supply side model gives us the re-optimized entry-exit and price decisions of HMOs. This in turn changes beneficiaries' decisions, which gives us the new equilibrium market shares, and, then, new consumer surplus, HMO profits, and government expenditure changes. This empirical framework is applicable to other differentiated product markets, to quantify the welfare effects of subsidies, taxes, entry regulations, or other competition policies.

Table 1: Overview of the Empirical Framework

Step of Estimation	Inputs	Outputs
1. Medicare health plan demand	Data for actually operating plans: market share and characteristics of plan and county	Demand parameters Consumer surplus Marginal costs for actual entrants
2. Marginal cost regression	Marginal costs for actual entrants County and plan characteristics Estimated demand parameters	Marginal costs for hypothetical potential entrants
3. Profit function with entry game	Data for all potential entrants: entry decision, marginal cost, county and plan characteristics Estimated demand parameters	Estimated parameters of profit function HMO profits
4. Counterfactual simulations	An exogenous change All estimated parameters	New consumer surplus, profits, gov. savings

All estimations are at the plan-county-year level.

My empirical strategy is as shown in Table 1. First, I estimate a discrete choice demand

model of the Medicare health plan market. The consumer surplus is calculated using these results. Second, I use the estimated demand parameters and assumptions on firms' price-setting behavior to recover the health plans' marginal costs. Then, I regress recovered marginal costs of the actually operating HMO plans on plan- and county-specific covariates to obtain marginal costs of all potential entrants. Third, I estimate HMO profit functions with an entry game. The observed market structure and the inclusion of the demand model allow me to identify the level of fixed and variable profits, despite the lack of cost information. Finally, the entire framework together with estimated parameters allows me to perform counterfactual welfare simulations. All estimations are at the plan-county-year level. To make the estimation with a large asymmetric entry game feasible, I propose first in the entry literature the use of the GHK simulator in the maximum simulated likelihood method, claiming that the GHK simulator can be applied to estimation of sequential move games with simple modification.

My main findings are as follows. First, I estimate the national welfare gain of having private health insurance plans in Medicare. My results show that the net welfare gain in 2003 is 7.53 billion dollars. Next I perform counterfactual simulations with different payment rates. Overall, the results suggest that social welfare may decline as the payment rate increases. Uniformly raising the payment rate enhances consumer surplus and HMO profits, but both are offset by the increase in government expenses. This supports the government's efforts to contain the payment rate in my sample periods. Comparisons of the payment rate simulations with and without entry and/or market power indicate that the welfare loss

does not come from additional entry, but instead market distortion from the payment rate subsidy. The oligopolistic market structure also adversely affects welfare by keeping price cost margins high and equilibrium quantity below the social optimum, but the subsidy effect is three to six times larger than this market power effect. The number of entrants is still likely to be insufficient, which should be dealt with by the government by some other means.

2   Literature

In the literature of health plan demand, my demand model follows Town and Liu [2003] closely, using market share data with the nested Logit model (Berry [1994]'s approach) for welfare analysis. They find that the creation of the Medicare HMO program resulted in approximately $18.7 billion in consumer surplus and $52 billion in profits from 1993 to 2000. Their assumptions on the simple supply side model, however, seem to be restrictive in this industry[2]. Furthermore, without a structural entry model, counterfactual simulations they can perform are limited.

I advance their work by incorporating a structural entry-exit model, which is crucial in obtaining more detailed welfare estimates and performing various counterfactual simulations. On the other hand, the entry literature, in spite of recent rapid development, has not been well applied to the field of welfare analysis, due to conceptual and computational difficulties.

The framework used in my supply side model is among a series of "multiple-agent

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[2]For example, they assume common fixed costs across plans in each county and the amount of fixed costs is equal to the least profitable plan's variable profits.

qualitative-response" models introduced into the industrial organization literature to evaluate entry strategies and market competition (Bresnahan and Reiss [1987, 1990, 1991a, 1991b] and Berry [1992]). In these models, firms' strategies are represented by discrete decisions (e.g., enter/do not enter a particular market) and the goal of the econometrician is to estimate parameters of the profit functions by using a game theoretic model and data on the firms' observed decisions.

In the first series of the entry literature with multiple-agent qualitative-response models, firm heterogeneity was either not taken into consideration, or modeled in very restrictive forms, because of one of the largest issues in this literature – how to find a unique equilibrium or a unique *set of equilibria*. To guarantee certain equilibrium properties the researchers have specified the econometric setting in a very restrictive way such as homogenous product markets, symmetric games, simple reduced-form profit functions, and a homogeneous and infinite pool of potential entrants.

Computational burden is another difficulty in this literature. This is especially problematic if a researcher tries to introduce firm heterogeneity. Berry [1992] avoids this problem by introducing firm heterogeneity into a fixed cost part, thus, keeping his game symmetric. This seminal approach, however, does not allow competitive effects to depend on firm characteristics.

Facing these difficulties, various approaches are proposed. Mazzeo [2002] models firm heterogeneity as endogenous choice of location or product types. Seim [2001, 2004] proposes the use of incomplete information setting to alleviate computational burden. Ciliberto and

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Tamer [2004] pursue a more flexible model of entry, heterogeneity and player identities, by not making point identifying assumptions on equilibrium selection. None of these attempts, nevertheless, fully solve computation and/or equilibrium issues. They still use reduced-form profit function and cannot fully introduce firms' heterogeneity.

The distinction of my model from the existing models in the entry literature stems from two major motivations: fully incorporating firm heterogeneity and structural combination of the demand and supply sides. In my model, the number and size of potentially entering HMOs vary across markets, with different profit structures. Structural combination of the demand and supply sides brings a significant advantage – counterfactual simulations by extrapolation. This structural approach is helpful in analyzing how various policy changes affect entry-exit, product variety, competition and each player's welfare.

I am not the first to nest demand into an entry model. Reiss and Spiller [1989] estimate the demand and supply of airline services simultaneously, but this challenging work is done for carefully selected small homogenous product markets. Berry and Waldfogel [1999] explicitly model profit functions in the broadcasting industry with price and quantity and allowing firms to vary across fixed costs, but the firms are symmetric in the game and the product market does not have product differentiation[3].

Berry and Waldfogel [1999] also precede my work in applying a structural entry model to welfare analysis. They attempt to quantify social inefficiency from free entry, a classical debate in the theoretical industrial organization literature. As discussed in Mankiw and

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[3]Listeners' demand for broadcasting is modeled as a discrete choice demand, but this is not the industry's product.

Whinston [1986] and Spence [1976], in a homogeneous product setting, firms' fixed costs of entry can lead privately optimal decisions by firms to excessive entry. Additional entry would decrease prices, which would expand consumer surplus, but, at the same time, entry by a firm reduces the market shares of other firms ("business stealing"), and this entry may lead to an inefficient replication of fixed costs. In differentiated product markets, however, the direction of bias is unclear, because consumers value variety from entry. Berry and Waldfogel [1999]'s specification of the radio station is basically homogeneous. No attempt has so far been made to quantify the inefficiency in differentiated product markets.

3   The Industry

The current Medicare program features private health plans under contract to the federal government (the Centers for Medicare and Medicaid Services, or CMS) in addition to a government-administrated fee-for-service "traditional" Medicare plan (hereafter traditional Medicare plan). Currently, the former part of the program is referred to as the Medicare Advantage (formerly Medicare+Choice) program and private health plans are referred to as Medicare Advantage plans. Medicare beneficiaries have a choice between the traditional Medicare plan and private plans offered in their areas.

Under the current Medicare Advantage program, several types of coordinated care plans are eligible to participate. Among others, HMOs (Health Maintenance Organizations) are dominant players in the program. Table 2 shows that HMOs' enrollment share within the private health plans is 85 percent in 2004. While I use most Medicare Advantage plan types

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Table 2: The Number of HMO Plans and their Market Share in 2004

	Number of Plans	Enrollment	Share
HMO (Health Maintenance Organizations)	145	4,684,304	85%
PPO (Preferred Provider Organizations)	41	119,110	2%
Other Medicare Advantage types	70	266,247	5%
Other prepaid plan types	44	428,833	8%
Total prepaid plans	300	5,498,494	100%
Entire Medicare eligibles		42,992,077	

Source: Medicare Managed Care Contract Report and SCP data

in the demand estimation, I focus my supply side behavioral model on HMOs because a) the other types' behavioral patterns may differ from HMOs' and b) HMOs are the dominant players in the program. Hence, I estimate profits only for HMOs. Throughout this research, the presence of non-HMO types and their characteristics are treated as exogenous.

A Medicare HMO works as follows. A participating HMO receives a monthly payment for each enrollee from the CMS, the amount of which varies across counties (but is common to all HMOs in a county). In return, the HMO is responsible for providing all covered services and takes full financial responsibility for the actual costs generated. HMOs may provide additional benefits beyond minimum services required by Medicare, such as outpatient prescription drug benefits. They are also allowed to charge monthly premiums to enrollees. Since 2003, the premium can be "negative" in the form of a Medicare premium rebate.

4   Data

Most of the data sources are from the government, either through the CMS website or directly from CMS staff. The three main data sources are the following: (1) the Enrollment data at

the county-plan level, (2) the Monthly Report data, and (3) the Plan Benefit Package data (PBP data). For the detailed discussion and description of the data, see Maruyama [2006].

4.1 The Unit of Observation

In my empirical framework, the unit of observation is a plan-county-year. I follow the CMS in considering the county the market definition. The time points I use are the years 2003 and 2004. These years are relatively stable compared to prior and later years[4].

In the CMS data files, there is a clear distinction between *organization*, *plan* (or *contract*, as the CMS sometimes calls it), and *product* (or *plan*, as the CMS sometimes calls it). The *organization* is the governing body: for example Pacificare, Aetna, Humana, etc. In the Medicare program, each organization may enter into one or more *plans* (or *contracts*) for the purpose of delivering health care. Each of these plans is assigned a unique contract number by the CMS. Finally, within each plan, enrollees may select a particular *product* — that is, a particular benefit package with unique payments, copays, premiums and service counties. I focus this study on the plan level analysis. The reason I use the plan level is that many important variables such as county enrollment are reported at the plan level. There is practically no data at the organization level in the CMS. Also the plan level analysis works favorably in analyzing both consumers' choice behavior and HMOs' profit maximization problems together[5]. Product level information is aggregated to the plan level in each county,

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[4]Before this period, the market experienced a huge exodus of HMOs, and this period is sufficiently before the implementation of the Medicare Prescription Drug Improvement and Modernization Act in 2006.

[5]In theory the product level analysis might be reasonable when the focus is on demand estimation because consumers are more likely to choose a product than a plan or an organization. However, HMOs are likely to

by choosing the product with the largest enrollment as the representative product. For ambiguous cases, I average the variables across products, but such cases are rare.

4.2 The Sample Population

I choose the observations used in this research as follows.

Omitted Plan Types With various types of Medicare Advantage plans, I exclude the plan types which are regarded as not open to regular Medicare beneficiaries, such as PACE (Program of All-Inclusive Care for the Elderly) plans and long-term care Demonstration plans. Since HMOs are dominant in the program, after dropping these different type plans about 97% of the entire Medicare Advantage enrollment remains in the data set.

Choosing *Operating* Plans Next, at the plan-county-year level, I determine *actually operating plans* and drop the other observations. In the CMS Enrollment data files, individual enrollees are assigned to counties according to the enrollees' residence. This implies that for many counties there is an unrealistically high number of health plans with very low enrollment. To be regarded as an actually operating plan and be included in my data set, a plan-county-year has to satisfy both of the following: (1) the plan-county-year is in the plan's service counties under the contract to the government and (2) it has at least 50 enrollees.

A very small number of observations with technical data problems are also dropped. After dropping these inappropriate observations, I recalculate the market size by subtracting the

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maximize their profits at the plan or organization level. For example, the plan application process, marketing, and cost managing are typically at the plan or organization level.

dropped observations' enrollment from the original numbers of Medicare eligibles. This completes the data set for the demand estimation. For the supply side estimation, I create and add hypothetical, potentially operating plan observations.

Creating Potential Entrants In my supply side model, all the potentially operating plans play a one-shot entry game in each year. The pool of potential entrants consists of *hypothetical* potential entrants as well as the actually operating HMOs observed in the data.

Table 3: Where the Medicare Plans Come from?

| | Incumbency status in previous year | | | | |
Sample year	1	2	3	4	Total
2003	894	17	66	10	987
2004	961	17	37	5	1,020

1 ... Incumbency in the same county
2 ... Incumbency not in the same county but in the same MSA
3 ... Incumbency not in the same MSA but in the same state
4 ... Brand-new Medicare Advantage plans
The unit of observation: a plan-county-year

I limit my entry model to entrants that are operating in other areas in the same state or the same MSA[6]. This means my framework excludes a) entrants from outside the state or MSA and b) brand-new entrants from the commercial sector. The potential bias due to this exclusion, however, seems to be minimal as a first order approximation. First, no entry from outside the state or MSA is observed during my sample periods. Second, although each Medicare Advantage plan has its main entity in the commercial sector, not many brand-new entrants from the commercial sector occur during my sample periods. Table 3 shows

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[6]Note that there exist multi-state MSAs. Entries from outside the state but in the same MSA are allowed in my model.

where the observations in my data set come from. For 2004, for example, there are 1,020 plan-county-year observations in the data set. Out of 1020, five plans are brand-new.

The pool of potential entrants consists of the following six types: (1) plans that operate actually in the county in the year, (2) plans that operate in the same MSA in the year, (3) plans that operate in the same state in the year, (4) plans that operate in the county in the previous year, (5) plans that operate in the same MSA in the previous year, and (6) plans that operate in the same state in the previous year. Thus, in my data set for the supply estimation, observations that qualify as one of (2) to (6) but not (1) are created and included as hypothetical potential entrants[7]. I create the characteristic variables of the newly created potential entrants as follows. The plan level characteristics are the same as the original plan. For the product level characteristics, I pick up the product with the largest enrollment under the plan and copy its characteristics to the created hypothetical observations.

4.3 Payment Rates and Other Variables

Payment Rates The payment rate data in the original CMS data sets is the standardized, payment base in each county. The actual payment for a particular enrollee is determined by certain formulae which take demographic and risk factors into consideration. In my data set, I estimate and use the average of actual payment rates so that it reflects the demographic and risk factors in the county, by using demographic and risk factor information as well as

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[7]As a result of adding the hypothetical entrants to the data set, the supply data set has many counties with no observed entrant. These counties are kept in the sample so as to avoid unwanted selection bias and make use of information value from the fact that no entry happens.

the CMS's payment formulae.

FFS Per Capita Costs FFS per capita costs are used to calculate government expenditure changes. Also, standardized FFS per capita costs are used in the marginal cost regression. This standardization is made to get rid of the demographic differences across counties and to make the per capita costs directly comparable across counties. Following the CMS, I standardize FFS per capita costs by using average demographic factors of the entire eligibles in each county.

Characteristics Variables The PBP data has a great amount of detailed information about the additional benefits a product offers. To summarize this information, I perform a factor analysis. Based on its results, I create six benefit quality composite variables.

4.4 Sample Size and Summary Statistics

Table 4 shows the sample size for the demand estimation. The welfare estimates are calculated based on this population. Table 5 shows the sample size of the HMO entry estimation. Table 6 shows descriptive statistics of selected variables. A comparison of the average and standard deviation of monthly premiums and payment rates indicates that the payment from the government is the primary source of revenues, but private plans take various strategies in regard to their premiums.

Table 7 shows distribution of the observations and average market size by the number of actual entrants in a county. The distribution suggests that, although the number of

Table 4: The Sample Size — Demand Data Set

	# plan-county	# plans	# HMO plans	# markets
2003	1,478	196	133	829
2004	1,811	207	138	938
Total	3,289	207	138	948

Table 5: The Sample Size — Entry Estimation Data Set

	# plan-county	(enter)	(not enter)	# plans	# markets
2003	9,617	997	8,620	133	2,574
2004	9,927	1,094	8,833	138	2,501
Total	19,544	2,091	17,453	138	2,630

Table 6: Descriptive Statistics of Selected Variables

	average	(2003)	(2004)	std.dev.	min	max
Medicare eligibles	61,299	64,462	58,717	110,339	370	1,046,829
plan enrollees	3,060	3,339	2,833	7,715	50	142,050
plan market share	0.063	0.066	0.061	0.070	0.0002	0.447
monthly premium	51.3	58.9	45.0	47.5	-62.6	189.0
payment rate	549.4	530.7	564.7	91.1	296.7	1067.5

The number of observations: 3289 plan-county-years

Numbers of monthly premium and payment rate are in $

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Table 7: Sample Distribution and Average Market Size by the Number of Actually Operating Plans in each County

# actually operating plans in a county	# plan-counties demand data		# plan-counties supply data		average number of eligibles	
	2003	2004	2003	2004	2003	2004
0			5,581	5,386		
1	500	497	1,853	1,860	15,550	13,583
2	342	456	993	1,167	38,214	32,183
3	246	339	543	635	56,121	47,116
4	168	184	301	367	70,448	58,611
5	75	130	125	180	97,730	65,552
6	30	84	43	146	141,533	130,593
7	21	21	40	40	230,569	234,969
8	40	24	63	41	187,832	157,267
9	36	36	49	56	309,351	261,881
10	20	40	26	49	686,134	513,123
Total	1,478	1,811	9,617	9,927		

Table 8: Average Monthly Out-of-Pocket Premiums and Government Payment Rates by the Number of Actually Operating Plans in each County

# operating plans	Premium		Payment Rate	
	2003	2004	2003	2004
1	59.8	59.4	493.2	527.6
2	54.8	40.8	507.7	536.9
3	59.8	40.8	550.7	582.2
4	63.2	38.5	541.3	574.7
5	39.8	46.7	535.1	579.3
6	69.5	29.4	568.2	598.3
7	21.6	12.8	642.5	700.6
8	26.1	0.7	706.1	760.3
9	10.1	-0.2	667.7	725.2
10	0.0	-1.2	739.1	698.3
Total	59.8	43.8	508.8	544.1

Market share weighted averages

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competing plans in a market varies across markets, the majority of the observations are from monopolistic or oligopolistic markets. The table also shows that larger counties accommodate more private plans. Table 8 shows average monthly premium and government payment rate by the number of actual entrants in a county. The table shows that in more competitive counties, payment rates are higher and premiums are lower.

5   Econometric Specifications

5.1   The Demand

A Medicare beneficiary chooses a Medicare plan every year by comparing the utility from each plan in his "choice set" and picking the plan with the highest expected utility[8]. The beneficiary's "choice set" is defined as the set of the traditional Medicare plan and private plans that have declared the beneficiary's county of residence to be within their official service counties. Utility is derived from health plan characteristics such as premiums, benefits, and so on. Here are some notations:

M : Year-Markets(year-counties), $m = 1, ..., M$

J : Medicare Advantage plans, $j = 1, ..., J_m$

   If $j = 0$, it means the traditional Medicare plan (the outside option).

I_m :   Medicare Beneficiaries, $i = 1, ..., I_m$.

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[8]In reality beneficiaries are permitted to switch plans or return to the traditional Medicare plan at the end of every month.

Beneficiary i's utility from plan j in year-market m is denoted as

$$
\begin{aligned}
u_{ijm} &= x'_{jm}\beta - \alpha P_{jm} + \xi_j + \xi_{MSA} + \Delta\xi_{jm} + \varepsilon_{ijm} \qquad (1)\\
&\equiv \delta_{jm} + \Delta\xi_{jm} + \varepsilon_{ijm}
\end{aligned}
$$

where x_{jm} is a vector of observed characteristics and a constant, $\xi_j + \xi_{MSA} + \Delta\xi_{jm}$ is a scalar contribution of the unobserved characteristics, and P_{jm} is the premium of plan j in year-market m. δ_{jm} is the "mean utility". I assume that beneficiaries can observe all the health plan characteristics and that there are some characteristics not observable to econometricians. Without loss of generality, normalize the error term as $E[\varepsilon_{ijm}] = 0$. A health plan sets the price depending not only on x_{jm} but also $\xi_j + \xi_{MSA} + \Delta\xi_{jm}$, so $\xi_j + \xi_{MSA} + \Delta\xi_{jm}$ and P_{jm} are not independent. To alleviate this endogeneity problem, I apply fixed effects to plans and selected MSAs, which are represented by $\xi_j + \xi_{MSA}$. Thus, $\Delta\xi_{jm}$ is the first-differenced demand shock[9].

For the traditional Medicare plan,

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u_{i0m} = \xi_0 + \Delta\xi_{0m} + \varepsilon_{i0m}.
$$

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[9]County fixed effect dummies are not used because many counties appear in the data set with only one observation. By the same token, fixed effect dummies are not used for small MSAs. I apply MSA fixed effects only to MSAs with at least ten observations.

Following previous studies, I normalize this as

$$u_{i0m} = \varepsilon_{i0m}.$$

This normalizations is appropriate for my welfare calculation, because it measures the consumer surplus gain of Medicare Advantage plans relative to the traditional Medicare[10].

Following the majority of previous research, I assume a nested Logit error. The group structure is the private plan group against the traditional Medicare plan. Thus, my assumption allows substitution among private plans to differ from substitution between private plans and the traditional Medicare plan. The market share of plan j is derived as:

$$
\begin{aligned}
s_{jm} &= s_{j|gm} \cdot s_{gm} \\
&= \frac{\exp\left(\frac{1}{1-\sigma}\delta_{jm}\right)}{D_m^{\sigma} \cdot \left[1 + D_m^{(1-\sigma)}\right]},
\end{aligned}
\tag{2}
$$

where σ represents for the similarity within the private plan group and

$$D_m \equiv \sum_{j|private,m} \exp\left(\frac{1}{1-\sigma}\delta_j\right).$$

The correlation within a group is possible through this parameter. As σ goes to one, the within-group correlation becomes to one, and when $\sigma = 0$, this model is reduced to the

multinomial Logit model.

When the market share data is used, this model can be simply estimated by transforming to a linear form as follows (see Berry [1994]):

$$\ln s_{jm} - \ln s_{0m} = x'_{jm}\beta - \alpha P_{jm} + \xi_j + \xi_{MSA} + \sigma \ln s_{j|gm} + \Delta \xi_{jm} \tag{3}$$

for $j = 1, ..., J_m$. If one has valid instruments, this equation is estimated by the regular instrumental variable method.

5.2 HMO's Behavioral Model

5.2.1 The Game Specification

In each market, there are J_m^{pot} potentially operating HMO plans. Each county can accommodate zero, one, or more than one HMO plan. At the beginning of each year, both incumbent plans and hypothetical potential entrants in each market play the following game. The game consists of two stages, an entry game and a price setting game. The entry game is assumed to be a sequential move game. The second stage game is a typical simultaneous-move Bertrand price-setting game. Only HMOs which choose "enter" play the second stage game. If a plan chooses not enter, it receives zero profit from the county. Entering plans receive some profits according to the profit functions which are defined below.

The game is assumed to be a public information game, because private information models are difficult to be estimated when the game is highly asymmetric. The number of

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potential entrants, each plan's characteristics and random shocks in their profits, and other information are all commonly known by all players. The only thing unknown to all the plans when they make decisions is the random shock in the demand, $\Delta\xi_{jm}$[11].

I employ a sequential move entry game. This guarantees existence of a unique subgame perfect Nash equilibrium, even for highly asymmetric games with firm heterogeneity and structural profit functions. There is no guarantee that this assumption will be realistic, but a simultaneous game is no less *a priori* than a sequential game is. Mazzeo [2002] estimates his model under several game structure assumptions. Einav [2003] endogenizes the order of decisions. These papers show that differences from employing different game settings are likely to be relatively small.

For the sequential game, I assume the decision order as follows. Among the entire potentially operating HMOs in a market, the incumbents move first. Among the incumbents, the proximity of incumbency matters. The incumbency is defined as (1) the previous year presence in the county, (2) the previous year presence in the same MSA, and (3) the previous year presence in the same state. Thus, the HMOs which operate in the county in the previous year make their decision first. Within the same incumbency class, HMOs make decisions in the order of their entire enrollment size. If incumbent HMOs and larger HMOs have to announce their service area changes earlier, this assumption is likely.

I use the subgame perfect pure strategy Nash equilibrium (SPNE) concept. I assume

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[11]This technical assumption is necessary to keep the estimation simple. If I assume $\Delta\xi_{jm}$ is known to everybody, it means HMOs can predict their sales perfectly and make their decisions based on the values of $\Delta\xi_{jm}$. However, the values of $\Delta\xi_{jm}$ can not be obtained for the hypothetical entrant observations, which brings another complication to the model.

profit functions to be additively separable across counties. An SPNE in a county is obtained when (1) all entering firms are profitable with their optimized prices and (2) all firms that do not enter expect non-positive profits from entry. Each HMO's entry-exit strategy in county m is represented by $y_{j,m}$, which takes "0" if plan j does not enter and "1" if enters. The equilibrium solution can be calculated by the backward induction algorithm, i.e. by deciding the optimal strategies from the most downstream decision nodes to the upstream nodes in the game tree.

5.2.2 Estimation of Marginal Costs

Before estimating the entry model, I estimate marginal costs. The estimation of marginal costs for the observations which actually enter relies on the first order condition of the second-stage price-setting game. The first order condition in market m can be written as

$$s_{jm}(P_{jm}, X_{jm}) + (P_{jm} + \text{Payment Rate}_m - MC_{jm})\frac{\partial s_{jm}}{\partial P_{jm}} = 0, \tag{4}$$

for $j = 1, ..., J_m^{enter}$, where *payment rate* means the government payment rate to HMOs per enrollee, J_m^{enter} is the number of actual entrants in the county, and s_{jm} is the market share of plan j. This equation can be solved for MC_{jm} by writing

$$
\begin{aligned}
P_{jm} + \text{Payment Rate}_m - MC_{jm} &= -\left(\frac{\partial s_{jm}}{\partial P_{jm}}\right)^{-1} \cdot s_{jm} = \frac{-1}{\eta_{jjm}} \tag{5} \\
&= \frac{1-\sigma}{\sigma}\frac{1}{\left(1 - \sigma s_{j|gm} - (1-\sigma)s_{jm}\right)}.
\end{aligned}
$$

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To calculate MC_{jm} by using (5), I use fitted shares for s_{jm} and $s_{j|gm}$, instead of observed shares, by the assumption that $\Delta\xi_{jm}$ is unknown to plans when they make decisions[12].

For hypothetical entrant observations, the lack of observed P_{jm} and s_{jm} requires MC_{jm} to be extrapolated. This extrapolation is done by a reduced-form linear regression, in which I choose independent variables that are likely to be exogenous or predetermined, such as non-profit status, chain affiliation, and market characteristics variables.

5.2.3 The Profit Function

I assume the profit to be additively separable across counties, so each plan's profit maximizing decisions can be reduced to county level optimization problems[13]. I assume the following local profit function for plan j in county m:

$$
\begin{aligned}
\pi_{jm}(X_{\cdot m}, \varepsilon_{jm}, y_m; \gamma) &= [P_{jm}(y_m, X_{\cdot m}) + \text{Payment Rate}_m - MC_{jm}] \quad (6) \\
&\quad \cdot Q_{jm}(y_m, X_{\cdot m}, P_{\cdot}(y_m, X_{\cdot m})) + X_{jm}\gamma + \varepsilon_{jm} \\
&\equiv VP(y_m, X_{\cdot m}) + X_{jm}\gamma + \varepsilon_{jm},
\end{aligned}
$$

where γ is a parameter to be estimated and ε_{jm} is idiosyncratic shocks to plan j in market m, observed by all the firms ex-ante, but unobserved by the econometrician. The square bracket part is per enrollee profits. $VP()$ denotes variable profits. HMOs are assumed to incur fixed

---

[12]This treatment is necessary to keep everything consistent and make the estimation procedure well-behaved.

[13]I also implicitly assume the additive separability across plans for an organization, although some large HMOs may offer more than one plan at the same area. Ideally, I would like to relax this assumption, but it is difficult to implement and beyond the scope of this article.

costs at the county level, which is the sum of the last two terms. A plan makes a decision by comparing payoffs from alternatives (i.e. enter/do not enter). Combined with the Subgame-Perfect Nash Equilibrium solution concept, this specification provides the market equilibrium configuration, y_m^{*}[14]. For the explanatory variables, X_{jm}, I choose market-specific variables and relatively exogenous or predetermined plan-specific variables, such as non-profit status, chain affiliation, and years of experience. I exclude variables that are likely to be correlated with ε_{jm}, such as benefit coverages, regarding this specification as a reduced form.

To estimate this profit function, (6), the (partial) equilibrium prices and quantities, $P_{\cdot m}$ and $Q_{\cdot m}$, need to be calculated, given a market configuration, y_m[15]. First I calculate $P_{\cdot m}$ by solving the system of the first order conditions in the price-setting game, (4). Given the estimated demand parameters, (α, β, σ), and the values of $MC_{\cdot m}, X_{\cdot m}$, Payment Rate$_m$, and y_m, there are J_m^{enter} equations and J_m^{enter} unknowns. Due to the numerical feature of the discrete choice model, however, the price function, $P_{jm}(X_{\cdot m}, \text{Payment Rate}_m, MC_{\cdot m})$, does not have a closed form solution. I numerically solve the equation system for P_{jm} by the following numerical algorithm. The first order condition, (4), can be written as:

$$P_{jm} = -s_{jm}\left(P_{\cdot m}, X_{\cdot m}\right) \cdot \left(\frac{\partial s_{jm}\left(P_{\cdot m}, X_{\cdot m}\right)}{\partial P_{jm}}\right)^{-1} - \text{Payment Rate}_m + MC_{jm},$$

---

[14]For comparison, the previous literature typically uses the following reduced-form payoff function: $\pi_{jm}(X_{\cdot m}, \varepsilon_{jm}, y_m; \gamma, \zeta) \equiv X_{jm}\gamma + g(y_{-j,m}, X_{\cdot m}, \zeta) + \varepsilon_{jm}$, where γ and ζ are parameters to be estimated. The second term $g(\cdot)$ is a *competitive term*, which reflects the dependency of the profit on the other plans' decisions or characteristics in the market. "$-j$" denotes the subvector that excludes component j. The level of profits is not identified.

[15]The word "equilibrium" here means the Nash Equilibrium in the price-setting game, given y_m.

for $j = 1, ..., J_m^{enter}$. The following numerical iteration gives the numerical solution for P_{jm}.

$$P_{jm}^{T+1} = -s_{jm}\left(P_{.m}^T, X_{.m}\right) \cdot \left(\frac{\partial s_{jm}\left(P_{.m}^T, X_{.m}\right)}{\partial P_{jm}}\right)^{-1} - \text{Payment Rate}_m + MC_{jm}, \qquad (7)$$

for $j = 1, ..., J_m^{enter}$ and $T = 0, 1, 2, ...$ For the initial values of P_{jm}^T, the observed values of

P_{jm} are used. It turns out that this numerical iteration usually converges in a decent time[16].

After P_m is calculated, I can use the estimated demand equation, (3), to calculate Q_m. Once

$P_{.m}$ and $Q_{.m}$ are obtained given y_m, the profit function, (6), can be expressed as a linear

combination of numbers and the unknown parameters, γ.

5.3 The Estimation Algorithm

I specify the components unobserved to the econometrician as

$$\varepsilon_{jm} = \omega \eta_{jm} + \rho \eta_m. \qquad (8)$$

η_{jm} and η_m are assumed to be independent of $X_{.m}$, and distributed i.i.d. standard normal

across plans and markets. The correlation of the unobservable ε_{jm} across plans in a given

market is then ρ^2.

In principle, the estimation relies on the maximum likelihood estimation method. Denote

---

[16]Again note that the demand shock, $\Delta\xi_{jm}$, is consistently excluded from all of these calculations of the HMO behavioral model. The share function, $s_{jm}()$, is the fitted share and MC_{jm} is calculated as such. If I use MC_{jm} calculated with $\Delta\xi_{jm}$, the performance of this numerical iteration is sometimes poor.

observed market configuration as y_m^o. The maximum likelihood problem can be written as

$$\widehat{\theta}_{ML} = \arg\max_\theta \left\{ \frac{1}{M} \sum_{m=1}^{M} \ln \Pr\left[y_m^o = y_m^*(X_{\cdot m}; \theta)\right] \right\}, \tag{9}$$

where θ is the vector of model parameters, (γ, ω, ρ).

The probability in the likelihood, however, does not have an analytical form solution due to multidimensional integrals. Following the literature, I use the maximum simulated likelihood method (MSL). However, simple discontinuous simulators, which are typically used in the literature and require many random draws, are practically infeasible, because my data set has at most sixteen players in a county and the use of the backward induction technique makes each likelihood evaluation very expensive. To simulate the probabilities in the likelihood with a small number of random draws, I extend the GHK (Geweke-Hajivassiliou-Keane) simulator. The GHK simulator is an unbiased simulator with continuity and differentiability with respect to parameters and is one of the most accurate and computationally fast simulators. The original GHK simulator, however, allows interactions across j only through the disturbance structure, so has not been used in the entry or other game theoretic empirical literature. I modify this simulator to fit to my model, by claiming the GHK simulator can be harmonized with sequential games by exploiting its recursive conditioning structure. For the details, see Appendix B.

5.4 Welfare Measures and Simulations

The net welfare gain of having Medicare Advantage plans in Medicare is given by

$$\Delta W = (CS_{w/MAPlans} - CS_{w/oMAPlans}) - \tag{10}$$

$$(G_{w/MAPlans} - G_{w/oMAPlans}) + \text{MA plan profits,}$$

where CS_x denotes aggregated consumer surplus attributable to program x, and G_x denotes government expenditures. Not only beneficiaries and suppliers but also the government enjoys the welfare gain from the program. This gain comes from the per enrollee cost difference between the fixed payment rate from the government to private plans and the expected per capita costs in the traditional Medicare plan that the government would have to pay without the Medicare Advantage plans. I calculate $G_{w/oMAPlans}$ by using the average cost data of traditional Medicare. I use HMO profits instead of the profits of the entire Medicare Advantage plans, due to the difficulty of dealing with non-HMO plans' behavior.

Following McFadden [1981], annual expected consumer surplus from the Medicare Advantage program can be derived as:

$$\Delta CS_m \equiv (CS_{w/MAPlans} - CS_{w/oMAPlans}) \tag{11}$$

$$= I_m \cdot \frac{12}{\widehat{\alpha}} (1 - \widehat{\sigma}) \ln \left[\sum_{j=0}^{J_m^{ent}} \exp \left(\frac{\widehat{\delta}_{jm} + \Delta \xi_{jm}}{1 - \widehat{\sigma}} \right) \right].$$

The welfare effect is assumed to be zero. In the data set, all the premiums and payment

rates are defined on a monthly basis, so the calculated surplus is multiplied by twelve.

Counterfactual simulations use the same framework as above. The only difference is that I exclude $\Delta\xi_{jm}$ from all calculations in the simulations. This is because $\Delta\xi_{jm}$ can be calculated only for observed entrants as residual. In the simulations, ΔCS_m is calculated by:

$$\Delta CS_m \text{ without } \Delta\xi_{jm} = I_m \cdot \frac{12}{\widehat{\alpha}}(1-\widehat{\sigma})\ln\left[\sum_{j=0}^{J_m^{ent}}\exp\left(\frac{\widehat{\delta}_{jm}}{1-\widehat{\sigma}}\right)\right].$$

Due to the convexity of the function in the square bracket, consumer surplus is understated without $\Delta\xi_{jm}$. By the same token, the predicted number of HMO enrollees is also understated, which affects the aggregated numbers of government gain, G_x, and HMO profits as well. In the simulations, we should focus on the change in numbers, not the level.

6   Results

6.1   Parameter Estimation

Tables 9, 10, and 11 show the variables and their definitions used in this research. The last three columns in each table show in which estimation of demand, supply, or marginal cost a variable is used.

Demand Estimation   To estimate demand, instruments are necessary for dealing with the potentially endogenous variables in the demand equation (3) — monthly premium, P_{jm}, and within-group share, $\ln(s_{j|gm})$; these two variables may be correlated with the plan demand

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Table 9: Definitions of Plan Level Variables and Estimations Used (Demand, Supply, or Marginal Cost Estimation)

Variable name	Definition	D	S	MC
entire enrollees	Total enrollees of the plan over its entire service areas (in 1,000)			X
expyear	Years in business since the first HMO Medicare enrollee	X	X	X
expyear sq	Squared expyear	X		
d_nonprofit	Dummy variable: not-for-profit organizations		X	X
d_chain	Dummy variable: national chains		X	X
d_group model	= 1 if the plan is a group model HMO (The omitted category is network, mixed, and other models)		X	X
d_staff model	= 1 if the plan is a staff model HMO		X	X
d_IPA model	= 1 if the plan is an IPA model HMO		X	X
d_DEMO plan	Dummy variable: DEMO plans			X
d_cost plan	Dummy variable: cost contract HMOs			X
d_cost missing	Dummy variable: cost contract HMOs w/ missing data			X
d_PPO plan	Dummy variable: PPO plans			X
d_PFFS plan	Dummy variable: PFFS plans			X
d_PSO plan	Dummy variable: PSO plans			X
d_POS	Dummy variable: HMOPOS			X

shock, $\Delta\xi_{jm}$. As I use the fixed-effect approach, the identification of parameters comes from within-plan and within-MSA changes in the instruments.

I construct instruments using three strategies. The first set of instruments is the number of hospitals per 10,000 residents, the number of hospital beds per 1,000 residents, and the number of general practice medical doctors per 1,000 residents in 2001. These variables are valid instruments because they affect the plans' relative bargaining power with providers, and thus their cost structure and the number of competitors. Second, I use the characteristics of competing plans in a county. This approach is traditional in the literature of

Table 10: Definitions of Plan-County Level Variables and Estimations Used (Demand, Supply, or Marginal Cost Estimation)

Variable name	Definition	D	S	MC
s_{jm}	Plan j's market share in market m	X		
s_{0m}	The market share of the traditional Medicare plan	X		
$\ln s_{j|gm}$	$\ln s_{jm} - \ln s_{jm|MAPlan}$	X		
monthly premium	Monthly premium in \$ (Medicare premium not included)	X		
OOPC	Monthly out-of-pocket cost in \$			X
# products in plan	The number of products the plan offers in the market	X		
ben_drug	A composite score: optional benefits in outpatient prescription drug	X		
ben_edu	A composite score: optional benefits in health education/wellness	X		
ben_physical	A composite score: optional benefits in routine physicals	X		
ben_periph1	A composite score: optional benefits in preventive and comprehensive dental, chiropractic, and acupuncture	X		
ben_periph2	A composite score: optional benefits in eye exams, eye wear, hearing exams, and hearing aids	X		
ben_screen	A composite score: optional benefits in screenings	X		
avg # competitor	Average number of competitors in the other markets served by the plan	IV		
competitor npo	The number of competing NPO plans in the market	IV		
competitor chain	The number of competing national-chain plans in the market	IV		
competitor IPA	The number of competing IPA model plans	IV		
competitor Group	The number of competing Group model plans	IV		
competitor Staff	The number of competing Staff model plans	IV		

"IV" means the variable is used in the estimation as an instrument.

Table 11: Definitions of County Level Variables and Estimations Used (Demand, Supply, or Marginal Cost Estimation)

Variable name	Definition	D	S	MC
payment rate	CMS monthly payment rate per enrollee for parts A&B		X	
demo factor	Demographic factors (e.g. institutional status, age) to adjust the payment rate (the higher, the more costly)			X
demo factor HMO	Demographic factors for HMO enrollees			X
risk factor HMO	Risk factors for HMO enrollees (e.g. disease group, social factors) to adjust the payment			X
FFS per capita cost	Average fee-for-service monthly cost per enrollee			
Std FFS pc cost	FFS per capita cost standardized by demographic factor		X	X
medigap premium	Monthly Medigap premium in $			X
# hospital 01	# of hospitals per 10,000 residents in the county	IV	X	X
# hospital bed 01	The # of hospital beds per 1,000 residents in the county	IV	X	X
hospital expenditure 01	Total reported facility expenditures per 1,000 residents in $1,000 in the county			X
inpatient days 01	Total Medicare inpatient days in 1,000 days			X
# medical doctor 01	The number of general practice M.D.s (non-fed) per 1,000 residents in the county	IV	X	X
HMO penet rate 98	Estimated (HMO enrollment / total population)	X		X
eligibles	Medicare eligibles in the count (in 1,000)			X
d_MSA	Dummy variable for counties: an MSA county		X	
d_county medium	Dummy variable for counties: 5,000 < # eligibles < 50,000		X	
d_county large	Dummy var for counties: 50,000 < # eligibles < 150,000		X	
d_county huge	Dummy variable for counties: 150,000 < # eligibles		X	
d_year 2004	Year 2004 dummy variable		X	X

"IV" means the variable is used in the estimation as an instrument.

product-differentiated market demand (e.g. Bresnahan [1987], Berry [1994])[17]. This is valid

if competitors' entry-exit decisions and changes in product characteristics are uncorrelated

with changes in $\Delta \xi_{jm}$. Specifically, I choose indicator variables for not-for-profit ownership,

chain affiliation, and two HMO network types (IPA and Group models), as instruments,

which are supposed to be relatively fixed and predetermined. The last instrument I use is

the average number of competitors in the other markets in which the plan operates. This

use of the panel structure of data is a strategy similar to that of Hausman [1997] and Nevo

[2001]. Private Medicare plans set premiums typically not for individual counties but for

each product, so the premium in a county is likely to be correlated with the competitive

environment in the plan's other service counties. $\Delta \xi_{jm}$ is specific to the market, so it is

likely to be uncorrelated with this instrument. In the end, I have eight instruments for

two endogenous variables. The detailed results of the first stage regression are shown in

Appendix A. Overall, these instruments have reasonable coefficients.

Table 12 shows the results of the demand estimation. The significant coefficient of $\ln s_{j|gm}$

implies the imposed grouping structure is relevant. Table 13 shows price elasticities, mar-

ginal costs, and per-capita consumer surplus that are calculated using the estimated demand

parameters[18]. The regular price elasticity is not defined, because in the Medicare HMO pro-

gram, charging a non-positive premium is a common practice. Table 13 shows two alternative

measures of price sensitivity — the semi-elasticity, $\eta_{jm} \equiv (\partial s_{jm}/\partial P_{jm}) \cdot (1/s_{jm})$ and the price

---

[17]Dafny and Dranove [2005] also use this approach in the demand estimation of Medicare HMOs.

[18]As discussed in the model section, the calculation of these values can be done in one of two ways,
depending on whether I include $\Delta \xi_{jm}$. If $\Delta \xi_{jm}$ is in calculation, the obtained values will be more precise, but
the values calculated without $\Delta \xi_{jm}$ are necessary for the later use to make the entire estimation framework
consistent.

Table 12: Nested Logit Demand with Fixed Effects

Dependent variable:	Nested Logit			
$\ln(s_{jm}) - \ln(s_{0m})$	w/o IV		w/ IV	
ln $s_{j|gm}$	0.641	(.014)	0.326	(.056)
monthly premium	-0.0023	(.0008)	-0.0082	(.0057)
ben_drug	0.184	(.062)	0.319	(.069)
ben_edu	-0.133	(.146)	-0.268	(.167)
ben_physical	0.503	(.149)	0.458	(.166)
ben_periph1	0.493	(.195)	0.669	(.225)
ben_periph2	0.087	(.112)	0.122	(.124)
ben_screen	0.319	(.196)	0.419	(.234)
# products in plan	0.112	(.021)	0.168	(.027)
expyear	0.175	(.039)	0.127	(.049)
expyear sq	-0.008	(.002)	-0.008	(.002)
HMO penet rate 98	1.802	(.137)	1.200	(.195)
constant	-4.632	(.281)	-5.468	(.423)
# of Obs	3286		3286	
Adjusted R^2	0.831		0.796	

elasticity from producers' point of view, $\eta_{jm} \cdot (P_{jm} + \text{Payment Rate}_m)$ [19]. The latter elasticity is well-defined because premiums are much smaller than payment rates. With values less than -1.0, the estimated elasticity does not contradict with profit-maximizing firms.

Before estimating the entry model, I make the fitted values of marginal costs to the hypothetical entrants. The results are provided in Appendix A.

Entry Estimation Table 14 shows the results of the HMO entry estimation. The estimated coefficients represent each variable's contribution to fixed profits. ω and ρ are the parameters for the error components, η_{jm} and η_m, respectively. The estimated values indicate market-specific shocks account for 30% of the variance of error components and plan-

---

[19] If the semi-elasticity is -0.02, it means a \$1 increase in the monthly premium is expected to reduce the plan's enrollment by 2%.

Table 13: Price semi-elasticity, marginal cost, and consumer surplus

$\Delta\xi_{jm}$	Mean	Std Dev	Min	Max
Own-price semi-elasticity (in 100%)				
Yes	-0.0095	0.0019	-0.0121	-0.0045
No	-0.0095	0.0017	-0.0121	-0.0058
Own-price elasticity for MA plans (in %)				
Yes	-5.729	1.649	-13.204	-2.196
No	-5.766	1.588	-12.334	-2.294
Marginal costs (monthly in $)				
Yes	490.5	105.2	172.1	1128.1
No	492.1	104.5	167.4	1121.4
Consumer surplus (per capita, monthly in $)				
Yes	74.8	109.1	0.03	683.1
No	57.8	86.7	0.16	527.6

obs = 3,289 plan-county-years (elasticities, marginal costs)
obs = 1,767 county-years (consumer surplus)

and market-specific shocks for 70%.

6.2 Welfare Analysis and Simulations

Table 15 summarizes the calculated net social welfare gain of the Medicare Advantage program. The net welfare gain is calculated from the above four components according to (10). The results show the net welfare gain in 2003 is 7.53 billion dollars; of this amount, consumer surplus accounts for 52%, HMO profits for 26%, and government net welfare gain for 23%.

These values turn out to be reasonable when compared to the results of Town and Liu [2003], which is shown in the last column. The differences can be explained by the fact that the period between their sample years and mine experienced a drastic decrease in the

Table 14: Entry Estimation

Dependent variable: County level fixed profits in $ 1,000,000		
expyear	-0.007	(.012)
d_nonprofit	0.237	(.121)
d_chain	-0.175	(.119)
d_Group model	1.418	(.364)
d_IPA model	1.121	(.357)
d_Staff model	1.027	(.404)
Std FFS per capita cost	-0.007	(.001)
# hospital 01	-1.591	(.319)
# hospital bed 01	-0.028	(.028)
# medical doctor 01	0.994	(.394)
d_MSA	1.927	(.184)
d_county medium	1.303	(.185)
d_county large	3.362	(.311)
d_county huge	4.414	(.451)
year 2004	0.463	(.130)
constant	-4.352	(.528)
ω	3.120	(.134)
ρ	2.048	(.134)
# of potential entrants	19,544	
# of markets	5,075	
# of simulation draws	40	

number of participating HMOs and in payment rates[20].

Payment Rate Simulations I perform welfare simulations with different hypothetical payment rates. In the simulations, a change of the payment rate first affects the cost structure of HMOs, so they re-optimize their entry-exit and price decision. This then changes the

---

[20]Another possible explanation for the difference in HMO profits may be the difference in the entry models. While I use a structural entry-exit model, they assume common fixed costs in each county, which is equal to the variable profits of the least profitable plan in the county. If a plan with larger variable profits has larger fixed costs, their approach overestimates the total profits.

Table 15: Welfare Results

	2003	2004	2000 (Town&Liu)
Consumer surplus	3,881	3,963	4,061
HMO profits	1,945	2,120	8,757
Net government gain	1,753	2,885	
CMS payment to Medicare Advantage plans			
	34,147	37,825	41,726
Expected FFS payment without Medicare Advantage plans			
	35,900	40,711	
Net social welfare gain	7,531	8,937	
Consumer surplus w/o $\Delta \xi_{jm}$	3,110	3,378	
HMO profits w/o $\Delta \xi_{jm}$	1,897	2,089	
Net government gain w/o $\Delta \xi_{jm}$	1,432	2,695	
Net social welfare gain w/o $\Delta \xi_{jm}$	6,439	8,161	

Annual, in million dollars

beneficiaries' decision, which leads to different consumer surplus. Based on the recalculated market shares, HMO profits and net government gain are also recalculated.

Table 16 shows the results with four different payment rates. For example, uniformly raising the payment rate by 50 dollars leads to a decrease in the average premium and increases in the enrollment and entrants. In turn, this leads to: a) an increase in consumer surplus by 2.53 billion dollars (81.5%), b) an increase in HMO profits by 0.15 billion dollars (7.7%), and c) a decrease in government net welfare gain from +1.43 billion to -1.53 billion dollars. As a result, net welfare gain decreases from 6.44 billion dollars to 6.15 billion dollars (-4.4%). Overall, my results suggest that social welfare may decline as the payment rate

Table 16: Payment Rate Simulation for 2003

Payment rate:	−$50	−$25	±$0	+$25	+$50
Consumer surplus	1,786	2,358	3,110	4,257	5,644
HMO profits	1,785	1,837	1,897	1,963	2,042
Net government gain	2,922	2,332	1,432	219	-1,533
CMS payment to HMO	19,997	24,725	30,366	38,135	46,648
Expected FFS payment	22,919	27,057	31,798	38,354	45,116
Net social welfare gain	6,493	6,527	6,439	6,440	6,153
Enrollment: Total w/ $\Delta\xi_{jm}$			4,934,982		
Enrollment: Total w/o $\Delta\xi_{jm}$	3,162,194	3,730,062	4,383,119	5,242,051	6,143,967
Enrollment: HMO w/ $\Delta\xi_{jm}$			4,501,071		
Enrollment: HMO w/o $\Delta\xi_{jm}$	2,717,071	3,310,675	3,989,339	4,873,359	5,799,228
# plan*mkt (Total)	1,442	1,459	1,478	1,493	1,507
# plan*mkt (HMO)	961	978	997	1,012	1,026
Avg premium (HMO)	97.12	73.08	49.23	25.82	2.63

All welfare measures are in million dollars, calculated without $\Delta\xi_{jm}$

increases. Uniformly raising the payment rate enhances consumer surplus and HMO profits, but both are offset by the increase in government expenses. This gives cause to support the government's efforts in my sample years to contain the payment rate.

Table 17 shows where new HMO entry occurs when the payment rate is raised by 50 dollars. The counties are classified by their number of incumbent plans, which is shown in the first column. The following columns show the number of counties in the data, the average number of simulated entrants, and the ratio of these two columns. While entry is observed in all county types, it is more likely to occur in larger counties.

Table 17: Where New Entries Occur with Payment Rate Raised by $50

Initial # of HMO	2003			2004		
plans in a county	# mkts	# entrants	ratio	# mkts	# entrants	ratio
0	1997	7.9	0.4%	1918	7.3	0.4%
1	357	7.0	2.0%	362	5.7	1.6%
2	146	5.3	3.6%	181	5.6	3.1%
3	55	3.9	7.1%	49	2.6	5.3%
4	19	1.1	5.9%	27	1.3	4.9%
5	2	0.5	26.0%	3	0.4	11.7%
6	3	0.7	21.7%	2	0.4	20.0%
7	3	0.6	20.0%	3	0.8	25.0%
8	5	1.5	29.4%	5	1.1	21.0%
9	2	0.5	22.5%	3	0.4	11.7%
Total	2,589	28.9	1.1%	2,553	25.4	1.0%

Non-HMO plans are not included.

Simulating Entry By turning the entry and exit response on and off in a payment simulation, I can confirm the welfare impact of entry-exit competition. Table 18 compares the simulation results for the cases with and without entry when the payment rate is raised by 50 dollars. The case without entry gives fewer HMO enrollees compared to the case with entry. The consumer surplus gain is compressed by 0.76 billion dollars (24.6%) and the HMO profit gain is boosted by 0.01 billion dollars (0.7%). These signs are consistent with standard theories. Figure 1 summarizes all the results so far.

The fact that the welfare gain is larger with entry indicates that excessive entry is not the source of the welfare decrease. If excessive entry is not the source of the welfare decrease, what causes the welfare decrease? There are two possible sources of welfare decrease – HMO's market power and subsidy effect.

Figure 1: Payment Rate and Entry-Exit Simulation: Welfare
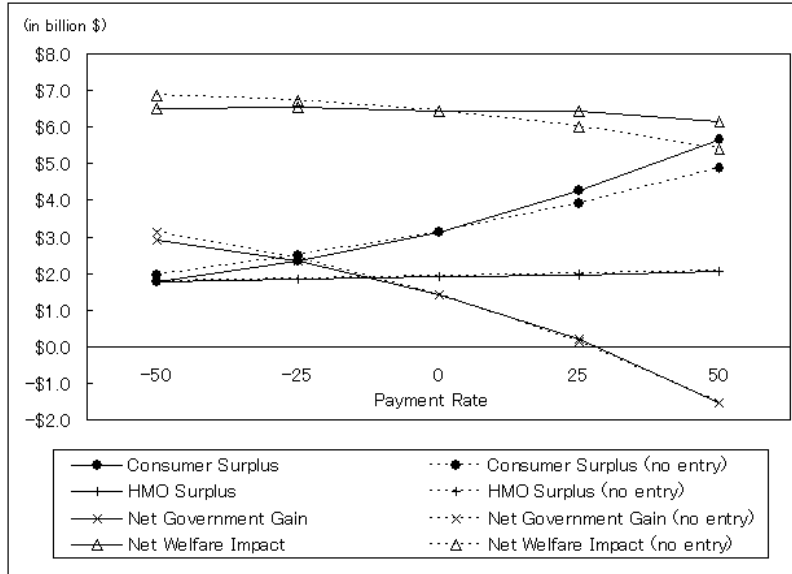
HMOs' Market Power One possible source of the welfare loss is HMOs' market power. To clarify this point, the average premium changes when the payment rate is raised by 50 dollars are shown in Table 19 for each type of county. The second and fourth columns show the results without entry, and the third and last columns show the results with simulated entry. Each plan sets its premium according to the first order condition, (5), with the price cost margin depending on its market power. The results in the case without entry clearly show that the market power decreases as the number of competing firms increases. While monopolists "bank" about 10% of the payment rate change through increased price-cost margins, when there are nine entrants, most of the payment rate increase goes to enrollees through premium reduction. This discrepancy is one source of the dead weight loss – firms'

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Table 18: Payment Rate and Entry Simulation for 2003

	±0	+$50 w/ entry	+$50 w/o entry
Consumer surplus	3,110	5,644	4,879
HMO surplus	1,897	2,042	2,056
CMS payment to HMO	30,366	46,648	42,295
Expected FFS payment	31,798	45,116	40,768
Net government gain	1,432	$-1,533$	$-1,527$
Net social welfare gain	6,439	6,153	5,409
Total enrollment	4,383,119	6,143,967	5,618,335
HMO enrollment	3,989,339	5,799,228	5,263,638
Available plan*mkt (total)	1,478	1,507	1,478
Available plan*mkt (HMO)	997	1,026	997

All numbers are calculated without $\Delta\xi_{jm}$

All welfare numbers are in million dollars

market power makes a production level below the social optimum[21].

New entry reduces the market power. The third and fifth columns in Table 19 show that the new entry slices off incumbents' market power. To see this point even more clearly, Table 20 shows the average payment rate changes in incumbents that face new entrants. The more concentrated the market is, the lower market premiums (the larger premium reduction) the market expects from entry.

Simulating Market Power The per enrollee payment from the government to HMOs can be seen as subsidy, and inappropriate level of subsidy is another possible source of the dead weight loss.

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[21]Concerning pass-through behavior of a firm with a cost advantage, see Besanko et al. [2001].

Table 19: Premium Changes in All Incumbents with Payment Rate Raised by $50

Initial # of HMO	2003		2004	
plans in a county	W/O entry	W/ entry	W/O entry	W/ entry
1	-44.98	-45.51	-44.37	-44.80
2	-46.83	-47.17	-46.83	-47.12
3	-47.60	-47.96	-47.57	-47.82
4	-48.04	-48.19	-48.16	-48.30
5	-48.07	-49.59	-48.12	-48.50
6	-49.02	-49.28	-48.91	-49.44
7	-49.15	-49.61	-49.10	-49.66
8	-49.24	-49.58	-49.21	-49.60
9	-49.26	-49.42	-49.25	-49.36

Average over plans and simulation draws.

Table 20: Premium Changes of Incumbents Facing Entry with Payment Rate Raised by $50

Initial # of HMO	With entry	
plans in a county	2003	2004
1	-75.97	-73.85
2	-57.53	-56.78
3	-53.96	-52.98
4	-50.49	-50.90
5	-54.72	-50.73
6	-53.44	-51.92
7	-53.53	-52.27
8	-52.34	-51.23
9	-49.98	-50.30

Average over plans and simulation draws.

To quantify these two possible sources of the dead weight loss, I attempt further welfare decomposition. The additional experiment simulation I perform here is designed as: (1) no entry simulation, and (2) each firm passes all the incremental payment along to its enrollees through premium reduction, i.e. new premiums are not solved by the price-setting game but instead are set $50 higher than the original premiums[22]. Suppose the following approximate decomposition holds in a payment rate simulation:

$$\Delta \text{Welfare} \approx \text{Entry Effect} + \text{Market Power Effect} + \text{Subsidy Effect}. \tag{12}$$

Now that I have the simulation results with and without entry, the last task is to decompose the right hand side of the following.

$$\Delta \text{Welfare} - \text{Entry Effect} \approx \text{Market Power Effect} + \text{Subsidy Effect}.$$

The market power simulation, in which I assume no entry effect and no market power effect, allows me to do this decomposition.

The results of this decomposition are shown in Table 21. The second column shows the total changes from the payment rate increase, which I have already discussed so far. The remaining three columns show the three individual effects, which sum up to the total effect.

In the table, all figures have reasonable signs[23]. Among the three effects, the subsidy

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[22]Note that I do not assume HMO's price cost margins are zero; I assume there is no room for them to exploit their market power for the $50 payment rate increase.

[23]The reason the market power effect on government gain is positive is that, at this level of payment rate, having more HMO enrollees worsens the government's net savings. It is beneficial for the government to

Table 21: Welfare Change Decomposition: Payment +$50

		Total Effect	Subsidy Effect	Market Power	Entry Effect
2003	Total Welfare	-285.3	-893.7	-135.9	$+744.3$
	Cons Surplus	$+2,533.6$	$+1,961.5$	-192.3	$+764.4$
	Prod Surplus	$+145.4$	$+154.7$	$+4.9$	-14.2
	Gov Savings	$-2,964.3$	$-3,010.0$	$+51.5$	-5.8
	Enrollment	$+1,819,889$	$+1,397,032$	$-122,733$	$+535,590$
	Premium	-46.60	-50.00	$+3.37$	$+0.03$
2004	Total Welfare	-432.0	-634.3	-160.8	$+363.0$
	Cons Surplus	$+2,254.2$	$+2,114.5$	-207.1	$+346.8$
	Prod Surplus	$+163.9$	$+166.5$	$+5.4$	-8.0
	Gov Savings	$-2.850.1$	$-2,915.3$	$+40.9$	$+24.3$
	Enrollment	$+1,677,539$	$+1,507,361$	$-136,846$	$+307,025$
	Premium	-46.29	-50.00	$+3.52$	$+0.19$

All welfare figures are in million dollars.

effect is dominant and the market power effect is the smallest. Although the payment increase significantly enhances consumer surplus both through providing more choices and lowering premiums, the costs the government incurs are larger.

7 Concluding Remarks

In this paper I develop an econometric model to perform welfare analysis of the Medicare HMO market, focusing on an entry game and a differentiated product demand system. The national welfare gain of the Medicare Advantage program is calculated and counterfactual simulations of the government payment rate are performed. Comparisons of the payment rate simulations with and without entry and/or market power indicate that the welfare loss

---

have fewer HMO enrollees even if it is because of HMOs' price-cost margins.

from a $50 payment rate increase does not come from excessive entry, but instead market distortion from the payment rate subsidy.

The empirical framework I develop has a potential for a broad range of further studies. First, this framework has potential to be applied to other industries. Whether the government should subsidize entry to promote competition will be an important policy question in many differentiated product markets. The empirical framework also provides insights for deeper understanding of an industry through various counterfactual simulations and welfare change decomposition. Endogenizing discrete product choice is another possible application of my framework, especially in markets where quality competition is policy makers' great concern. This extension is conceptually straightforward, though it might be computationally challenging.

On the other hand, several major caveats of the framework need to be clarified. I make no attempt to deal with dynamic optimization; I use a reduced model in this regard. There is no precommitment device or entry deterrence in the game. There is no strategic product proliferation; I assume additive separability, or no scale of economy, in profit functions across products as well as markets. These limitations remain for future study.

Appendix A: Additional Tables

Table 22 shows the results of the first stage regression in the demand estimation. Overall, the instruments have reasonable coefficients and significances.

Table 22: The 1st Stage IV Regression

Dependent variable:	ln $s_{j|gm}$		premium	
avg # competitor	-0.057		-0.445	
	(.068)		(1.22)	
competitor npo	-0.212	***	-5.276	***
	(.056)		(1.03)	
competitor chain	0.028		-6.520	***
	(.057)		(1.20)	
competitor IPA	-0.548	***	0.944	
	(.058)		(1.03)	
competitor Group	-0.272	***	0.189	
	(.033)		(.596)	
competitor Staff	-0.593	***	3.020	
	(.120)		(1.95)	
# hospital 01	1.811	***	3.774	
	(.568)		(9.964)	
# hospital bed 01	-0.003		0.005	
	(.004)		(.072)	
# of Obs	3286		3286	
R^2	0.769		0.920	

Notes: *denotes p<.1, **denotes p<.05, ***denotes p<.01

Heteroschedasticity consistent standard errors are used.

Other independent variables and fixed effects are also used.

Marginal Cost Regression   Table 23 shows the results of the marginal cost regression

for both marginal costs with and without $\Delta \xi_{jm}$. Since this estimation is reduced-form and

simply for extrapolation purpose, the estimated coefficients should be read as such.

Appendix B: Details on Estimation Method

B.1   Formal Setup

Notation   In this appendix, I follow the customary notation and change the subscript for

each market from m to $i = 1, ..., N$. In the maximum likelihood framework, each market is

Table 23: Marginal Cost Regression

Dependent variable:	MC with $\Delta \xi_{jm}$		MC without $\Delta \xi_{jm}$	
(OOPC - premium)	-0.130	(.023)	-0.126	(.023)
entire enrollees	-0.101	(.011)	-0.095	(.011)
expyear	-0.455	(.243)	-0.431	(.236)
d_nonprofit	18.00	(2.57)	17.62	(2.54)
d_chain	20.99	(2.42)	19.30	(2.37)
d_group model	-35.23	(4.17)	-34.61	(4.19)
d_staff model	-24.88	(5.79)	-25.39	(5.84)
d_IPA model	-25.85	(4.70)	-26.24	(4.69)
d_DEMO plan	29.76	(7.18)	29.95	(7.09)
d_cost plan	32.13	(4.75)	31.68	(4.53)
d_cost missing	-153.0	(9.43)	-152.4	(9.26)
d_PPO plan	0.81	(7.79)	-1.71	(7.64)
d_PFFS plan	-14.79	(4.79)	-16.70	(4.72)
d_PSO plan	-37.72	(14.3)	-38.45	(13.7)
d_POS	33.99	(4.61)	31.88	(4.58)
demo factor HMO	341.4	(22.0)	344.2	(21.7)
risk factor HMO	150.5	(10.2)	149.1	(10.1)
std FFS per capita cost	0.341	(.015)	0.344	(.015)
medigap premium	0.437	(.049)	0.439	(.048)
# hospital 01	2.788	(5.05)	2.75	(4.83)
# hospital bed 01	-0.357	(.402)	-0.166	(.408)
hospital expenditure 01	0.774	(.834)	0.714	(.890)
impatient days 01	0.033	(.012)	0.029	(.012)
# medical doctor 01	-10.41	(6.44)	-9.38	(6.29)
HMO penet rate 98	78.83	(9.57)	83.54	(9.30)
eligibles	-0.047	(.032)	-0.047	(.031)
year 2004	31.85	(2.22)	31.43	(2.18)
constant	-210.5	(28.2)	-214.1	(27.7)
# Obs	3289		3289	
R^2	0.818		0.823	

Heteroschedasticity consistent standard errors are used.

Plan and MSA fixed effects are included in the estimation.

the unit for which the individual likelihood is defined. Furthermore, the subscript for each market, i, is dropped for simplicity whenever no ambiguity would arise.

For a vector of indices $(1, ..., J)$, the notation "$< j$" denotes the subvector $(1, ..., j-1)$, "$\leq j$" denotes the subvector $(1, ..., j)$, and "$-j$" denotes the subvector that excludes component j. Thus, for a vector ε, $\varepsilon_{<j}$ is the subvector of the first $j-1$ components. For a matrix L, $L_{j,<j}$ denotes a vector containing the first $j-1$ elements of row j.

In the sequential move game, the order of subscript for firms $(1, 2, ..., J_i)$ comprises the reverse of the decision order in market i — in other words, firm J_i makes a decision first, firm 1 makes a decision last, and so on.

Strategies and Payoffs Firm j's strategy in market i is represented by $y_{j,i}$. This is an indicator variable that takes "0" if the firm does not enter and "1" if enters. The profits of entering firm j in market i is:

$$\pi_{ji}(X_{\cdot i}, \varepsilon_{ji}, y_{i,-j}; \gamma) \equiv VP(y_i, X_{\cdot i}) + X_{ji}\gamma + \varepsilon_{ji}. \tag{13}$$

The Equilibrium A subgame perfect pure strategy Nash equilibrium (SPNE) in a market is obtained when (1) all entering firms are profitable with their optimal prices and (2) all firms that do not enter expect non-positive profits from entry. Formally, an SPNE strategy in market i, (y_i^e), is any strategies that satisfy:

$$\pi_{ji}\left[X_{\cdot i}, \varepsilon_{ji}, y_{-j,i}^e\right] \geq 0, \text{if firm } j \text{ enters} \tag{14}$$

$$\pi_{ji}\left[X_{\cdot i}, \varepsilon_{ji}, \left(y^e_{>j,i}, y^*_{<j,i}(y^e_{>j,i}, y_{j,i}=1)\right)\right] \leq 0, \quad \text{if firm } j \text{ does not enter} \qquad (15)$$

for all $j = 1, ..., J_i$, where $y^*_{<j}(y_{\geq j})$ is the solution to the downstream subgame, i.e. the best responses of the downstream players given the upstream players' strategies. Given parameters γ, exogenous characteristics, X, and unobservables, ε_{ji}, the unique equilibrium solution always exists. Denote this solution, after dropping index i, as

$$y^*(X, \varepsilon; \gamma) \equiv \{y \text{ is the unique solution in the sequential move game with } X, \varepsilon, \gamma\}.$$

For any subgames of the entry game in a market, given $X, \varepsilon_{<k}, \gamma$, and the upstream firms' strategies, $y'_{\geq k}$, its unique solution is denoted as

$$y^*_{<k}(y'_{\geq k}) \equiv y^*_{<k}(X, \varepsilon_{<k}, y'_{\geq k}; \gamma).$$

The Error Terms The component unobserved to the econometrician is specified as

$$\varepsilon_{ji} = \omega \eta_{ji} + \rho \eta_i. \qquad (16)$$

η_{ji} and η_i are assumed to be independent of $X_{\cdot i}$, and distributed i.i.d. standard normal across firms and markets[24]. Unlike the previous studies, no normalization such as $\omega^2 + \rho^2 = 1$ is necessary because the level of profits is identified.

---

[24]This specification is not crucial for the use of the following estimation method. In literature, this framework of the GHK simulator encompasses more flexible error structures, such as multinomial probit, multivariate rank ordered probit, multiperiod Tobit, etc.

The Likelihood Function The estimation relies on the maximum likelihood estimation method. Denote the observed market configuration as y_i^o. The log likelihood function can be written as

$$\widehat{\theta}_{ML} = \arg\max_{\theta} \left\{ \frac{1}{N} \sum_{i}^{N} \ln \Pr\left[y_i^o = y_i^*(X_{\cdot i}; \theta)\right] \right\}, \tag{17}$$

where θ is the vector of model parameters, (γ, ω, ρ).

However, the probability in the likelihood does not have an analytical form solution due to the multidimensional integrals, and unless the dimension of the unobservables is very small the numerical calculation is infeasible. Hense, I rely on the maximum simulated likelihood (MSL).

B.2 The Modified GHK Simulator

The most straightforward simulator for the MSL is the crude frequency simulator, first proposed by Lerman and Manski [1981]. However, simple discontinuous simulators like this, which require many random draws, are practically infeasible, because my data set has at most sixteen players in a market and the use of the backward induction technique makes each likelihood evaluation very expensive. To simulate the probabilities with a small number of random draws, I rely on the GHK (Geweke-Hajivassiliou-Keane) simulator.

The GHK simulator is a smooth recursive conditioning simulator and is useful in many cases when the log-likelihood function involves high dimensional integrals with the multivariate normal distribution. The GHK algorithm draws recursively from truncated univariate

normals. It relies on the decomposition,

$$f(v_1, ..., v_J) = f(v_1)f(v_2|v_1)...f(v_{J-1}|v_{J-2}, ..., v_1)f(v_J|v_{J-1}, ..., v_1)$$

along with the fact that the conditional normal density can be written as a univariate normal. The GHK simulator produces probability estimates that are bounded away from 0 and 1. The estimates are continuous and differentiable with respect to parameters, because each contribution is continuous and differentiable. It is also an unbiased estimator of individual likelihood, $l(\gamma, \omega, \rho; y_i^o, X_{\cdot i})$. It has a smaller variance than the crude frequency simulator, because each element is bounded away from 0 and 1. Currently, the GHK simulator appears to be the most accurate simulator available for a given computation time[25].

Despite its advantages, the GHK simulator has so far mainly been used in the micro data context, and no previous work of "multiple-agent qualitative-response" models uses this type of simulator. This is because the original GHK simulator can only deal with the interactions across j through the disturbance structure, while in typical entry games, not only a firm's idiosyncrasy shock but also its decision affects the others' decisions. My applying the GHK simulator to the entry game relies on the sequential game assumption. In the sequential move game, a player cares only about its downstream players, as the upstream players' decisions are given for the player. This feature of the sequential game harmonizes the entry model

---

[25]For a starting point of GHK simulator and related methods, see Contoyannis et al. [2004]. A key intuition behind these excellent features is that the Cholesky triangularization underlining the GHK method implies an importance-sampling distribution that, while computationally extremely tractable, provides an excellent approximation to the true correlation structure of the unobservables.

with recursive conditioning simulators, as proved below.

The GHK simulator relies on the Cholesky triangular decomposition to decompose the multivariate normal into a set of univariate normal distributions. Here I introduce some more notations for the unobservable terms. The multivariate normal disturbance vector ε_i defined above can be rewritten as

$$\varepsilon_i = \Gamma_i \eta_i$$

where η_i is a $(J_i + 1) \times 1$ vector of independent standard normal variates,

$$\eta_i \sim N(0, I_{J_i+1})$$

and Γ_i is a $J_i \times (J_i + 1)$ parametric array[26],

$$\Gamma_i = \begin{bmatrix} \omega & & & 0 & \rho \\ & \ddots & & & \rho \\ & & \ddots & & \vdots \\ 0 & & & \omega & \rho \end{bmatrix}.$$

Thus, ε_i can be rewritten as

$$\varepsilon_i \sim N(0, \Omega_i),$$

---

[26]More flexible models can be dealt with by changing Γ_i and the size of η_i.

where Ω_i is the following positive definite matrix:

$$\Omega_i \equiv \Gamma_i \Gamma_i'.$$

It follows that ε_i can be written by using the Cholesky decomposition as:

$$\varepsilon_i = L(\Omega_i) \cdot v_i, \tag{18}$$

where $L(\Omega)$ is the lower-triangular Cholesky factor of Ω, or $LL' = \Omega$, and v_i is another multivariate standard normal vector:

$$v_i \sim N(0, I_{J_i}).$$

The individual likelihood can be written, after dropping index i, as

$$
\begin{aligned}
l(\theta; y^o, X) &= \Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] \\
&= \int_{y^o = y^*(X, \varepsilon; \gamma)} n(\varepsilon, \Omega) d\varepsilon.
\end{aligned}
$$

This expression involves multiple integrals, which is hard to compute straightforwardly. The general objective here is to obtain random draws from the distribution ε_i subject to $y^o = y^*(X; \gamma, \omega, \rho)$. To do so, first rewrite the probability expression which explicitly expresses

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the rectangle in which the event, $y^o = y^*(X; \gamma, \omega, \rho)$ occurs:

$$\Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] = \Pr\left[\text{for } \forall j, \ \pi_j(X_j, \varepsilon_j, (y^{o'}_{>j}, y^*_{<j}(y^{o'}_{>j}, 1)'); \gamma) \left\{ \begin{array}{l} > 0 \text{ if } y^o_j = 1 \\[2mm] \leq 0 \text{ if } y^o_j = 0 \end{array} \right.\right].$$

$$(19)$$

By defining

$$\left\{ \begin{array}{l} a^*_j = 0, b^*_j = \infty \text{ if } y^o_j = 1 \\[2mm] a^*_j = -\infty, b^*_j = 0 \text{ if } y^o_j = 0 \end{array} \right\},$$

the probability can be written as:

$$\Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] = \Pr[\text{for } \forall j, \ a^*_j(y^o_j) \leq \pi_j(X_j, \varepsilon_j, (y^{o'}_{>j}, y^*_{<j}(y^{o'}_{>j}, 1)'); \gamma) \leq b^*_j(y^o_j)].$$

$$(20)$$

Remember the form of the profit function, (13). By defining

$$a_j \equiv a^*_j - X_j\gamma - VP((y^{o'}_{>j}, y^*_{<j}(y^{o'}_{>j}, 1)'), X)$$

$$b_j \equiv b^*_j - X_j\gamma - VP((y^{o'}_{>j}, y^*_{<j}(y^{o'}_{>j}, 1)'), X),$$

(20) can be rewritten as

$$\Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] = \Pr[\text{for } \forall j, \ a_j(y^o, X, \varepsilon_{<j}; \gamma) \leq \varepsilon_j \leq b_j(y^o, X, \varepsilon_{<j}; \gamma)].$$

This expression shows us the rectangle in which the event, $y^o = y^*(X; \gamma, \omega, \rho)$, occurs.
Note that to obtain the interval of ε_j, we only need $\varepsilon_{<j}$. This is because the upstream

firms' decisions are given for firm j. When firm j makes a decision, the downstream firms' disturbances are relevant to predict the downstream responses to each option of firm j's. By using the Cholesky decomposition, (18), this equation becomes:

$$\Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] = \Pr[\text{for } \forall j, \ a_j(y^o, X, v_{<j}; \gamma, \Omega) \leq L(\Omega) \cdot v \leq b_j(y^o, X, v_{<j}; \gamma, \Omega)]$$

(21)

or,

$$\Pr\left[y^o = y^*(X; \gamma, \omega, \rho)\right] = \int_{\text{for } \forall j, \ a_j(y^o, X, v_{<j}; \gamma, \Omega) \leq L(\Omega) \cdot v \leq b_j(y^o, X, v_{<j}; \gamma, \Omega)} \left[\prod_{j=1}^{J} \phi(v_j)\right] dv,$$

where $\phi()$ is the probability density function of standard normal.

Now we are ready to apply the GHK simulator. For each time of simulation, prepare a vector of independent uniform $(0, 1)$ random variates, $(u_1, ..., u_{J_i})$. Define the following function:

$$q(u, a, b) \equiv \Phi^{-1}\left(\Phi(a) \cdot (1 - u) + \Phi(b) \cdot u\right), \text{ where } 0 < u < 1 \text{ and } -\infty \leq a < b \leq \infty. \quad (22)$$

This function, $q(\cdot)$, is a mapping that takes a uniform $(0, 1)$ random variate into a truncated standard normal random variate on the interval $[a, b]$.

For given y^o, X, u, γ, L, define recursively for $j = 1, ..., J$:

$$\widetilde{v}_1 \equiv q\left(u_1, \frac{a_1}{L_{11}}, \frac{b_1}{L_{11}}\right)$$

$$\widetilde{v}_2 \equiv q\left(u_2, \frac{a_2(\widetilde{v}_1) - L_{2,1}\widetilde{v}_1}{L_{22}}, \frac{b_2(\widetilde{v}_1) - L_{2,1}\widetilde{v}_1}{L_{22}}\right)$$

$$...$$

$$\widetilde{v}_J \equiv q\left(u_J, \frac{a_J(\widetilde{v}_{<J-1}) - L_{J,1}\widetilde{v}_1... - L_{J,J-1}\widetilde{v}_{J-1}}{L_{JJ}}, \frac{b_J(\widetilde{v}_{<J-1}) - L_{J,1}\widetilde{v}_1... - L_{J,J-1}\widetilde{v}_{J-1}}{L_{JJ}}\right)$$

and

$$Q_1 \equiv \Pr\left(\frac{a_1}{L_{11}} \leq v_1 \leq \frac{b_1}{L_{11}}\right)$$

$$Q_2 \equiv \Pr\left(\frac{a_2(\widetilde{v}_1) - L_{2,1}\widetilde{v}_1}{L_{22}} \leq v_2 \leq \frac{b_2(\widetilde{v}_1) - L_{2,1}\widetilde{v}_1}{L_{22}}\right)$$

$$...$$

$$Q_J \equiv \Pr\left(\frac{a_J(\widetilde{v}_{<J-1}) - L_{J,1}\widetilde{v}_1... - L_{J,J-1}\widetilde{v}_{J-1}}{L_{JJ}} \leq v_J \leq \frac{b_J(\widetilde{v}_{<J-1}) - L_{J,1}\widetilde{v}_1... - L_{J,J-1}\widetilde{v}_{J-1}}{L_{JJ}}\right).$$

Given all the a, b, L, and $\widetilde{v}$, every Q_j is truncated univariate standard normal, so can be calculated by, for example,

$$Q_1 = \Phi\left(\frac{b_1}{L_{11}}\right) - \Phi\left(\frac{a_1}{L_{11}}\right).$$

Repeat this simulation R times and define the likelihood contribution simulator as

$$\widetilde{l}(\gamma, \Omega; y^o, X; R, u) \equiv \frac{1}{R}\sum_{r=1}^{R}\prod_{j=1}^{J} Q_j(\widetilde{v}_{1r}, ..., \widetilde{v}_{J-1,r}). \tag{23}$$

The model is estimated by solving the following maximum simulated likelihood problem:

$$
\begin{aligned}
\widehat{\theta}_{MSL} &= \arg\max_{\theta} \left\{ \frac{1}{N} \sum_{i}^{N} \ln \widetilde{l}(\gamma, \Omega; y_i^o, X_{\cdot i}; R, u_i) \right\} \qquad (24) \\
&= \arg\max_{\theta} \left\{ \frac{1}{N} \sum_{i}^{N} \ln \frac{1}{R} \sum_{r=1}^{R} \prod_{j=1}^{J} Q_j(\widetilde{v}_{1r}, ..., \widetilde{v}_{J-1,r}) \right\}.
\end{aligned}
$$

In the computation, I use the Quasi-Newton method with BFGS updating algorithm for the maximization routine. When I make the random draws for the simulator, I use antithetics to reduce simulation variance and bias. For more details of computation and the simulator, see Maruyama [2006].

References

[1] Berry, Steven T. (1992), "Estimation of a Model of Entry in the Airline Industry," *Econometrica*, 60(4):889-917.

[2] Berry, Steven. T. (1994), "Estimating Discrete-Choice Models of Product Differentiation," *Rand Journal of Economics*, 25(2):242-262.

[3] Berry, Steven and Joel Waldfogel (1999), "Free Entry and Social Inefficiency in Radio Broadcasting," *Rand Journal of Economics*, 30(3):397-420.

[4] Besanko, David, David Dranove, and Mark Shanley (2001), "Exploiting a Cost Advantage and Coping with a Cost Disadvantage," *Management Science*, 47(2): 221-235.

[5] Bresnahan, Timothy F. and Peter C. Reiss (1987), "Do Entry Conditions Vary across

Markets," *Brookings Papers on Economic Activity*, (3):833-881.

[6] Bresnahan, Timothy F. and Peter C. Reiss (1990), "Entry in Monopoly Markets," *Review of Economic Studies*, 57(4):531-553.

[7] Bresnahan, Timothy F. and Peter C. Reiss (1991a), "Entry and Competition in Concentrated Markets," *Journal of Political Economy*, 99(5):977-1009.

[8] Bresnahan, Timothy F. and Peter C. Reiss (1991b), "Empirical-Models of Discrete Games," *Journal of Econometrics*, 48(1-2):57-81.

[9] Ciliberto, Federico and Elie Tamer (2004) "Market Structure and Multiple Equilibria in Airline Markets," Working paper, Princeton University.

[10] Contoyannis, Paul, and Andrew M. Jones, and Roberto Leon-Gonzalez (2004), "Using Simulation-Based Inference with Panel Data in Health Economics," *Econometrics and Health Economics*, 13:101-122.

[11] Dafny, Leemore S., and David Dranove (2005), "Do Report Cards Tell Consumers Anything They Don't Already Know? The Case of Medicare HMOs," *NBER Working Paper*, 11420.

[12] Einav, Liran (2003), "Not All Rivals Look Alike: Estimating an Equilibrium Model of the Release Date Timing Game," mimeo, Stanford University

[13] Hausman, J.A. (1997), "Valuation of New Goods under Perfect and Imperfect Competition," *The Economics of New Goods*, edited by T.F. Bresnahan and R.J. Gordon, *NBER Studies in Income and Wealth*, vol.58, Chicago; University of Chicago Press.

[14] Lerman, S. and C. Manski (1981), "On the Use of Simulated Frequencies to Approximate Choice Probabilities," *Structural Analysis of Discrete Data with Econometric Applications*, edited by C. Manski and D. McFadden, Cambridge, MA: MIT Press:305-319.

[15] Mankiw, N. Gregory and Michael D. Whinston (1986) "Free Entry and Social Inefficiency," *Rand Journal of Economics*, 17(1): 48-58.

[16] Maruyama, Shiko (2006), "Welfare Analysis Incorporating a Structural Entry-Exit Model: A Case Study of Medicare HMOs," Unpublished Ph.D. Dissertation, Northwestern University.

[17] Mazzeo, Michael J. (2002), "Product Choice and Oligopoly Market Structure," *Rand Journal of Economics*, 33(2):221-242.

[18] McFadden, Daniel (1981), "Econometric Models of Probabilistic Choice," *Structural Analysis of Discrete Data with Econometric Applications*, edited by Charles F. Manski and Daniel McFadden, Cambridge, Mass.: MIT Press.

[19] Nevo, Aviv (2001), "Measuring Market Power in the Ready-To-Eat Cereal Industry," *Econometrica*, 69(2):307-342.

[20] Seim, Katja (2001), "Spatial Differentiation and Market Structure: The Video Retail Industry," Unpublished Ph.D. Dissertation, Yale University.

[21] Seim, Katja (2004), "An Empirical Model of Firm Entry with Endogenous Product-Type Choices," Mimeo.

[22] Spence, A. Michael (1976), "Product Selection, Fixed Costs, and Monopolistic Competition," *Review of Economic Studies*, 43: 217-236.

[23] Town, Robert and Su Liu (2003), "The Welfare Impact of Medicare HMOs," *RAND Journal of Economics*, 34(4):719-736.