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Experts' agency problems: evidence from the prescription drug market in Japan

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This article examines the physician-patient agency relationship in the context of the prescription drug market in Japan. In this market, physicians often both prescribe and dispense drugs and can pocket profits in so doing. A concern is that, due to the incentive created by the markup, physicians' prescription decisions may be distorted. Empirical results using anti-hypertensive drugs suggest that physicians' prescription choices are influenced by the markup. However, physicians are also sensitive to the patient's out-of-pocket costs. Overall, although the markup affects prescription choices, physicians appear more responsive to the patient's out-of-pocket costs than their own profits from markup.

1. Introduction

■ An "expert-client" relationship emerges when clients do not possess sufficient expertise to solve a problem. An expert instead acts as the client's agent. An incentive problem may arise in such a relationship because clients cannot observe without cost whether the agent's actions are in their best interests. Moreover, vertical integration between diagnosis and service, which often exists in expert services, may exacerbate the problem because the expert faces a further incentive to create demand for his or her services. For example, auto repairers may try to replace brake shoes even when they are not necessary, and salespersons in a wine shop may recommend a high-markup wine regardless of customer preference. Potential agency problems of this kind may arise wherever an expert-agent provides both diagnosis and service. On the other hand, however, various arrangements and market responses exist that may mitigate the agency problem.[1,2] It remains to be seen empirically, therefore, how important the agency problem is in specific sectors of the economy.

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[1] For example, the expert service literature, which focuses on "hidden information" cases, shows that market conditions such as repeat sales, specialization, and capacity constraints may mitigate the agency problem (Darby and Karni, 1973; Dranove, 1988; Wolinsky, 1993; Emons, 1997).

[2] Similarly, classic agency theory literature, which mostly discusses "hidden action" cases, suggests that agency costs may be reduced by monitoring, bonding activities, and reputation, though not being eliminated completely (Jensen and Meckling, 1976; Holmstrom, 1982).

This article attempts to shed light on the extent of the agency problem by examining the prescription drug market in Japan. A striking feature of the Japanese prescription drug market is that, unlike in many other countries, physicians not only prescribe drugs but also purchase and dispense them. Furthermore, physicians can make profits by dispensing drugs. A concern is that physicians may respond to the markup and their prescription decisions may be distorted. First, physicians may choose drugs based not on efficacy, safety, or cost, but solely on the extent of the markup they obtain. Second, over-prescribing may result as well because physicians can earn more profits by dispensing more drugs. These are real concerns in the prescription drug market because it is usually difficult for patients to judge the appropriateness of the drugs they receive.

An advantage of the data used for this study is that I can observe physician markup for each drug over time. Using these data, I examine whether physicians' prescription decisions are influenced by the markup. In addition, I compute an estimate on how physicians trade off their wealth from markup and the cost of medication to the patient in terms of dollars.

I start my analysis by estimating the demand for prescription drugs using a utility-based random-coefficients discrete-choice model. I assume physicians choose a hypertension drug from more than 40 brands to maximize their utility, which is allowed to be a function of physician markup and patient utility associated with each drug. Because I only have product-level data and do not have micro data, I follow the estimation strategy advanced by Berry (1994) and Berry, Levinsohn, and Pakes (1995). Using the generalized method of moments and instrumental variables, I account for the endogeneity of physician markup and retail price. Utilizing the estimated parameters, I further conduct counterfactual experiments to assess the impact of physician markup on pharmaceutical demand.

Results suggest that physicians' decisions are influenced by the markup they obtain. This suggests the existence of the agency problem in this market. Interestingly, however, I also find that physicians prefer to dispense drugs that cost less to the patient, *ceteris paribus*. Estimated parameter values indicate that physicians are willing to give up one dollar of their profit in order to reduce the copayment of non-elderly patients by 28 cents. This implies that, although physicians do take advantage of markup, they care more about patient welfare than their own profits from markup. This may be because, for example, physicians are concerned about their reputation or they are altruistic about their patients' welfare.

A counterfactual experiment suggests that if the physician markup is eliminated, demand and prescription drug expenditures decrease as much as 10.6% and 15%, respectively, holding retail prices and other factors constant. This implies that current expenditures on hypertension drugs are inflated by substitution into high-price, high-markup drugs by 4.4% and overuse of drugs by 10.6%. Thus, the economic impact of the physician markup does not appear to be trivial in this market. Due to the partial equilibrium nature of the experiment, however, these results have to be viewed with great caution.

This article contributes to the growing empirical literature on expert services. For example, Chevalier and Ellison (1997) find that mutual fund managers often try to increase the inflow of funds against the interests of their customers, who would rather maximize their risk-adjusted returns. Hubbard (1998) shows that auto repairers conduct vehicle inspections differently depending on whether the vehicles are on warranty or not. In the prescription drug market, Hellerstein (1998), Stern and Trajtenberg (1998), Coscelli (2000), and Lundin (2000) examine the importance of physicians in the choice of prescription drugs. They find that physician "habit" or "authority" is important in explaining market shares. Lundin (2000) also finds that physicians put higher weights on patients' costs than insurers' costs when choosing a drug. These papers, however, do not address physicians' financial incentives in determining prescriptions.

More traditionally, the physician agency problem has been discussed in the supplier-induced demand literature. For example, Rice (1983) and Rice and Labelle (1989) have shown a negative correlation between price change and utilization of medical service, which is implied by the physician's inducement behavior. Similarly, Grytten, Holst, and Laake (1990) and Rossiter and Wilensky (1983) show a positive correlation between availability of physicians and utilization.

More recently, Gruber and Owings (1996) documented a negative correlation between birth rate and Cesarean section delivery.[3] Regarding the Japanese prescription drug market, very few empirical studies exist. Anegawa's (1999) is one of the very few studies that look at the market empirically that estimates the demand for cardiovascular drugs using a log-linear demand system. IHEP (1996) is another exception which examines the choice of prescription by taking into account physician markup.

The remainder of the article is organized as follows: In Section 2, I describe the prescription drug market in Japan and the incentive problem. In Section 3, after briefly discussing theoretical underpinnings, an econometric model is introduced. Sections 4 and 5 discuss identification issues and data, respectively. Estimation results are presented in Section 6. A counterfactual experiment is conducted in Section 7. Section 8 concludes the article.

2. The prescription drug market in Japan

■ **Price control and incentive problems.** Two unique features are important in order to understand the potential agency problem in the prescription drug market in Japan. The first is the historic *non-separation* between prescribing and dispensing prescription drugs. Unlike many other countries, doctors in Japan not only prescribe drugs but also purchase and dispense them to their patients. It is a tradition of Oriental medicine that patients receive drugs directly from their physicians. Even though the government tried to enforce separation after World War II, this effort did not succeed because of strong opposition by the physicians' association. As a result, 80% of drugs were still dispensed by physicians in 1995.[4] Thus, the degree of separation between prescription and distribution has traditionally been weak in the Japanese market.[5]

Another important feature of the market is that the government regulates prescription drug prices using a pricing formula called *Yakka Kijyun*. The pricing rule can be summarized in the following way. First, at the time of entry, the government determines the *retail price* of the drug in comparison to similar drugs already on the market. If the new drug exhibits significantly higher quality than existing ones, it gets a higher initial retail price than the incumbents. This is designed to encourage innovation in pharmaceuticals. Following entry into the market, the retail price of the drug will be revised every two years based on the following dynamic formula[6]:

$$P_t^R = P_{t-1}^W + P_{t-1}^R * R_t, \tag{1}$$

where P_t^R is the retail price at time t, P_{t-1}^W is the wholesale price at time $t-1$, and R_t is called "*reasonable-zone*" (*R-zone*), set by the government, which is designed to cover technical fees and transaction costs to dispense drugs. The government learns the (average) wholesale price based on extensive surveys and uses them to update the retail price. The *R-zone* was set at 15% when it was first introduced in 1992, but was reduced gradually to 10% in 1997 in the hope of reducing discrepancies between the retail price and the wholesale price.

A crucial point of the price control rule is that the government sets *only* the *retail price* based on the formula whereas the *wholesale price* is determined freely by the seller. Thus, firms may try to increase current demand by lowering wholesale prices below retail prices. How firms set their wholesale prices optimally under the constraints is certainly an interesting question but beyond the scope of this article. A key fact for this article is, however, that the data show that firms set their wholesale prices almost always *below* the retail prices. This means physicians can pocket the difference between the wholesale price (their purchasing price) and the retail price. The size

[3] For a summary of the literature, see Folland et al. (1997) and Gruber and Owings (1996). Theoretical models on this issue include Dranove (1988), and McGuire and Pauly (1991).

[4] Even when the separation takes place, prescriptions are often filled by a pharmacy that is connected financially with the prescribing physician through ownership or rebate. These explicit forms of financial connections became illegal in 1996, but the practice has lasted at least for a while. See *Yomiuri Shinbun* (1998).

[5] As of 2005, approximately half of all prescriptions are still dispensed by physicians.

[6] Retail prices were also revised in 1997 to reflect changes in the sales tax.

of physician markup has been quite large: in 1996, physician markup accounted for 14% of total medical expenditure and amounted to $43,000 per physician.

The fact that physicians can make profits by dispensing drugs raises a concern that physicians' prescription choices may be distorted. Physicians may choose a drug based not on efficacy, safety, or cost-effectiveness of the drug but rather on the extent of the markup they obtain. Overuse of drugs may result as well, as physicians can make more money by dispensing more. These are realistic concerns, as it may be difficult for patients (or third parties) to verify the appropriateness of the prescription and legally penalize physicians. Such a practice, if it exists, may not only affect patient welfare because drugs have side effects and high-markup drugs are usually more expensive to patients but also increase medical expenditures, as prescription drugs are commonly covered by insurance in Japan.

Some anecdotal evidence suggests that the consumption of pharmaceuticals is indeed high in Japan. According to the United Nations Industrial and Development Organization (UNIDO), per-capita consumption of pharmaceuticals (including over-the-counter drugs) was significantly higher in Japan at $277 in 1990 compared to the United States at $128 (Ballance, Pogany, and Forstner, 1992). Similarly, the pharmaceutical share in GDP was higher in Japan, with 1.6% of GDP in 1994 compared to 1.3% in the United States in 1996.

□ **The health insurance system.** The Japanese health insurance system may also have an important effect on physician behavior. Currently, most of the population is insured under universal health coverage. Fees for medical services (including prescription drugs) are standardized by the government. Thus, all physicians get the same reimbursement for the same treatment, and doctors have to charge the same price for all patients. Patients pay different copayments depending on their eligibility.

One important distinction exists in the amount of copayments that patients have to pay. Specifically, whereas elderly people (over age 70) pay fixed copayments *per visit* (about $5) regardless of the cost of the prescription, non-elderly people pay a *proportion* of the cost, which ranges between 10% and 30% depending on eligibility.[7] I expect this to have an important effect on patients' incentive to monitor physicians. Because the marginal cost of receiving additional care is zero for elderly people but positive for non-elderly people, the incentive for elderly patients to monitor physician behavior is expected to be weak. I will utilize this distinction of the insurance status to set up my empirical model.

□ **The hypertension drug market.** I use hypertension drugs as an example to examine the physician agency problem. Hypertension drugs are appropriate for my purpose for at least three reasons. First, because there are more than 40 alternative brands to choose from with different prices and markups but similar product characteristics, there is room for physician markup to affect the choice of prescription. Second, the large number of drugs allows me to estimate a discrete-choice model with the market-level data I have. Finally, the market is important in itself given the number of hypertension patients and the size of the market.[8]

There are five major therapeutic classes of the drugs used to treat hypertension. They are angiotensin converting enzyme (ACE) inhibitors, calcium blockers, α-blockers, β-blockers, and diuretics. These drugs are differentiated in various ways. Most importantly, the mechanisms of actions to reduce hypertension are distinctively different across these five therapeutic classes, and drugs in each class share similar mechanisms of actions and have similar chemical structures.[9]

[7] This rule changed in 2002. Now, similar to the non-elderly, the elderly also have to pay a proportion of the cost, including the cost of medication.

[8] Hypertension is the most common reason for physician visits. The hypertension drug market is one of the largest markets in prescription drugs, with sales of 424 billion yen (approximately $3.5 billion) in 1997.

[9] For example, whereas diuretics reduce high blood pressure by eliminating excess fluid from the body, ACE inhibitors do so by preventing the conversion of angiotensin I into angiotensin II, which increases blood pressure.

TABLE 1 Definition of the Variables

Price and markup	
Retail price	Reimbursement price officially determined by the government
Physician markup	Average markup physicians obtain by dispensing the drug
Product characteristics	
Half-life	Time required for a drug concentration to be reduced by 50%
# of indications	Number of approved indications
# of contraindications	Number of contraindicated conditions
Foreign drug	Dummy = 1 if the drug is developed in a foreign country
Move 1st	Dummy = 1 if the drug is the first one marketed in Japan in its molecular class
Time from entry	Number of months from entry
(Time from entry)^2	Number of months from entry squared

This grouping is commonly used in a number of medical studies. I exploit this prior knowledge of the segmentation to set up my econometric model.

Hypertension drugs are also differentiated in other dimensions even within each therapeutic class. For example, the number of indications to treat patients approved by the government, contraindications, and pharmacokinetic attributes such as half-life period also vary from drug to drug. In the econometric model, I treat hypertension drugs as differentiated products in these dimensions. Product characteristics used in the analysis and their definitions are listed in Table 1.

About 39 million Japanese, approximately one out of three people, were estimated to have elevated blood pressure in 1993.[10] Hypertension is most common in the elderly population, where more than 80% of people age 70 or above suffer hypertension. However, not all of the 39 million people are treated by physicians with hypertension drugs. For one reason, not all of these people go to see a doctor. For another reason, doctors may treat these people by non-drug therapies first, as is recommended in the guidelines (e.g., JNC V, 1993).[11] The number of patients who are "at risk" of getting hypertension drugs, or "potential market size," was computed using detailed government health statistics (Appendix A discusses this in more detail). Although surgery can sometimes treat hypertension patients, this applies only to a small fraction of patients, and thus surgery is generally a poor substitute for hypertension drugs.[12,13]

3. The model

■ **Theoretical considerations.** The theoretical literature on the expert's service emphasizes the role of repeat transactions and the physician's altruism in mitigating the expert's agency problem. The central tradeoff pointed out in the former literature is that an expert who tries to shirk today is likely to suffer negative consequences in the future through the reduction of demand and profits (e.g., Darby and Karni, 1973; Dranove, 1988). These negative effects may arise because current (and potential) clients may learn that the expert does not work in their best interest, and thus clients choose not to return to the expert in the future. The second strand of literature considers the possibility that altruistic physicians provide medical treatments by taking into account the patient's benefit from the treatments. For example, Ellis and McGuire (1986) and Chalkley and Malcolmson (1998) study the model in which patient's benefit from treatments

[10] Hypertension is defined as follows: systolic blood pressure $\geq$ 140 mm Hg and/or diastolic blood pressure $\geq$ 90 mm Hg and/or using antihypertensive therapy.

[11] Interventions based on life-style factors, such as a high sodium intake, an excessive consumption of calories, physical inactivity, and excessive alcohol consumption have been emphasized as the first steps to treat hypertension.

[12] Approximately 95% of hypertension cases have no identifiable cause, and these are labeled essential (or primary) hypertension. These patients are treated by life-style changes, including weight loss and exercise, and by drug therapies. Surgery cannot treat patients with essential hypertension because doctors do not know the cause of the hypertension.

[13] Among the secondary hypertension that accounts for the remaining 5%, a small fraction of patients who suffer renovascular hypertension can be treated both by medications and surgery. Generally, however, except for these patients, surgery is a poor substitute for medication for hypertension.

directly enters physician's utility function. Ma and McGuire (1997) consider a model in which altruism provides a lower bound of health benefits that a physician is willing to provide to a patient. Similarly, McGuire and Pauly (1991) and Gruber and Owings (1996) assume shirking provides disutility to physicians and that they will thus limit its amount.

Following the literature, in my empirical model, I allow the physician to choose a drug by considering his/her own benefits from markup and patient welfare. In particular, I will examine: (i) whether physician prescription is influenced by the markup that the physician obtains, (ii) whether the physician is sensitive to the patient's out-of-pocket costs, and (iii) the extent to which the physician trades off her own profits from markup and the patient's out-of-pocket costs.

The extent to which the physician acts in the interest of the patient will depend on various factors. For example, physicians may completely ignore patient welfare and choose a drug by solely looking at their own markup. This may happen if, for example, information asymmetry between the two parties is severe and physicians do not care about patient welfare at all. On the other hand, physicians may choose a drug by putting more weights on patients' welfare than their own profits from markup. This could happen if, for example, the patient can limit the extent of the agency problem through referrals or repeat visits, or if physicians are altruistic. Because of the various forces that might influence physician behavior, whether, and to what extent, the physician acts in the interest of the patient is primarily an empirical issue.

□ **Econometric model.** I estimate the demand for hypertension drugs using a utility-based random-coefficients discrete-choice model. My empirical model is motivated by the product-level data I have, which contains more than 40 hypertension drugs for 1991–1997. For each drug in each year, I observe retail price, physician markup, various product attributes, and quantity sold for each drug (Section 5 discusses the data in detail). I do not have individual-level data, however, that would allow me to control for detailed patient characteristics. A discrete-choice model is particularly useful in my case to account for high dimensionality, as one hypertension drug has to be chosen from more than 40 alternate brands. A simple constant elasticity demand model will face "too many" elasticities to estimate if used in this type of market.

Following the theoretical discussion above, I permit doctors to choose a drug by taking into account patient utility as well as the markup obtained from each drug. Specifically, I assume that a doctor chooses drug j for patient i at time t among $J+1$ alternatives (including outside goods) that would maximize the objective function, V_{ijt}, defined below:

$$\max_{j\in 0,J} V_{ijt} = X'_{jt}\beta_i - \alpha_i P^R_{jt} + \xi_{jt} + \gamma M_{jt} + \mu_{ijt}, \tag{2}$$

where X_{jt} is observed product characteristics of drug j at t, P^R_{jt} is retail price of drug j at t, and ξ_{jt} is unobserved product quality of j at t, which both physicians and manufacturers observe but we (econometricians) do not. M_{jt} $(=P^R_{jt} - P^W_{jt})$ is physician markup for drug j at t, and μ_{ijt} is an idiosyncratic error term. Parameters to be estimated are α_i, β_i, and γ, and I allow α and some β coefficients to vary depending on the type of patient.

I allow the error term μ_{ijt} to have a group-specific component as well as an *i.i.d.* term: $\mu_{ijt} = \zeta_{ig}(\sigma) + (1-\sigma)\varepsilon_{ijt}$, where ε_{ijt} is an identically, independently distributed extreme value and ζ_{ig} is a function of σ. As the parameter σ approaches one, the within-group correlation goes to one, and as the parameter σ approaches zero, the within-group correlation goes to zero. Cardell (1997) shows the distributional assumption required for ζ_{ig}. The nested logit error structure fits naturally in the group structure of the hypertension drugs as discussed in Sections 2 and 3.

I assume there exist two types of patients, namely *elderly* and *non-elderly*, and allow them to have different price coefficients and separate group-specific constants. I believe that price sensitivity and an intrinsic value of drug treatment can be systematically different between the two types because of the difference in insurance coverage and health conditions. To repeat, briefly, although elderly people pay fixed copayments *per visit* regardless of the treatment, non-elderly

patients pay copayments of 10%–30% of the cost of treatments.[14] Thus, it is reasonable to expect that physicians become more sensitive to retail price when they prescribe a drug to non-elderly patients.

Based on the distributional assumptions, the market share for drug j at t for type i patient will be given by the standard nested logit-share equation (McFadden, 1978):

$$s_{jt}^{i} = \frac{exp((X'_{jt}\beta_i - \alpha_i P_{jt}^{R} + \gamma_i M_{jt} + \xi_{jt})/(1-\sigma))\left[\sum_{j\in g} exp((X'_{jt}\beta_i - \alpha_i P_{jt}^{R} + \gamma_i M_{jt} + \xi_{jt})/(1-\sigma))\right]^{-\sigma}}{\sum_{g\in G}\left[\sum_{j\in g} exp((X'_{jt}\beta_i - \alpha_i P_{jt}^{R} + \gamma_i M_{jt} + \xi_{jt})/(1-\sigma))\right]^{(1-\sigma)}}, \tag{3}$$

where s_{jt}^{i} is predicted share for drug j (in group g) at t for type i patient. In my case, I assume two types of patients, an elderly type ($i = 1$) and a non-elderly type ($i = 2$). A total market share for drug j at t can be obtained by the weighted average of the shares for different types:

$$s_{jt} = \kappa_t^1 s_{jt}^1 + \kappa_t^2 s_{jt}^2, \tag{4}$$

where s_{jt}^{1} is the market share of drug j at time t in the elderly population, s_{jt}^{2} is the share of drug j at time t in the non-elderly population, and κ_t^1 and κ_t^2 are the share of the elderly and non-elderly population in the potential market at time t, respectively. As discussed in Appendix A, I obtain κ_t from separate government statistics. This additional information, which separately provides potential market size for the elderly and non-elderly, is important because this helps me identify the different price coefficients corresponding to each population.[15]

I estimate the model using a generalized method of moments utilizing the instruments discussed below. The estimation strategy closely follows recent advances in empirical industrial organization literature from Berry (1994), Berry, Levinsohn, and Pakes (1995) and Nevo (2001), and I do not repeat the general discussion here. One difference is, however, that I use the following contraction mapping when "inverting" the market-share function with respect to "mean valuation" δ:

$$f(\delta) = \delta + (1-\sigma)\{ln\, S - ln\, s(\delta)\}, \tag{5}$$

where S denotes observed market share. Appendix B provides a proof that equation (5) is a valid contraction mapping.

4. Identification and instruments

■ A central issue in the estimation is how to identify the coefficients for physician markup and retail price. First, retail price is likely to be correlated to physician markup due to the government's pricing rule. As shown in Figure 1, however, given a year, there is a good variation in retail price and markup across drugs, which helps us identify the two coefficients. Second, physician markup and retail price are likely to be correlated to the error term because high-quality drugs are likely to be priced higher and offer lower markup *ceteris paribus*. An endogeneity problem may arise here because both producers and doctors make decisions based on these drug attributes unobserved to us. To deal with this potential problem, I construct instruments.

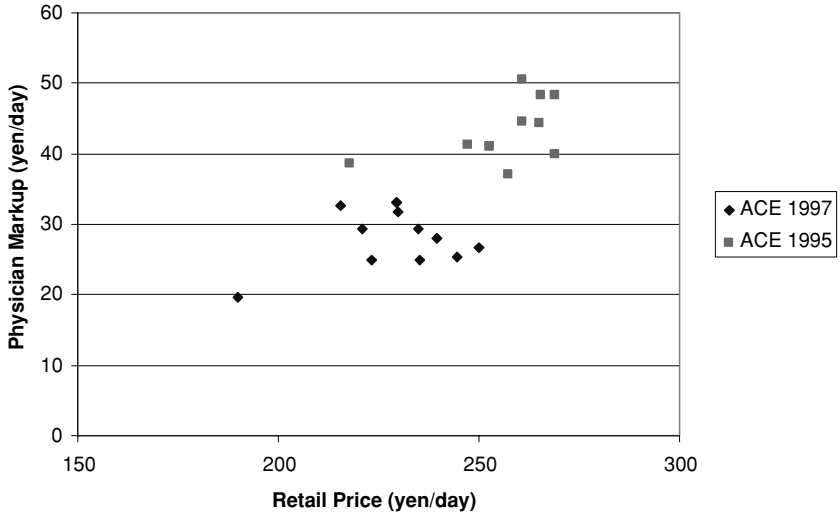
Following the literature (e.g., Berry, Levinsohn, and Pakes, 1995; Stern, 1996; Bresnahan, Stern, and Trajtenberg, 1997; Petrin, 2002), I use instruments that capture (i) how crowded product space is in the area of the given product, and (ii) the ownership pattern of the products. First, given the oligopolistic nature of the hypertension drug market, a drug's wholesale price should

[14] Ideally, one would like to estimate the coefficient on markup by physician type. For example, physicians in small clinics may be more sensitive to markup than those in large hospitals. Unfortunately, my data do not have such variation; thus, I will focus on the average effect of physician markup.

[15] As discussed in the previous paragraph, I also allow that elderly and non-elderly patients have different intercepts. Therefore, I do *not* force the price coefficients to explain all of the differences in market shares between elderly and non-elderly patients.

FIGURE 1

PHYSICIAN MARKUP VERSUS RETAIL PRICE



go down as the number of close substitutes increases.[16] Because physician markup is simply the difference between retail price (which is predetermined by the government) and wholesale price, physician markup is also correlated with the crowdedness of the product space. Second, in order to maximize joint profits from all products, multi-product firms set different wholesale prices, depending on whether the close substitutes are produced by their own firm or by competitors. If, for example, all products in a category are produced by the same firm, the firm would set higher wholesale prices for all products to maximize joint profits across products. Thus, the degree of multi-product ownership should be correlated to the wholesale price and physician markup. Based on this discussion, I construct the following instruments:

(A) *the number of drugs and the sum of product characteristics for other products sharing the same therapeutic class at t, and*
(B) *the number of drugs and the sum of product characteristics for other products sold by the firm selling product j at t.*

In addition to the above, in order to better predict retail price, I also *lagged* the above instruments by one year and included them as instruments. This is because retail price is predetermined by the government at the beginning of each year, and thus does not reflect current market structure and ownership conditions.[17] Instead, retail price closely reflects the previous year's market structure and ownership conditions. Altogether, 24 instruments are used in the estimation. I conduct the over-identification restrictions test in the estimation.

It should be noted that these instruments rely on the assumption that the crowdedness of the product space is not correlated with ξ. Although the assumption is commonly made in the literature, it may be strong in general. However, I believe my case is less severe than others due to the nature of the drug discovery process. Note that brand-name drugs dominate the market and that it takes 10–15 years to develop a new drug.[18] The decision to develop a drug is made long

[16] During the period I examine, I observe a number of new entries into this market which affect market structure and firms' pricing strategies. See Section 5 for more detail.

[17] Note that retail price is completely determined by the previous year's retail price and wholesale price, that is, $P^R_{jt} = P^W_{jt-1} + r P^R_{jt-1}$.

[18] During the time period I examine, most of the drugs examined did not have generic competitors. Also, unlike in the United States, generic drugs play a minor role in Japan; the share of generics is only 8% of all prescription drugs, due in part to the lack of mandatory substitution laws.

before the drug is actually marketed. Moreover, the drug discovery process faces a number of uncertainties throughout its development, clinical trial, and FDA review process, which creates a great deal of noise around the arrival rate of new drugs. In addition, once the drug is developed, the firm has few incentives not to launch the drug because major costs of development, such as R&D and clinical trials, are sunk at this stage. This makes the above assumption more plausible in this market than others. Using rival product characteristics as instruments is also a concern if foreign drug makers can enter the Japanese market quickly by introducing their successful drugs overseas. This, however, was not the case during the time period I examine. Even successful foreign drugs had to repeat a lengthy clinical trial process in Japan to make sure the drug was effective and did not have adverse effects in the Japanese population.

5. Data

■ **Data construction.** To estimate the discrete-choice model described above, I need retail price, physician markup, market share, and product characteristic for each drug. For this article, I constructed a new market-level unbalanced panel data covering more than 40 products for 1991–1997. The data set contains 258 observations.[19] In addition, I have limited information on the distribution of patients taken from government health statistics. I include only brand name drugs in the data set because the market share of generics is small and difficult to obtain.[20] In this section, I mainly discuss how I constructed the wholesale price and physician markup for each drug. Additional details on data construction are summarized in Appendix A.

Among the required data, retail prices and product attributes are obtained relatively easily. For example, retail prices are announced by the government every year and can be found in various publications. In contrast, the government does not disclose data for wholesale price and physician markup. Thus, I computed these numbers by exploiting the nature of the dynamic pricing rule. Recall that the government uses the following formula to determine retail prices:

$$P_t^R = P_{t-1}^W + P_{t-1}^R * R_t. \tag{1'}$$

Because I know both retail prices at time t, P_t^R, and $t-1$, P_{t-1}^R, and *R-zone* at t, R_t, it is easy to backup the wholesale price at $t-1$, P_{t-1}^W. Then, physician markup is simply the difference between retail price and wholesale price. Free samples, rebates, and other perks such as a trip to Hawaii which may distort the pricing mechanism are prohibited by the government and not common[21] Thus, on average, the calculated physician markup should reflect the actual one reasonably well.[22,23] In order to compare different drugs with various dosages per day, patient-day prices and markups for each drug are calculated based on the maximum volume of the recommended dosage. All prices are deflated by the Consumer Price Index and expressed in constant 1995 prices.

□ **Data overview.** Table 2 provides summary statistics for all variables used in this article. Patient-day retail prices vary across therapeutic classes, but it is about 190 yen on average (roughly speaking, 1 yen equals 1 cent). Physicians, in turn, make profits around 30 yen on average per

[19] Getting detailed price and quantity data for prescription drugs is a major challenge in the Japanese market. Although the government has data on detailed price and quantity based on their extensive surveys, they do not disclose the data to the public. Accordingly, I have to rely mostly on aggregate data.

[20] Please see footnote 18 for more about generics in the Japanese market.

[21] I note, however, that several drugs that violated this rule have been excluded from the government's list of insured drugs.

[22] It should be noted, however, that wholesale prices and markups could vary depending on the bargaining power between medical institutions and sellers. Unfortunately, there is no systematic data available that show the extent of heterogeneity of wholesale prices. Because of this difficulty, I use average wholesale prices in my empirical model.

[23] Available snapshot data indicate, however, that such differences may not be too large. According to the Association of Public and Private Hospitals (1995), markup to retail price ratios are 0.227 and 0.211 in small and large hospitals, respectively. The same ratios for private and municipal hospitals are 0.219 and 0.215, respectively.

TABLE 2 Summary Statistics

	Mean	St. Dev.	Min	Max
Price and markup				
Retail price	189.58	62.11	47.68	308.68
Physician markup	30.69	12.10	4.39	69.58
Product characteristics				
Half-life	8.46	8.70	.35	36.35
# of indications	2.71	1.62	1	9
# of contraindications	5.40	3.95	1	15
Foreign drug	.59	.49	0	1
Move 1st	.87	.34	0	1
Therapeutic dummies				
ACE inhibitors	.267	.444	0	1
Calcium blockers	.330	.471	0	1
α-blockers	.081	.274	0	1
β-blockers	.267	.444	0	1
Time-trend and year dummies				
Time from entry	8.88	7.85	.33	34.19
(Time from entry)^2	140.24	244.48	.11	1168.9
Year 1997	.171	.377	0	1
Year 1996	.167	.373	0	1
Year 1995	.155	.363	0	1
Year 1994	.155	.363	0	1
Year 1993	.132	.339	0	1
Year 1992	.120	.326	0	1

patient-day (or 10,000 yen per patient-year) by dispensing a hypertension drug. Among the five therapeutic classes, calcium blockers are the most popular hypertension drugs, followed by ACE inhibitors and β-blockers. The hypertension drug market observed a number of entries during the 1990s. Entry was most frequent in the newer therapeutic classes such as ACE inhibitors and calcium blockers. For example, there were only 9 drugs in the calcium blockers class in 1991, but the number increased to 16 in 1997. This large change in the choice set over time helps identify the parameter values.

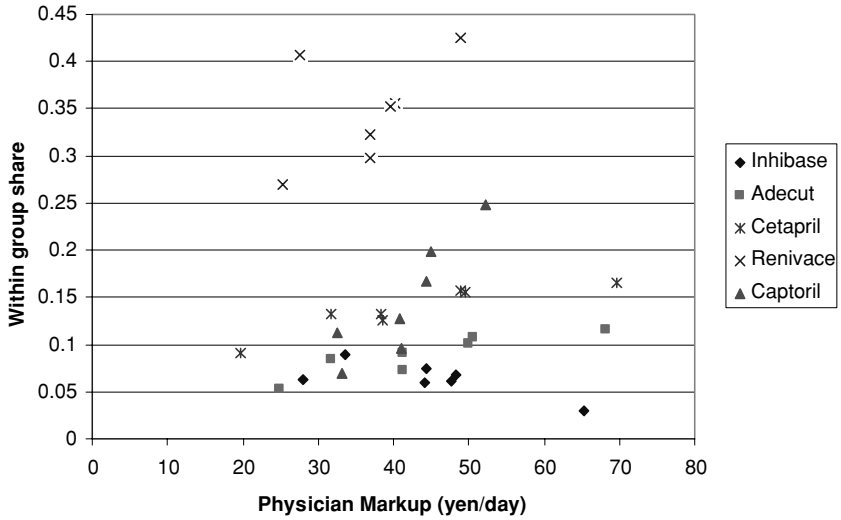
Figure 1 shows the relationship between retail price and physician markup for ACE inhibitors for 1995 and 1997. Although retail price and markup are certainly correlated, given a year, there is a good variation in retail price and physician markup even within the same therapeutic class. For example, retail price and physician markup of ACE inhibitors in 1997 are distributed between 190 and 250 yen for retail price and 25 and 33 yen for physician markup. This variation helps identify the two coefficients separately. A similar pattern is observed for the remaining time periods as well as in other therapeutic classes. Note also that retail prices and physician markups in 1997 are *lower* than those of 1995. This is true for all drugs due to the government's pricing rule.

Figure 2 examines how physician markup affects within-group market shares, using ACE inhibitors that entered the market before 1991. A general trend observed in the figure is that, as physician markup went down over time, within-class market share also fell. For example, within-class market share for Cetapril was 16.5% in 1991 when its physician markup was 70 yen per day, but the share went down to 9.1% in 1997 when its physician markup slipped to 20 yen per day. This suggests the possibility that physicians choose a drug that provides them with a higher markup. On the other hand, given a year, it is not necessarily true that the drugs that provide higher markups have a higher market share. This may be because hypertension drugs are differentiated even within each therapeutic class.

□ **First-stage regressions.** To better understand the data and check the validity of the instruments, I ran simple regressions of retail price and physician markup on exogenous regressors and excluded instruments. Table 3 shows the results.

FIGURE 2

PHYSICIAN MARKUP VERSUS MARKET SHARE: ACE INHIBITORS 1991–1997



In the retail price equation, I find that many of the estimated coefficients for the exogenous variables are significant with expected signs. Retail prices are higher for higher-quality drugs in terms of "half-life" and "# of contraindications." Regardless of the price control by the government, market mechanisms may be working, at least to some extent. Second, therapeutic-class dummies have a large impact on prices. In addition, diuretics (omitted category) are priced lower than the other drugs, controlling for other quality measures. Time-trend variables show a clear downward trend in "quality-adjusted" prices during the 1990s. On average, retail price drops sharply after an entry but to a lesser extent over time.

The fourth group of estimates shows the coefficients for the excluded instruments. As discussed in Section 4, two types of instruments, represented as (A) and (B), are included. Several excluded instruments enter the equation significantly. Also, as expected, *lagged* instruments have more explanatory power than *current* market structure. The partial R^2, which shows the additional explanatory power of the excluded instruments, is 0.05. Also, the first-stage F-statistic is 65, which is substantially higher than the minimum F-statistics standard of 10 proposed by Staiger and Stock (1997). These statistics suggest that these instruments are reasonable.

In the markup equation, many coefficients for the exogenous variables are also statistically significant. As expected, *current* market structure is more important in this equation than in the retail price equation, although many lagged instruments also enter the markup equation significantly. If we compare the price and markup equations, there are several cases in which excluded instruments have different signs in the two equations. Although they are often not statistically significant, they would help identify the two coefficients. The partial R^2 and F-statistics for this equation are 0.04 and 53, respectively, which are similar to those of the retail price equation.

6. Results

■ **Main results.** Table 4 shows the results. The first two columns show the results for the nested logit model with and without instruments. The third column shows the results for the random-coefficients model, where I allow the coefficient for retail price and group-specific constant to be different between the elderly and non-elderly. I will discuss the coefficients of our main interests, physician markup and retail price, across the models first and delay the discussions of other variables.

TABLE 3 First-Stage Regressions

	Dependent Variable = P^R		Dependent Variable = M	
	Coef.	Std. Err.	Coef.	Std. Err.
Product characteristics				
Half-life	.675**	.295	.045	.063
# of indications	2.187	3.307	.714	.707
# of contraindications	−9.590***	1.449	−1.163***	.310
Foreign drug	−3.095	10.11	−2.707	2.162
Move 1st	−12.42	8.846	−6.740***	1.892
Therapeutic dummies				
ACE inhibitors	215.0***	25.32	36.17***	5.414
Calcium blockers	93.38***	32.09	15.82**	6.863
α-blockers	132.9***	37.21	24.74***	7.957
β-blockers	184.7***	43.21	25.54***	9.24
Time-trend and year dummies				
Time from entry	−17.40***	6.621	−6.376***	1.416
(Time from entry)^2	7.311***	2.254	1.454***	.482
Year 1997	−23.07**	9.295	−15.90***	1.988
Year 1996	−13.09	9.426	−10.93***	2.016
Year 1995	−2.292	8.985	−4.902**	1.922
Year 1994	−10.32	9.236	−6.589***	1.975
Year 1993	3.278	7.124	−2.700*	1.524
Year 1992	−5.780	6.908	−4.873***	1.477
Const.	144.6***	53.42	35.62***	11.42
Excluded instruments				
# of drugs (A)	−9.141	11.41	−4.438*	2.440
# of drugs (B)	20.19	27.92	3.545	5.971
Half-life (A)	.211	.194	.108**	.042
Half-life (B)	−1.635***	.589	−.260**	.126
# of indications (A)	−3.239	2.712	−.689	.58
# of indications (B)	3.869	5.824	.751	1.245
# of contraindications (A)	−.322	.881	−.195	.189
# of contraindications (B)	.072	1.424	−.106	.305
Foreign drug (A)	.430	8.002	.576	1.711
Foreign drug (B)	17.33	13.08	4.225	2.796
Move 1st (A)	11.31	11.83	4.569*	2.53
Move 1st (B)	−15.35	17.40	−2.719	3.721
# of drugs (A) lagged	15.12*	7.778	4.941***	1.663
# of drugs (B) lagged	37.64	27.79	4.032	5.944
Half-life (A) lagged	.009	.204	−.053	.044
Half-life (B) lagged	−.446	.571	.022	.122
# of indications (A) lagged	−.01	3.448	.932	.737
# of indications (B) lagged	−7.513	5.777	−.634	1.235
# of contraindications (A) lagged	1.587*	.889	.495***	.190
# of contraindications (B) lagged	.06	1.404	.161	.300
Foreign drug (A) lagged	−9.805	7.225	−3.252**	1.545
Foreign drug (B) lagged	−23.60*	12.57	−5.051*	2.689
Move 1st (A) lagged	−19.83**	8.950	−7.857***	1.914
Move 1st (B) lagged	−5.197	17.15	−1.338	3.667
Adj. R	.896		.875	
Partial R^2	.052		.038	
F-statistics	65.5		53.3	

***1% significant level; **5% significant level; *10% significant level.

Nested logit models. Let us begin by looking at the result from the nested logit model with instruments shown in the second column of Table 4 (Model 2). Note that this model does not allow heterogeneity between the elderly and non-elderly. First, the significantly positive coefficient for physician markup suggests that physicians are sensitive to the extent of the markup in choosing

TABLE 4 Estimated Parameter Values

	(1) Nested Logit without IV		(2) Nested Logit with IV		(3) Random Coefficients with IV	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Price and markup						
Physician markup (in 100)	.476***	.162	2.365***	.646	1.659***	.542
Retail price (in 100)	−.123***	.032	−.454***	.095	−1.202$^{\Sigma}$***	.292$^{\Sigma}$
Product characteristics						
Half-life	.002**	.001	.006***	.001	.005***	.002
# of indications	.004	.006	.019**	.009	.007	.015
# of contraindications	−.006	.005	−.002	.008	.017**	.007
Foreign drug	.008	.012	.047***	.017	.031	.020
Move 1st	.025	.019	.205***	.046	.131***	.050
Therapeutic-class dummies						
ACE inhibitors	.75***	.068	.618***	.130	.706***	.230
Calcium blockers	1.981***	.054	1.782***	.081	1.973***	.174
α-blockers	−.882***	.059	−.947***	.106	−.902***	.209
β-blockers	.499***	.077	.324**	.145	.231	.199
Time trends						
Time from entry	.080**	.033	.383***	.076	.402***	.090
(Time from entry)^2	−.025**	.011	−.113***	.023	−.131***	.026
Year dummies	Significant		Significant		Significant	
Others						
Sigma	.981***	.008	.871***	.029	.886***	.028
Const.	−3.082***	.080	−3.671***	.189	−3.367***	.460
Const. (dev. for non-elderly)					.138	.378
Generalized method of moments objective function					27.99	
Over-identifying restrictions test					Satisfied [df = 22, χ^2 (.95, 22) = 33.93]	

***1% significant level; **5% significant level; *10% significant level.
$^{\Sigma}$These numbers correspond to the non-elderly patient. The coefficient for the elderly is fixed at zero in this model.

among hypertension drugs. This provides support for the agency problem. Interestingly, however, physicians are also sensitive to the patient's out-of-pocket costs. Holding other factors constant, demand for drugs decreases significantly as the retail price goes up. This implies that physicians represent patients' interests, at least to some extent.

Model 1 in Table 4 shows the result when I treat retail price and physician markup as exogenous. Note that qualitative results are very similar to the previous case. In particular, the coefficients for physician markup and retail price are both significant with the same signs as above. I find, however, that these coefficients are larger (in absolute values) in Model 2 than in Model 1. This is as expected because, holding observed quality attributes constant, unobserved quality level and retail price (physician markup) should be positively (negatively) correlated. Therefore, without instruments, the retail price (physician markup) coefficient should be biased upward (downward). The results also provide weak evidence of the endogeneity problem.

Random-coefficients model. Model 3 in Table 4 shows the result when I allow physicians to treat the two types of patients, the elderly and non-elderly, differently. In this model, the price coefficient for elderly patients is fixed at zero, as the marginal cost of additional treatments for the elderly is zero. In addition, I allow these two groups to have a different group-specific constant.[24]

[24] Ideally, I would like to allow additional parameters to vary across the two types of patients. However, I only know the distribution between the elderly and non-elderly over time (= κ) and thus cannot relax the assumption further.

As discussed in Section 3, this group-specific constant is primarily determined by the additional information on the distribution of the two groups.

The estimated coefficients for retail price and physician markup are significant with the same signs as before. This confirms the previous findings that physicians are sensitive to markup as well as to the cost to their patients.[25] The price coefficient for non-elderly patients is larger (in absolute terms) than before. This is reasonable, as the non-elderly are presumably *more* price sensitive than the "average" patient assumed in the previous regressions due to insurance coverage. The group-specific constant corresponding to non-elderly patients is not statistically significant. Thus, the data do not provide evidence that the intrinsic value of drug treatment is systematically different between the two types. At the end of the Table, I report the test statistics for the over-identification test, which shows the moment restrictions are satisfied.

□ **Implications of the estimates.** The results so far suggest that physician markup affects prescription choice and yet, nonetheless, physicians care about the cost of drugs to patients. The estimates from Model 3 (the preferred specification) allow me to further examine how physicians trade off the markup from the drug and their patients' welfare in choosing a drug. If I assume the non-elderly on average pay 20% of the cost of medication,[26] these estimates suggest that physicians are willing to give up 1 dollar of their profit from markup if they can reduce the cost to the patient by 28 cents.[27] Thus, although physicians do not represent the patient's interests 100%, physicians appear to put a greater weight on patient welfare than their own profits from markup. This may be because, for example, patients can limit the extent of the agency problem through referrals or repeat visits. Alternatively, the physician may be altruistic about the patient's welfare, as some of the previously discussed theoretical models consider. The conclusion that physicians are more responsive to the patient's out-of-pocket costs than their own profits from markup holds for all models in Table 4, although the extent of the tradeoff varies across models.

□ **Other parameter values.** Many other parameter values in Table 4 are also interesting for understanding the demand for pharmaceuticals in this market. Because they are used primarily as controls in this article, I discuss them only briefly using the results from Model 2. First, *half-life*, an important pharmacokinetic attribute that determines the frequency of dosage, affects the demand significantly: the longer the drug lasts, the higher the demand. This is probably because the patient's compliance improves if the patient takes a drug less frequently. The coefficient for *# of indications* is also positive as expected and statistically significant. The coefficient for the dummy variable for *foreign drug* is positive and significant, suggesting that the drugs developed by foreign firms are favored over domestic drugs. *1st mover advantage* (*Move 1st*) appears to exist in this market when the drug is the first one marketed in Japan in its molecular class. Therapeutic-class dummies suggest that the demand for calcium blockers is the largest in this class, followed by ACE inhibitors. Time-trend variables indicate that demand for hypertension drugs pick up initially after entry but the speed of increase declines over time.

7. Accessing the impact of vertical integration

■ If the agency problem exists in this market, one may ask the following questions. What would happen if the vertical integration between prescribing and dispensing drugs is eliminated? To what extent does demand for prescription drugs decline? This section addresses these questions by utilizing the estimated parameter values. In particular, I consider a hypothetical case in which

[25] Conditional on markup, price elasticity for the 40 drugs in 1995 is, on average, −2.3. This is comparable to Rizzo (1999), who examined the U.S. hypertension drug market and found that price elasticity ranges between −0.48 and −2.14.

[26] This is obviously a simplified assumption, given that most non-elderly patients pay either 10% or 30% of the cost of medication.

[27] That is, $1.659/(-1.202/0.2) = 0.276$.

physicians no longer make profits by dispensing drugs. Instead, as in the United States, physicians can only write prescriptions and independent pharmacies fill these prescriptions. Under this condition, there is no room for physician markup to affect prescription choices.

To simulate the impact of the hypothetical vertical separation on pharmaceutical demand, I do the following. First, I remove physician markup from the physician's objective function. Then, using the estimated parameter values and observed data, I simulate new market shares and prescription drug expenditures for all drugs. In order to focus my analysis on the effect of the vertical separation on pharmaceutical demand, I assume that the government continues to regulate pharmaceutical prices, and retail prices are fixed at the current level. In addition, physicians are assumed to be equally sensitive to retail prices and quality of drugs as before. By comparing these to the current outcome, we can understand the impact of physician markup on pharmaceutical demand and prescription drug expenditures.

Obviously, the partial equilibrium nature of the experiment comes with a host of caveats. First, I should stress that both wholesale and retail prices are likely to change if such a vertical separation takes place, but I hold them constant in this experiment. For example, the government may employ a new pricing rule, as the current dynamic pricing rule will not work if physician markup is eliminated. Another concern is that physicians' price sensitivity may decline if they no longer purchase drugs by themselves. Moreover, pharmaceutical firms may try to affect the prescription choice of physicians using alternative promotional measures. Due to these difficulties, the results of this experiment are only suggestive and have to be viewed with great caution.[28]

With all caveats in mind, I report the results from the experiment. First of all, demand for prescription drugs (in terms of patient-day volume) decreases by 10.6%, suggesting that over-prescribing due to physician markup is not trivial. This is consistent with the common perception that physicians in Japan tend to over-prescribe. Second, expenditures for hypertension drugs decrease by 15.0%. This is because of the combination of two effects: reduction in total demand and substitution into alternative, presumably cheaper, drugs. Given that the demand decreased by 10.6%, substitution into cheaper drugs accounts for the reduction of total expenditures by 4.4%. Given the large size of the prescription drug market, the potential economic effect of physician markup is substantial.

It is also interesting to note how the elimination of physician markup affects pharmaceutical manufacturers. First, it is clear that the supply side as a whole will lose if physician markup is eliminated and prescription drug expenditures decline, holding retail prices constant. This may explain why Japan's pharmaceutical manufacturers' association has long supported the current policy. Second, however, the payoffs of the firms may be different depending on the products they have. In particular, firms that currently have high-markup drugs (i.e., newer drugs) will lose more from this change because the demand is likely to shift to currently low-markup drugs (i.e., older drugs). Thus, vertically separating prescribing and dispensing may also affect firms' incentives to introduce new drugs in this market.

8. Conclusions

■ I examine the physicians' agency problem in the prescription drug market in Japan, where physicians can make profits by prescribing and dispensing drugs. Estimation results suggest that physicians' decisions are affected by the markup they obtain. Interestingly, however, physicians still appear to care about patient welfare and choose drugs that cost less to the patient, *ceteris paribus*. Overall, although the agency problem appears to exist in this market, physicians do represent the patient's interest, at least partially. This may be because, for example, patients can limit the extent of the agency problem through referrals or repeat visits. Alternatively, the physician may be altruistic about the patient's welfare.

[28] Another potential concern for this procedure is that estimated coefficients may not be relevant in the zero-markup region. This is true in a strict sense, but it turns out that the data provide good support for a wide range of physician markups between 4 and 70 yen.

Two implications follow from the fact that physician markup affects prescription choices: first, some patients may be taking drugs even when none is necessary. That is, over-prescribing exists. Second, patients may get drugs that are different from the ones they would obtain in the absence of physician markup. These should raise concerns not only from public health viewpoints but also from public finance perspectives. A counterfactual experiment suggests that the magnitude of these problems is not trivial.

Although the analysis holds primarily for the unique market environment in Japan, similar issues may be present in other markets as well. For example, some medications, including chemotherapy drugs, are commonly purchased and dispensed by medical institutions in the United States. Like the Japanese case, vertical separation between prescribing and dispensing is weak in this setup.[29] It would be intriguing to examine whether similar over-prescribing and substitution among alternative drugs take place in such circumstances.

Appendix A

■ This appendix discusses additional details on data construction. I draw retail prices from various issues of the *Prescription Drug Directory* (*Hokenyaku Jiten*). Most of the product characteristics are taken from *Today's Prescription Drug* (*Kyo-no Chiryo Yaku*). In addition, detailed drug safety information, such as the extent of adverse reactions and pharmacokinetic attributes, were supplemented by manufacturers' data provided by the UMIN (University Hospital Medical Information Network) and the Organization for Pharmaceutical Safety and Research.[30]

To compare different drugs with various dosages per day, I calculated patient-day prices and markups for each drug based on the maximum recommended dosage listed in *Today's Prescription Drug*. As explained below, unlike the price data, the sales data I have do not distinguish the strength/form for each drug. Thus, when patient-day prices and markups are different across strength/form for each drug, I took the average of these to represent the drug. Also, when an extended-release formula became available for a drug, I used these prices and markups to represent the drug. This simplification is due mainly to the tractability of the data. However, I believe that it is a reasonable approximation because, as seen in the U.S. market, extended-release formulas tend to dominate the market due to the high compliance of patients. In addition, physicians may prefer to use these drugs because they provide higher markups in general.

Market share for each drug is based on the data provided by Pharma Marketing Survey Research Laboratory (PMSRL), a pharmaceutical consulting firm in Japan. PMSRL publishes the *Management Strategy Dictionary* (*Keiei senryaku jiten*), which lists estimated annual sales for major drugs based on annual reports of the pharmaceutical companies and other industry sources. I calculate the sales volume for each drug using annual sales and patient-day wholesale prices. The market share for each drug was obtained by dividing the estimated patient-day volume by the potential market size.

The potential market size was computed using the *Patient Survey* (*Kanja chosa*), which contains detailed government health statistics. To compute the number of patients who are "at risk" of getting hypertension drugs, first, I computed the number of patients by age group who saw a doctor who could prescribe hypertension drugs.[31] Then, I obtained the potential market size by multiplying this number by the distribution of hypertension by age group as shown in Horibe (1996). The potential market size is about twice as large as the actual market size based on my product-level data. Because the results may be sensitive to potential market size, I checked the robustness of the results by changing this number. Qualitative results do not change regardless of the assumption.

One potential concern for the data is that the data do not cover minor drugs with small sales, including generics. I am confident, however, that the data cover the vast majority of the hypertension drugs on the market. Also, it should be noted that I do not have detailed advertising data on the pharmaceutical market. Unfortunately, these data are not available in the Japanese market. However, detailed advertising is typically high at entry and decreases over time. Thus, it is likely that the time-trend variables largely capture the effects of advertising. Beyond this, I assume that instruments discussed in Section 4 are orthogonal to the error term.

Appendix B

■ In this appendix, I will show that the proposed procedure to invert the market share function, i.e., equation (5), is a valid contraction mapping. Appendix I of BLP (1995) establishes a theorem and provides conditions that a valid contraction mapping has to satisfy. This Appendix shows that equation (5) also satisfies these conditions and is a valid contraction mapping. I closely follow the notation used in Berry (1994). The main conditions to show are:

[29] For the controversy on chemotherapy drugs, see, for example, "Drug Sales Bring Huge Profits, and Scrutiny, to Cancer Doctors." *New York Times,* January 26, 2003.

[30] The data were available from www.pharmasys.gr.jp/ (accessed August 1, 2000), but the website no longer exists as of 2007. Similar data can be obtained from pharmaceuticals and Medical Devices Agency, www.info.pmda.go.jp/.

[31] The data provide the estimate of patients for more than 60 disease categories.

A) $\forall\, \delta \in R^K$, $f(\delta) : R^K \to R^K$ is continuously differentiable, with, $\forall$ j and k,

B) $\dfrac{\partial f_j(\delta)}{\partial \delta_k} \geq 0$

C) $\displaystyle\sum_{k=1}^{K} \frac{\partial f_j(\delta)}{\partial \delta_k} < 1$

Regarding the first condition, $f(\delta) = \delta + (1-\sigma)\{\ln S - \ln s(\delta)\}$ is differentiable because $s(\delta)$ is differentiable. Next, I show $\frac{\partial f_j(\delta)}{\partial \delta_k} \geq 0$ in three parts. First, for $j = k$,

$$\frac{\partial f_j}{\partial \delta_j} = 1 - (1-\sigma)\frac{1}{s_j}\frac{\partial s_j}{\partial \delta_j} = 1 - (1-\sigma)\frac{1}{s_j}\left\{\sum_i \kappa^i \left(s^i_{j|g}\frac{\partial s^i_g}{\partial \delta_j} + s^i_g \frac{\partial s^i_{j|g}}{\partial \delta_j}\right)\right\} \tag{1}$$

where $i(=1, 2)$ denotes the type of patient. The partial derivatives inside the parenthesis are:

$$\frac{\partial s^i_g}{\partial \delta_j} = s^i_j\left(1 - s^i_g\right),\ \frac{\partial s^i_{j|g}}{\partial \delta_j} = \frac{1}{1-\sigma}s^i_{j|g}\left(1 - s^i_{j|g}\right) \tag{2}$$

Therefore,

$$\frac{\partial f_j}{\partial \delta_j} = 1 - (1-\sigma)\frac{1}{s_j}\left[\sum_i \kappa^i s^i_j \left\{s^i_{j|g}\left(1 - s^i_g\right) + \frac{1}{1-\sigma}\left(1 - s^i_{j|g}\right)\right\}\right] = \frac{1}{s_j}\sum_i \kappa^i s^i_j s^i_{j|g}\left\{1 - (1-\sigma)\left(1 - s^i_g\right)\right\} > 0 \tag{3}$$

Similarly, for $j \neq k$, j and $k \in g$,

$$\frac{\partial s^i_g}{\partial \delta_k} = s^i_k\left(1 - s^i_g\right),\ \frac{\partial s^i_{j|g}}{\partial \delta_k} = -\frac{1}{1-\sigma}s^i_{j|g}s^i_{k|g} \tag{4}$$

Thus,

$$\frac{\partial f_j}{\partial \delta_k} = \frac{1}{s_j}\sum_i \kappa^i s^i_j s^i_{k|g}\left\{1 - (1-\sigma)\left(1 - s^i_g\right)\right\} > 0 \tag{5}$$

Finally, for $j \neq k$, $j \in g_j$, $k \in g_k$, the partial derivatives reduce to:

$$\frac{\partial s^i_{g_j}}{\partial \delta_k} = -s^i_{g_j}s^i_k,\ \frac{\partial s^i_{j|g_j}}{\partial \delta_k} = 0 \tag{6}$$

Therefore, in this case,

$$\frac{\partial f_j}{\partial \delta_k} = (1-\sigma)\frac{1}{s_j}\sum_i \kappa^i s^i_j s^i_k > 0 \tag{7}$$

Thus, I have shown that $\frac{\partial f_j}{\partial \delta_k} > 0$, with, $\forall$ j and k.

The last step is to prove the third condition, i.e., $\sum_{k=1}^{K} \frac{\partial f_j}{\partial \delta_k} < 1$. Using the expressions above, we obtain:

$$\begin{aligned}\sum_{k=1}^{K}\frac{\partial f_j}{\partial \delta_k} &= \sum_{k\in g_j}\frac{1}{s_j}\left[\sum_i \kappa^i s^i_j s^i_{k|g_j}\left\{1 - (1-\sigma)(1 - s^i_{g_j})\right\}\right] + (1-\sigma)\sum_{k\notin g_j}\frac{1}{s_j}\left(\sum_i \kappa^i s^i_j s^i_k\right)\\ &= \frac{1}{s_j}\left[\sum_i \kappa^i s^i_j\left\{1 - (1-\sigma)(1 - s^i_{g_j})\right\}\right] + (1-\sigma)\frac{1}{s_j}\sum_i \kappa^i s^i_j\left(1 - s^i_{g_j} - s^i_0\right)\\ &= \frac{1}{s_j}\sum_i \kappa^i s^i_j\left\{1 - (1-\sigma)s^i_0\right\} < 1\end{aligned} \tag{8}$$

QED. Hence, $f(\delta)$ is a valid contraction mapping.

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