COMPETITION AND MARKET POWER IN PHYSICIAN PRIVATE PRACTICES

TIMOTHY S. GUNNING*
ERNST & YOUNG LLP
TRANSFER PRICING & ECONOMICS
5 TIMES SQUARE
NEW YORK, NY 10036

ROBIN C. SICKLES
RICE UNIVERSITY
DEPARTMENT OF ECONOMICS
6100 MAIN STREET SOUTH
HOUSTON, TX 77005

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Abstract

This paper presents a theoretical and empirical model that examines competition in physician private practices using a conjectural variation framework. Our study uses the 1998 American Medical Association Socioeconomic Monitoring Survey and tests for the degree of collusion and market power in physician private practices. The year 1998 is of particular interest due to charges filed in Federal court by The United States Department of Justice against a number of large physician practices, ruling that physicians could no longer engage in joint negotiations. The indictments by the Department of Justice were based on anecdotal economic and legal observations rather than the result of empirical evidence from accepted econometric modeling. Our model indicates that the behavior of physicians in medical subspecialties and surgical subspecialties is consistent with a Nash game in prices.

Keywords: physician, multi-product cost function, competition, conjectural variation
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* Corresponding author, telephone: 1-212-773-5866, e-mail: timothy.gunning@ey.com

1 INTRODUCTION

Healthcare in the United States has received extraordinary attention from both a political and fiscal perspective. Some estimates suggest the U.S. Government will spend in excess of $560 billion on its two healthcare programs – Medicare and Medicaid – accounting for approximately twenty percent of all U.S. Government spending and five percent of gross domestic product. Estimates by the Congressional Budget Office (CBO) indicate that if the current per enrollee spending trend should continue, the cost of the two federal programs would exceed twenty percent of the nation's gross domestic product by the year 2050, as a result of (1) rising illness rates in metropolitan areas and (2) an increase in the demand for publicly subsidized healthcare funds to properly treat the poor population.[1] The 2008 budget proposal from the Bush Administration recommended decreasing Medicare's budget in an attempt to eliminate the inefficiencies and the alleged overspending of the system. In contrast, the Obama Administration suggested that a spending shock and increase in government resources or reforms would result in a more efficient system going forward. An example of proposed reforms is electronic health record incentives, a revision of Medicare's reimbursement payment mechanism, and an updating of the Center for Medicaid and Medicare Services (CMS) resource-based relative value scale (RBRVS) index.[2]

At the heart of this debate is the role of public versus private insurers and the impact that reimbursement schedules have on reimbursing physicians and hospitals at

[1] See CBO Testimony before the Committee on the Budget (U.S. House of Representatives), "Performance Budgeting: Applications to Health Insurance Programs and Tax Policy", September 20, 2007.
[2] Pham, Ginsburg, Verdier (2009).

competitive rates. Physicians and hospitals are the largest recipients of reimbursements by third party payers (public and private). Consequently, physician markets and physician reimbursement pricing have undergone a great deal of scrutiny, with patients petitioning that fees are too high and physicians countering that reimbursements do not recover their true cost of service and a competitive profit margin. This paper seeks to address those concerns.

Physician productivity has been examined to a modest extent dating back to Reinhardt (1972) with his production function specification. Gaynor and Pauly (1990) concluded that physician experience ultimately drives productivity in their study of physician partnerships, while Escarce and Pauly (1998) presented a theoretical model for estimating the marginal cost of certain physician services. Thurston and Libby (2002) and Gunning and Sickles (2011) examined physician productivity in the United States, and Sarma et al. (2010) performed a complementary study in their examination of physician private practices in Canada. Surprisingly, market competition models that examine physician private practices in an industrial organization context are quite sparse. McCarthy (1985) and Wong (1996) found evidence of monopolistic competition in the primary-care physician service market, while Gunning and Sickles (2011) suggest physician markets may exhibit more significant forms of market power based on an examination of price and marginal cost.

Before one can properly examine the market structure of physician private practices, it is first essential to understand how physicians collect revenue. A substantial percentage of Medicare and Medicaid payments are paid directly to physicians as a form of reimbursement payments for "reasonable costs" or "customary charges". Physicians are reimbursed for their services by way of a geographic practice cost index (Zuckerman et al., 1990) and the relative-value unit (RVU) for the cost of service. The geographic practice cost index (GPCI) is designed to control for pricing differences by geography, while the RVU weighting mechanism is used to examine the relative amount of resources necessary across service specialties to perform a given service. The result is the Resource-Based Relative Value Scale (RBRVS) – the government-based method for reimbursing physicians for their services. Meanwhile, private insurance companies reimburse physicians based on negotiated discounts that are agreed upon with physicians before performing the service (Kralewski et al., 1987). These substantial discounts can be equally, if not more problematic for a physician as the RBRVS.

This study is interested in examining the implications of the physician market structure as it relates to collusion and whether certain legal action can be corroborated by physician-level data. We are specifically interested in examining the year 1998, when the Department of Justice (DOJ) brought action against a number of large physician practices alleging that their cooperative efforts within- and between-networks led to Sherman antitrust violations. The DOJ ultimately concluded that physicians and physician groups do not have the authority to collude in negotiations with third-party payers, implying that physicians maintain a high, and in certain cases, illegal degree of market power.[3] As a result, certain physician groups continue to face strict regulatory guidelines – as recent as February 3, 2010 – with the FTC settling a case against a group

[3] See United States vs. Marshfield Clinic or United States vs. Federation of Physicians and Dentists, Inc.

of Colorado physicians that allegedly coordinated among members to set higher reimbursement prices; a direct violation of Section 5 of the FTC Act.[4] Moreover, the FTC has invested time in testifying before state legislatures to prevent the passing of certain physician-led legislation that would legalize physician collective bargaining.[5] Thus, the years following the action by the DOJ have been critical and have had a notable impact on physician pricing.

2 BACKGROUND AND ORGANIZATION OF THE PAPER

Before the action by the U.S. Government, physician networks and physician independent practice associations (IPAs) were growing at unprecedented rates. Haas-Wilson and Gaynor (1998) summarized the effects of the physician private practice market by noting that as of 1996, there were 4,000 IPAs with approximately 300 physicians each, up from 1,500 in 1990. Prior to 1998, some argued that the increase in physician networks was a response to a change in market structure and not due to a strategic attempt to manipulate economic surplus.[6] Prior to an inquiry by the Federal Trade Commission (FTC), it was believed that the market for physician services experienced monopolistic competition, with procedure pricing closely approximating marginal cost. However, the large increase in the number and size of practices, along with the rising difficulty to negotiate a fee-for-service by insurance companies, caused

[4] See "*In the Matter of Roaring Fork Valley Physicians I.P.A., Inc., FTC, File No. 061 0172 (Feb. 3, 2010)*" and "*FTC Settles Physician Collusion Claim: Changes Needed to Facilitate Delivery Models*", Eisenberg (2010).

[5] See *"The Threat of Consumer Harm Resulting from Physician Collective Bargaining under Alaska Senate Bill 37."*

[6] For example, Gaynor and Pauly (1990) and their conclusions regarding physician partnerships and productivity.

considerable speculation that the physician marketplace may exert a significant degree of market power on patients.

Haas-Wilson and Gaynor (1998) explained the potential effects of physician market power by noting that horizontal consolidation by physicians may facilitate two types of collusion: (1) within-network collusion and (2) across-network collusion.[7] For example, prior to government intervention in California, the California Healthcare Association predicted there could be as little as three to seven healthcare networks in the entire state over the course of the next decade.[8]

There are a number of factors that may contribute to physician collusion. Certainly, if physicians observe a highly sensitive demand for their services, or equivalently, if healthcare payers are highly responsive to a change in service price, then physicians may collude and share profits rather than engage in a market game of competition. Moreover, since the current healthcare structure is driven by large third-party payers, physicians may find it more efficient to engage in joint-price negotiations.[9] The contractual negotiation process of the physician and third-party payer is a costly one. Large networks provide an incentive for the physician to lower their costs, resulting in economies of scale with respect to network size. Hence, it is essential to determine whether large physician network size is a reflection of a deliberate attempt to manipulate the competitive pressures of the marketplace or whether it is merely a byproduct of a powerful third-party payer system.

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[7] The case by the federal government focused on the former, yet the latter is also problematic.
[8] "California Healthcare 1997 to 2005: A Millennium View of the Future.
[9] We note this may influence the efficiency of the contractual negotiation process, but not necessarily economic efficiency as a whole.

This paper examines the economic behavior of the physician private practice marketplace and explores the DOJ's claim that physicians possessed a high degree of market power in 1998. The paper is organized as follows: Section 3 provides our theoretical model and Section 4 provides the econometric specification. Section 5 discusses the data and how the data were constructed. We present our estimation method and our empirical results in Section 6 and conclude in Section 7.

3 MODEL

Our model is motivated by the market competition theoretical framework detailed in Bresnahan (1989).[10] An analogous theoretical framework has been applied to test the degree of competition across a variety of industries.[11] We discuss our application of Bresnahan's (1989) model throughout this section.

In a seminal theoretical contribution by Escarce and Pauly (1998) and a subsequent empirical application by Gunning and Sickles (2011), the authors conjecture that physician labor supply is the result of a utility maximization problem by the physician. The authors examine the physician production model in the context of a self-employed entrepreneur, resulting in physician labor acting as an endogenous input into the production process. Consequently, the endogeneity of physician labor implies

[10] See Perloff et al. (2007) for similar models.

[11] For example, see Graddy (1994), Alexander (1998), Captain and Sickles (1998), Wolfram (1999), Steen and Salvanes (1999), Roeller and Sickles (2000), and Bikker and Haaf (2002). The recent work by Puller (2007) uses a model reminiscent of Bresnahan (1989) to study the electricity market in California.

physician time is quasi-fixed in the short-run. From a theoretical perspective, this translates to physician time being close to its optimal level of supply.[12]

The result is a two-stage utility-maximization problem, with physician time optimized in the first stage, followed by the maximization of physician utility in the second stage. A brief overview of the theoretical framework developed by Escarce and Pauly (1998) and illustrated by Gunning and Sickles (2011) follows.

The physician seeks to minimize a cost function of physician and non-physician inputs, subject to a certain technological constraint,

$$\text{(1)} \qquad \min \sum W_i X_i \quad \text{subject to} \quad G(Y, X, T) \leq 0 .$$

In equation (1), *G* represents the transformation function of the production technology and *Y* represents the measures of output produced by the physician.[13] The input prices determined by the market and faced by the physician are *W*. In theory, *W* would correspond to their respective quantities of input (*X)*. The annual hours of labor the physician selects is represented in the model by *T*. The solution to the optimization problem in equation (1) yields the cost function,

$$\text{(2)} \qquad C = C(Y, W, T)$$

where *C* is the summation of practice costs incurred by the physician for his or her production of services.

The physician labor supply function is represented by:

[12] Gunning and Sickles (2011) noted that the empirical interpretation of the theoretical model is essentially an acknowledgement of temporary disequilibria as a result of the quasi-fixed input. These disequilibria may be a result of uncontrolled fluctuations in demand.
[13] Our choice for outputs is physician office visits; however, we defer that discussion to a later section. For a discussion of alternative outputs and their application in static and intertemporal models of health production, see Sickles and Taubman (1997), Behrman et al. (1998), and Sickles and Yazbeck (1998).

(3) $$T = T(Y, W).$$

Output prices (Y) and input prices (W) are defined in equation (1). In addition to the practice-level characteristics in the cost function, the labor supply equation includes physician-level characteristics that are expected to influence the supply of physician services, independent of their effect on non-physician costs.

With respect to the demand for physician services, consumers face K physicians producing a differentiated output, $Y = (Y_1, Y_2, \ldots, Y_K)$. It is assumed that patients have access to a reasonable amount of information with respect to the K physicians and therefore have the ability to observe differences in quality, yielding asymmetric residual demand functions for each of the K physicians.[14] The residual demand function for the services provided by physician k is:

(4) $$Y_k = Y_k(p_k, s_k)$$

where p_k is the price faced by the patient for an office visit with physician k and s_k is a vector of variables that shift demand.[15] Perceived marginal revenue is

(5) $$PMR = p_k + (D_k \cdot Y_k),$$

where $D_k = \dfrac{\partial p_k}{\partial Y_k}$.

In theory, the physician selects an amount of output such that $MC = PMR$. Therefore, the equilibrium condition facing physician k is:

[14] Those quality differences are experience, gender, and specialty. We explain this in more detail in Section 4 and 5. It has been proposed that malpractice insurance data would be the most appropriate proxy for quality; however, that presumes such data are available to all patients across all physicians and patients can consult the data prior to visiting a physician. Moreover, the availability of malpractice data is limited.

[15] We note that p_k is the revenue received by physician k for his/her service and not necessarily the price paid by the patient. We discuss this in a later section.

(6) $$\frac{\partial C(Y_k, W_k, T_k)}{\partial Y_k} = p_k + (D_k \cdot Y_k) \cdot \theta .$$

We include the parameter θ as a measure of the degree of competition faced by the physician which can be used to derive the behavioral equation. Bresnahan (1989) demonstrates that under symmetry in costs, the behavioral equation reduces to:

(7) $$p_k - MC_k = \frac{Y}{\frac{\partial Y}{\partial p}} \theta ,$$

where the term on the left, $p_k - MC_k$, indicates the mark-up by the physician.

4 ECONOMETRIC SPECIFICATION

This section presents the background and details of the econometric model. The econometric model is a system of equations derived from the theoretical model in the prior section, and estimates the price, output, and degree of competition in the physician private practice market.

Gunning and Sickles (2011) proposed a generalized Leontief multi-product cost that is locally flexible and places no *a priori* restrictions on factor substitution elasticities. Prior to that, Li and Rosenman also (2001) highlighted the advantages of the Leontief in their examination of production function flexibility in the hospital industry. When examining either physician or hospital data, the treatment of true zero values is an important discussion due to many physicians and hospitals specializing in certain procedures, resulting in zero production for certain outputs. For example, the transcendental logarithmic (translog) is convenient in the presence of non-zero outputs as it readily handles the necessary theoretical restrictions and it is easy to interpret estimated coefficients; yet without certain transformations or assumptions made for zero values, the translog becomes problematic.[16] In contrast, the globally flexible Symmetric Generalized McFadden (SGM) developed by Diewert and Wales (1987) is more flexible than the translog and tends to handle zero outputs quite well. However, the need to impose global concavity may reduce the inherent flexibility of the SGM. We found this to be the case in our examination; resulting in our estimates being unstable as well as having little economic interpretation under the SGM.

As noted by Guilkey, Lovell, and Sickles (1983), the most appropriate functional specification is ultimately determined by the underlying data. We found that the generalized Leontief provides the best theoretical representation of the physician data and the underlying production technology due to its ability to handle true zero values in the output terms and the ease of calculating input substitutability. Our specification is reminiscent of the multi-product generalized Leontief cost function used by Li and Rosenman (2001) and Gunning and Sickles (2011), thus reconciling issues related to true zero outputs.[17]

The econometric specification for the cost equation faced by the physician is modeled by the non-homothetic generalized Leontief below:

[16] See Christensen et al. (1971) and Berndt and Christensen (1979).

[17] The work by Li and Rosenman (2001) was a key extension from the single output setting to the multi-output setting as it relates to health services.

$$
C(Y,W,T) = \alpha_T T + \sum_{i=1}^{4}\left(\sum_{j=1}^{3}\sum_{k=1}^{3}\alpha_{i,j,k} W_j^{\frac{1}{2}} W_k^{\frac{1}{2}}\right) Y_i + \sum_{i=1}^{4}\sum_{j=1}^{3}\beta_{i,j} W_j Y_i + \sum_{i=1}^{4}\left(\sum_{j=1}^{3}\varphi_{i,j} W_j\right) Y_i^{2} + \sum_{1 \le i < l \le 4}\sum_{j=1}^{3}\varphi_{j,i,l} W_j Y_i Y_l + \sum_{j=1}^{3}\gamma_j W_j + \Gamma + \Psi \quad (8)
$$

In equation (8), *Y* are the measures of output: annual office visits with established patients, new patients, emergency room trips, and hospital rounds.[18] Input prices, *W*, are for the cost of office rent, payments to non-physician employees (i.e., nurses, surgical technicians, and clerical support), and malpractice insurance costs (i.e., premiums and pay-outs), and correspond to their respective quantities of input (*X)*. The annual hours worked by the physician are *T*. Practice controls for whether the physician practices in a metropolitan location and if the physician is board-certified are contained in Γ. In addition, we include the percentage of patients that pay with Medicaid to control for patient demographics and a variable for the number of physicians in the practice to control for practice size. The four physician-reported variables are represented by Ψ and describe the area of physician specialization: general practice, medical specialty, surgical specialty, and a fourth category for all specialties not indentified in the first three categories.[19] The generalized Leontief is homogeneous in input prices by construction and symmetry is imposed prior to estimation. The flexible nature of equation (8) allows us to test the potential non-linearity of marginal costs and the presence of scale economies. Scale economies are tested by recovering and

[18] As noted by Gunning and Sickles (2011), hospital visits may be endogenous if physicians can accurately plan the time they commit to a hospital setting. This was tested by performing a Durbin-Wu-Hausman test, which resulted in our rejection of endogeneity. This is most likely attributable to the unpredictable forecast of the consult time required in a hospital setting as a result of complex patient needs.

[19] This represents approximately 7% of the sample.

inverting the elasticities of output as demonstrated by Panzar and Willig (1977). Scope economies are tested by recovering and examining the cross-product terms to test the presence of weak cost complementarities, consistent with Vita (1990). We examine scale and scope economies in more detail in Section 6.

Input demand equations are derived to improve the efficiency of the estimation of the cost function. The unconditional factor demands for the inputs are derived by differentiating the cost function with respect to each input price.[20] The factor demand equation for any factor price (W_k) is generally represented by:

(9)

$$X_j = \frac{\partial C}{\partial W_j} = \frac{1}{2}\sum_{i=1}^{4}\left(\sum_{j=1}\alpha_{i,j,k}\frac{W_k^{\frac{1}{2}}}{W_j^{\frac{1}{2}}}\right)Y_i + \sum_{i=1}^{4}\sum_{j=1}^{3}\beta_{i,j}Y_i + \sum_{i=1}^{4}\varphi_{i,j}Y_i^{2} + \sum_{1\le i<l\le 4}\sum_{j=1}^{3}\varphi_{j,i,l}Y_iY_l + \gamma_j\,.$$

As indicated in our theoretical model, *T* is the result of a utility-maximization problem by the physician; thus yielding the optimal supply of physician labor, conditional upon the prices of the non-physician inputs. The physician labor equation is also specified as a non-homothetic generalized Leontief:

(10)

$$\begin{aligned} T(Y,W) = {} & \sum_{i=1}^{4}\left(\sum_{j=1}^{3}\sum_{k=1}^{3}\alpha_{i,j,k}W_j^{\frac{1}{2}}W_k^{\frac{1}{2}}\right)Y_i + \sum_{i=1}^{4}\sum_{j=1}^{3}\beta_{i,j}W_j + \sum_{i=1}^{4}\left(\sum_{j=1}^{3}\varphi_{i,j}W_j\right)Y_i^{2} \\ & + \sum_{1\le i<l\le 4}\sum_{j=1}^{3}\varphi_{j,i,l}W_jY_iY_l + \sum_{j=1}^{3}\gamma W_j + \Gamma + \Psi + \zeta \end{aligned},$$

[20] i.e,. Shepherd's Lemma

where ζ are physician-specific heterogeneity controls. We include linear and quadratic terms for age and years of experience.[21] Our decision to model the labor equation with essentially the same flexibility as the cost function is due to the supply of physician labor facing many of the same economic conditions that the cost function faces; though not subject to the imposed restrictions. Clearly, a simple linear or quadratic specification could have been selected instead of equation (11); however our identification strategy and the overall performance of the joint estimation are influenced by the endogeneity of physician labor supply. Our identification strategy relies upon the estimation of the physician labor supply model presented by Escarce and Pauly (1998) and Gunning and Sickles (2011). We also test for homotheticity, with our results suggesting significant price and output interaction.[22]

The demand specification is best approximated using the information perceived by the average consumer when selecting a physician. Much of our demand specification is ultimately determined by the availability of market-level physician data; a discussion we defer to Section 5. In summary, we seek information on market prices, geography, experience, a proxy for whether the physician accepts Medicare or Medicaid, and the degree of physician specialization:

$$\begin{aligned} Y(P) = {} & \beta_P P + \beta_{P^2} P^2 + \beta_{EXP} EXP + \beta_{EXP^2} EXP^2 + \beta_{GEN} GENDER + \beta_{MET} METRO \\ & + \beta_{MED} MEDCAID + \sum_{i=1}^{4} \beta_{SPEC_I} SPEC_i \end{aligned} \qquad (11)$$

[21] Alternatively, the age and experience variables could be modelled using dummies for all age and experience classifications; however, this alternative fixed effect treatment led to poor or nonexistent identification of coefficients on variables that do not change much over the dimension of the dummy variable categories. Therefore, we selected the specification detailed in equation (10).

[22] We defer this discussion to Section 6.

In equation (11), *P* is the average revenue the physician receives for a single office visit. After first testing a linear specification, we selected a quadratic specification in price as this had more predictive power.[23] The physician's level of experience is measured in the *EXP* and EXP^2 variables and is entered into the specification in levels by years. The *METRO* variable is a dummy variable capturing whether the physician practices in a metropolitan location. We include the *MEDCAID* variable that measures the percentage of patients that pay with Medicaid to control for whether the physician accepts government reimbursements and to approximate patient load with respect to servicing the poor population. The four fields of specialty are controlled by dummy variables ($SPEC_i$).

We append additive error terms to the cost, share, labor and demand equations, and estimate the system of equations jointly. The estimation and identification of the system is discussed in detail in Section 6.

5 DATA

The data for this study are from the 1998 American Medical Association (AMA) Physician Socioeconomic Monitoring Survey (SMS) and the 1998 GPCI originally proposed by Zuckerman et al. (1990). We summarize our data in Table 1. The SMS is an annual telephone survey designed to provide information on non-federal physicians practicing in the United States. The SMS survey is based on the AMA's random selection of member physicians from the AMA Physician Masterfile – a historical index for the

[23] Perloff and Shen (2001) demonstrate that the market competition model by Bresnahan (2001) suffers from collinearity issues when restricted to a linear system of cost and demand.

United States physician population. The SMS data have long been considered the most comprehensive data source of their kind, appearing in studies by Wong (1996), Escarce and Pauly (1998), and Gunning and Sickles (2011). In addition to academic research, the AMA data have been used to study a number of policy and government initiatives. The study was constructed by surveying 3,700 physicians that practice exclusively in the United States. The survey is geographically comprehensive and occupationally detailed, reporting on key physician, practice, and demographic characteristics.

The total cost variable is constructed by summing the non-physician employee payments as they relate to malpractice insurance expenses and office expenses, as reported by the physician. Non-physician employee payments include secretarial support, nurses, and assistants. Insurance expenses consist of malpractice premiums and any additional malpractice costs associated with the practice.[24] Office expense is the cost of leasing, renting, or owning the infrastructure in which the practice is located. The office expense variable also includes rent expense as it relates to the lease or ownership of capital. The SMS derives the components of the cost variable by asking the physician to report their respective costs incurred by the practice. The costs reported by the physician are often a rough estimate, rather than a detailed reconciliation of the practices' financial records. We interpret the summation of costs reported by the physician as the total costs related to the practice as a whole and not the individual physician.[25]

[24] Malpractice insurance may include legal fees associated with malpractice cases.

[25] We control for the variations in cost due to practice size by including a practice size variable in the cost specification.

The physician labor variable is constructed by multiplying the average hours worked per week, as reported by the physician, by the number of hours practiced in the 1998 calendar year. We use the same methodology to construct the four outputs in the cost function – established patient office visits, new patient offices visits, hospital visits, and emergency room visits – by multiplying reported weekly outputs by the number of weeks the physician worked in the year.

The Medicaid variable represents the percentage of patients that pay with Medicaid.[26] The age and experience variables are reflected in levels, thus allowing the model to capture both the level and squared level effects. We include age and experience due to the nature of the data. In particular, physician specialties tend to have a great deal of variance with respect to the duration of residency programs and post-doctoral training.[27] The price variable represents the average total revenue collected from an office visit with an existing patient (including third party remunerations).[28] All demographic and sociological characteristics considered in our study are reported by the physician and are detailed in Section 4.

The SMS does not contain information on the price physicians pay for practice inputs. Zuckerman et al. (1990) developed the GPCI as a means for estimating various practice components using a relative scale. The GPCI is a normalized Laspeyres index designed to control for price fluctuations in health markets by assigning weighted values

[26] We sought to include a Medicare variable by taking a similar approach; however, lack of data prevented its inclusion.

[27] For instance, an internist may serve a two-year residency, while a neurosurgeon may spend eight years in post-doctoral training.

[28] Retail pricing is a term used to characterize the price a physician would solicit before any insurance or government discounts. Physicians are rarely compensated at retail rates.

to three key categories that drive physician costs: average office rents, salary and hourly wages for non-physician employees, and the average price paid for malpractice insurance premiums. The GPCI is one of two components used to calculate the RBRVS for the purpose of reimbursing physicians for services rendered on behalf of patients that pay with Medicare or Medicaid. Our study uses the three components of the GPCI as a means for approximating the input prices that appear in the cost and labor equations.

The AMA survey seeks to interview a distribution of physicians with characteristics consistent with that of the general physician population. However, the survey is limited to the extent that the distribution of respondents may be inconsistent with the underlying physician population. Similarly, our selection of data is dependent upon physicians responding to key questions. Of the 3,700 physicians reported in the AMA survey, we considered only those physicians that practice at least 20 hours per week in a private practice setting and report their full practice costs. Moreover, respondents that spent the majority of their time in a hospital or a school setting were not considered for this study. While these restrictions limited our sample size, it resulted in a sample of physicians with complete information, which was critical to performing an informative analysis.[30] Our final sample is based on 939 AMA-member physicians practicing in the United States.

[30] To ensure our sample was consistent with the AMA sample, we tested the mean of our sample against a random draw of data from the survey. There were a number of variables that had statistically different means, yet by inspection, we found the only noticeable differences were with respect to the physician count number, implying that physicians surveyed from larger practices were more inclined to not respond to questions related to practice cost, and our sample had more specialists than generalists.

6 Estimation and Results

We estimate a five-equation system using the cost equation (8), two of the three input demand equations (9), the physician labor equation (10), and the demand equation (11). Additive error terms are appended to the cost, share, labor, and demand equations and are assumed to be normally distributed. The system of equations is estimated via three-stage least squares (3SLS).[32] Table 2 and 3 provide parameter estimates with robust standard errors in parentheses.

Escarce and Pauly (1998) and Gunning and Sickles (2011) demonstrate that the physician characteristics unique to the physician labor equation but excluded from the cost equation, identify the cost function. Specifically, they are control variables for the gender of the physician and linear and quadratic controls for age and experience (ζ). Our motivation to exclude these demand shifters as a means for achieving identification is based on the observation that the variable costs (e.g., nursing staff and clerical support) included in the total cost variable are not significantly affected by the age or the experience of the physician. We tested our assumption by performing a regression test on the overidentifying restrictions and found that these restrictions could not be rejected (χ^2 =8.46; p=0.58); thus implying that the cost equation was sufficiently identified. To test for the presence of strong instruments, we calculated the Stock-Yogo

[32] The ordinary least squares (OLS) estimator was used to perform sensitivity tests on the demand equation; however, was not appropriate in lieu of our model being a system of equations and the endogeneity of physician labor. Two-stage least squares (2SLS) was considered, but rejected in favor of the 3SLS estimator, with the latter being at least asymptotically equivalent. It is also worth noting that in our case, the 3SLS is asymptotically equivalent to the Generalized Method of Moments (GMM) estimator. We thank an anonymous referee for pointing out the importance of this discussion.

critical values and tested the results against both the Kleibergen-Paap F-statistic and the Cragg-Donald F-statistic.[33] The two F-statistics were significantly higher than the 5% Stock-Yogo critical values of maximal size and relative bias, indicating our instruments are sufficiently strong.

The demand equation is identified vis-à-vis exclusion of the input prices.[34] Our motivation to exclude input prices as a means for achieving identification is based on our understanding that patients do not explicitly observe the rent, staffing cost, or malpractice premiums paid by physicians. Moreover, our input price index is a relative index, constructed using geographic data and hence does not determine the actual market price solicited to consumers for physician services.

The cost function maintains all of the theoretical properties implied by economic theory – it is linearly homogeneous in prices by construction and symmetry in factor prices is imposed prior to estimation. The cost function is concave in the three factor prices and in the quasi-fixed factor. We test the null hypothesis of non-homotheticity of the cost equation and the labor supply equation and reject it at the 1% level, implying there is significant evidence of price/output interaction.[35]

[33] See Stock and Yogo (2005), Kleibergen-Paap (2006), and Cragg and Donald (1993).

[34] We also calculated a Lagrange multiplier test statistic and our results (p=.9970) meet the conditions for weak instrument testing. Moreover, Moreira (2001) suggests the Conditional Likelihood Ratio test, as proposed in Andrews, Moreira, and Stock (2006) outperforms the Anderson-Rubin test in power simulations. Therefore, we performed the Conditional Likelihood Ratio test as well, with our result also generating a critical value (p=.9752) that rejects the hypothesis that the instruments are insufficient from a weak instrument hypothesis test perspective.

[35] The demand for physician services is contained in the cost function and the labor supply equation. Since output price is a function of office visits, we treat the output price variable in the demand equation as endogenous.

We report our measures for the cost of physician services at the margin and the opportunity cost of an hour of physician time in Table 4. There are a number of approaches for deriving an average estimate using the estimated coefficients from the explanatory variables in the cost function. The traditional approach is to derive marginal cost estimates at the mean by taking the estimated coefficients from the cost equation and the mean estimates from the data; thus backing into a point estimate with standard errors obtained via the delta method. We preferred the alternative approach undertaken by Li and Rosenman (2001) which consists of using the parameter estimates from the cost equation to obtain a unique marginal cost for each of the observations. The second approach tends to produce less error when dealing with non-linear marginal costs. Specifically, we use the estimated coefficients from the cost equation to recover the marginal costs by physician for output Y_i:

(11) $$\frac{\partial C}{\partial Y_i} = \sum_{j=1}^{3} \beta_{i,j} W_j + 2Y_i \left(\sum_{j=1}^{3} \varphi_{i,j} W_j \right) + \sum_{i \neq l} Y_l \left(\sum_{j=1}^{3} \varphi_{j,l} W_j \right),$$

where $\frac{\partial C}{\partial Y_i}$ represent the *S* data points for output Y_i. The *S* data points are then averaged over the sample with standard errors appearing in parentheses below the estimates:

(12) $$\frac{\partial C}{\partial Y_i} = \frac{\sum_{s=1}^{S} \left(\frac{\partial C}{\partial Y_i} \right)_s}{S}.$$

Our data set is limited in size and the number of terms in our system of equations makes it difficult to estimate the system by specialty. Instead, we estimated the entire sample and segmented the individual marginal cost estimates by specialty. We then grouped the marginal cost estimates by their respective specialty and averaged over the samples, resulting in marginal cost estimates by specialty, with all four group yielding significance at the 1% level.

Our results indicated that the marginal cost to the physician for an additional visit with an established patient is $27.23 and the additional cost of an office visit with a new patient is $75.97. Office visits with new patients are almost three times the cost (at the margin) of office visits with established patients, which is most likely attributable to the time the physician must take to learn the patient's medical history and the administrative and clerical cost associated with processing new medical records. Emergency room visits at the margin are quite low, $26.91, and is most likely due to the patient-related clerical burden borne by the hospital. We note that this cost is roughly half that of an hour of physician labor, implying that emergency room visits last approximately 30 minutes. Our results indicated that hospital visits cost approximately $16.32 at the margin. We suspect the relatively low hospital estimate is due to physicians performing scheduled hospital rounds that involve visiting many patients at a time. Moreover, we note that it is quite common for a physician to spend only a short period of time with a patient during a routine hospital round.

We interpret the estimated labor coefficient from the cost function as an estimate for the marginal cost for an additional hour of physician labor, holding all other factors constant. The estimated labor coefficient is negative, consistent with theory, implying that the physician would have to substitute his or her labor to lower total practice costs while maintaining the same level of productivity. Our estimate for the marginal cost of an additional hour of physician labor is $52.87 in 1998 dollars.[36]

Table 5 reports measures for the elasticity of output. We selected the number of office visits with existing patients as our output variable. Many of the physicians in our sample do not spend a great deal of time in a hospital setting and new patient office visits are not necessarily a genuine approximation for physician demand. Therefore, we used established patient office visits to approximate consumer demand. As expected, the demand equation is downward sloping and the estimated coefficient on the linear price term is significant at the 5% level. The results indicate high consumer sensitivity with respect to a change in the price of an office visit across all specialties. From the patient's perspective, the result may seem rather anomalous: the majority of patients pay a fixed copayment and therefore in theory, demand should be almost perfectly inelastic; especially in the case of a single office visit. However, the price variable in the demand equation represents the entire price of the office visit, not just the percentage paid by the consumer. Therefore, the measure of high price sensitivity is most likely an indication of the third-party payers' willingness to substitute existing physicians for less costly physicians when determining the services to make available to their subscribers. The point estimates for the elasticities of demand at the mean are all significant at the 1% level. The average price-elasticities generated from the demand equation range from -2.35 to -1.75 by specialty.

[36] Our point estimates for marginal cost and physician labor are consistent with those of Gunning and Sickles (2011).

We now turn our attention to the competition parameter, θ, reported in Table 5. We use our methodology for deriving the marginal costs reported in Table 4 as a means for recovering estimates for θ. Specifically, we estimate the competition parameter by recovering a unique measure for θ for each of our 939 observations by substituting the estimated coefficients from our system of equations into equation (7) and solving for θ. We then grouped our 939 estimates of θ based on the four categories of specialty and averaged the four sub-samples of physician to derive a representative point for the competition parameter by specialty. We note that this is identical to the methodology performed by Li and Rosenman (2001) and presented in equation (12) for deriving non-linear marginal cost estimates. Identification of θ is achieved by identification of the parameters in the system of equations. We test the null hypothesis of perfect competition by first estimating θ using the full sample of 939 physicians. In doing so, we *strongly* reject the null hypothesis of perfect competition, implying that our sample of physicians exhibit a form of imperfect competition (θ=-1.34). Bresnahan (1989) explains that θ equating to zero is a necessary and sufficient condition for perfect competition. A sufficient condition for a Nash reaction-based form of collusion is when $|\theta|$=1.

For medical subspecialties, surgical subspecialties, and "other" specialties, we fail to reject the hypothesis of a Nash game at the 1% level, implying that all specialties, with the exception of the general practice specialty, exhibit behavior consistent with a Nash outcome. We reject the hypothesis of a Nash equilibrium for general physicians, with a point estimate of θ = -1.97 (S.E. = 0.24); however, we note that the average markup over marginal cost is substantial, implying that physicians in general practice still may exhibit a high degree of market power, though their behavior may not be identified as collusive or reactionary. The average markup for an office visit with an established patient is approximately 140% over marginal cost. Our results imply there is evidence that physicians practicing in medical subspecialties, surgical subspecialties, and "other" specialties may strategically act in a reaction-based form of collusion, as indicated by our estimates of θ and the considerable differentials in price and marginal cost at the mean.

We can also test scale and scope economies by using the parameter estimates from the supply and labor equations to calculate ray returns. Escarce and Pauly (1998) and Gunning and Sickles (2011) found evidence of increasing returns to scale with respect to physician outputs.[37] Panzar and Willig (1977) first showed that ray economies of scale for a production process with a quasi-fixed factor can be calculated as follows:

(13)
$$\Psi = \frac{C\left(W, Y, T^*\right) - T^*\left(\frac{\partial C}{\partial T}\right)}{\sum_{i=1}^{4} \frac{\partial C}{\partial Y_i} \cdot Y_i}.$$

Ray economies of scale are tested by inverting the sum of the elasticities of output as expressed in equation (13) above. A value greater or less than one implies a greater or less than proportional expansion along the vector of physician outputs, respectively.

[37] We note that testing for scale economies with respect to practice size could be achieved by constructing a similar test; however, data restrictions prevented our ability to do so. See Cowing, Holtmann, and Powers (1983), Kass (1987), Vita (1990), and Gaynor and Vogt (2000), for a review of returns to scale in health services.

Due to the high degree of market power in the physician services industry, we suspect high returns to scale. Our results yield a point estimate of 2.76 (S.E.=0.18), indicating substantially high ray increasing returns. Empirically this translates to a 10% increase in output requiring only a 3.6% increase in practice cost. Alternatively, our estimate can be viewed as 36% of practice costs varying directly with physician output, while the remaining 64% are fixed.

Economies of scope can be computed a number of ways. Vita (1990) shows that weak cost complementarities are a sufficient condition for economies of scope (i.e., if $\frac{\partial^2 C}{\partial Y_i \partial Y_j} < 0$ for all $i \neq j$) and can be tested via summation of the estimated cross-product coefficients from the cost equation and testing their significance by taking a linear Taylor series expansion to derive the asymptotic covariance matrix for the outputs, commonly referred to as the Delta Method.[38] Our results yield a point estimate of 0.059 (S.E. 0.045), implying there may be modest scope economies. However, we reject this approach for two reasons: (1) summing the estimated coefficients of the cross-product terms is simply a sufficient condition for scope economies and does not provide any economic interpretation for the sensitivity that private practices may exhibit with respect to specialization and (2) our estimate is unreliable due to the high standard error. We favor a more traditional method:

(14)
$$\Gamma = \frac{\sum_{i=1}^{4} C(y_i, 0) - C(Y)}{C(Y)}.$$

[38] Greene H., 2003. Econometric Analysis. (Upper Saddle River, New Jersey: Prentice Hall)

The above expression describes the additional cost to the practice for producing the outputs separately rather than together.[39] Our estimate yields a measure of 15.75 (S.E.=5.37), implying there is evidence of scope economies. The mean measure for scope economies implies that it would cost the average private practice 15% more to produce the four outputs separately than to produce the outputs together. Our measure for scope economies validates there are synergies in cost; however, the high standard error implies that our measure is rather volatile, with cost synergies ranging from 5% to 25%. It is important to note that our cost function controls for field of specialty — therefore, our results indicate synergies within specialties, but do not necessarily imply that physician practices exhibit scope economies across specialties.

We report recovered measures for partial own-price (ε_{ii}) and cross-price elasticities (ε_{ij}) of substitution in Table 6 (Allen, 1938) and Allen-Uzawa partial elasticities of substitution (Uzawa, 1962) in Table 7.[40] The own-price elasticities for non-physician wages and office rent have the expected sign (-) and are statistically significant at the 1% level. Physician sensitivity to non-physician wages and office rent are inelastic, which is most likely attributable to long-term contractual obligations on office rent and office equipment, and the high cost of training new staff. The own-price elasticity for malpractice insurance does not have the expected signed (+), but is statistically insignificant. The cross-price elasticity for non-physician wages and office rent is positive and significant, implying physicians may substitute technological capital for human capital – an economic decision determined by the practice. The cross-price

[39] Values of zero fall within the full range of results.
[40] Due to symmetry in prices, we report only the upper triangular matrix in Table 7.

elasticities associated with malpractice rent and non-physician wages is negative, implying that malpractice insurance is a complement to all other inputs in the physician production process. However, we use caution interpreting the malpractice cross-price elasticity with respect to office rent due to the imprecision of the estimate.

7 Conclusion

The purpose of this paper was to investigate market power across physician private practices. To do so, we employed a conjectural variation framework to test degrees of market power by fields of specialty. We estimate a multi-product cost equation, physician labor supply equation, input demand equations, and a market demand equation to derive a competition parameter across physician specializations that expands upon the generalized market power model developed by Bresnahan (1989). The competition parameter estimates suggest that the behavior of medical subspecialties, surgical subspecialties, and “other” subspecialties is consistent with a Nash game in prices.

A physician office visit is typically compensated by two separate remunerations: a fixed fee co-payment by the patient and a payment by a third-party. In the case of the latter, the U.S. government reimburses physicians based on a Medicare fee schedule that is revisited every five years by a U.S. Congressional committee. Meanwhile, insurance companies negotiate large scale contracts with physician private practices as a means for securing volume discounts in exchange for the physician receiving a steady flow of patients. As a result, physicians rely heavily on insurance and government reimbursements. Patients are fairly insensitive to price changes in the short-run due to the fixed nature of the co-payment; therefore, our finding of high price sensitivity in demand suggests that the majority of price fluctuations must be borne by the third-party payer. This may prove to be problematic for the physician, causing insurance companies to respond drastically to a proposed rise in procedure or office visit prices, yielding a significant loss in revenue to the physician. This may result in the physician colluding as a means for offsetting potential losses in response to a highly elastic demand curve. This is further suggested by the cost and physician labor equations yielding marginal cost estimates that are well below recovered office visit prices. Moreover, physician practices exhibit increasing returns to scale and scope within their respective specialties. These key measures suggest significant market power even in the presence of a large and powerful third-party payer system.

Although our empirical model cannot directly test the DOJ investigation, we interpret our results as lending empirical dialogue to a challenging and ongoing debate. Moreover, our results are consistent with prior empirical studies. For example, Escarce and Pauly (1998) estimated the marginal cost of physician services using the 1987 AMA physician survey. After adjusting for inflation, their results are consistent with Gunning and Sickles (2011) and the results we present in Table 4; thus implying that under the assumption that physician office visit prices increased by at least an inflationary level from 1987 to 1998, there may be evidence of persistent market power over that period of time.

The DOJ cites illegal price fixing as their primary motivation for action and their investigation led to a number of out-of-court settlements. The FTC continues to raise inquiries against large physician private practices in an effort to ensure physician pricing is not the result of cooperative pressures or collusion. As discussed in our introduction, Eisenberg (2010) details the result of a settlement between the FTC and a group of Colorado physicians, alleging that physicians coordinated their agreements with insurers in an effort to set higher medical prices and place demands across insurance companies. The settlement involved 80 percent of the physicians in a single county, with the FTC taking the position that cooperative efforts raised the cost of service (i.e., the fees charged by physicians). Eisenberg (2010) goes on to comment that the proposed settlement is a long line of similar actions that address collusion or improper bargaining.

The case raised by the DOJ in 1998 has had a considerable impact on the physician private practice marketplace, with the FTC aggressively pursuing action across the U.S. As compelling as the empirical evidence presented by insurers to the FTC may be, one could argue that a formal empirical study that examines physician collusion by way of physician-level data, may provide a corroboratory tool to test whether the actions taken by physicians are (1) an effort to manipulate the economic surplus or (2) simply a dire attempt to remain profitable in a time of healthcare cutbacks and rising input costs. To that extent, the results from our empirical model shed light on the DOJ's motivation and suggest that the investigations by the FTC could have been more convincing by conducting an econometric examination of market power across physician specialties, with key estimates suggesting there was collusive activity in 1998.

References

Allen R., 1938. Mathematical analysis for economists. (London: Macmillan)

Alexander D., 1988. The oligopoly solution tested. *Economic Letters*, 28, 361-364.

Andrews, D., Moreira M., and J. Stock, 2006. Optimal two-wided invariant similar tests for instrumental variables regression. *Econometrica*, 74, 715-752.

Behrman, J., Sickles, R., and P. Taubman, 1998. Causes, correlates, and consequences of death among older adults. (Springer: New York)

Berndt E. and L. Christensen, 1979. The translog function and substitution of equipment, structures, and labor in U.S. manufacturing. *Journal of Econometrics,* 1, 81-114.

Bikker J. and K. Haaf, 2002. Competition and concentration in the EU banking industry. *Journal of Banking and Finance*, 29, 2191-2214.

Bresnahan T., 1989. Empirical studies of industries with market power. In Schmalensee and R. Willig (eds.) *Handbook of Industrial Organization Volume 3* (Amsterdam: North Holland).

Captain, P. and R Sickles, 1999. Competition and Market Power in the European Airline Industry: 1976-90. *Managerial and Decision Economics*, 18, 209-225.

Christensen L., Jorgensen D., and L. Lau, 1971. Conjugate duality and the transcendental logarithmic production function. *Econometrica*, 39, 255-256.

Cowing T., A. Holtmann, and S. Powers, 1983. Hospital cost analysis: a survey and evaluation of recent studies. In R. Scheffler (ed.) *Advances in Health Economics and Health Services Research Volume 4* (Greenwich: JAI Press).

Cragg, J. and S. Donald, 1993. Testing identifiability and specification in instrumental variable models. *Econometric Theory*, 9, 222 – 240.

Diewert W. and T. Wales, 1987. Flexible functional forms and global curvature conditions. *Econometrica*, 55, 43-68.

Eisenberg, S., 2010. FTC settles physician collusion claim: changes needed to facilitate delivery models. *Lexocology*, (online article).

Escarce J. and M. Pauly, 1998. Physician opportunity costs in physician practice cost functions. *Journal of Health Economics*, 17, 129-151.

Gaynor M. and M. Pauly, 1990. Compensation and productive efficiency in partnerships: evidence from medical group practice. *Journal of Political Economy*, 98, 544-573.

Gaynor M. and W. Vogt. 2000. Antitrust and competition in healthcare markets. In Handbook of Health Economics, vol. 1B, Culyer A. New House J. (eds). North-Holland: Amsterdam, 2000; 1405-1487.

Graddy K., 1994. Testing for imperfect competition at the Fulton Fish Market. *RAND Journal of Economics*, 26, 75-92.

Greene W., 2003. Econometric Analysis, 5th Edition. (Upper Saddle River: Pearson)

Guilkey D., C. Lovell, and R. Sickles, 1983. A Comparison of the performance of three flexible functional forms. *International Economic Review*, 24, 591-616.

Gunning T.S. and R. Sickles, 2011. A multiproduct cost function for physician private practices. *Journal of Productivity Analysis,* 35, 119-128.

Haas-Wilson D. and M. Gaynor, 1998. Physician networks and their implications for competition in healthcare markets. *Health Economics*, 7, 179-182.

Iwata G., 1974. Measurement of conjectural variations in oligopoly. *Econometrica,* 42, 949-966.

Kass D., 1987. Economies of scale and scope in the provision of home health services. *Journal of Health Economics*, 6, 129-146.

Kleibergen, F. and R. Paap, 2006. Generalized reduced rank tests using the singular value decomposition. *Journal of Econometrics,* 127, 97-126.

Kralewski J., B. Dowd, R. Feldman, and J. Shapiro, 1987. The Physician Rebellion. *New England Journal of Medicine*, 316, 339-342.

Li T. and R. Rosenman, 2001. Estimating hospital costs with a generalized Leontief cost function. *Health Economics*, 10, 523-538.

McCarthy, T., 1985. The competitive nature of the primary-care physician services market. *Journal of Health Economics*, 4, 93-117.

Moreira, M., 2003. A conditional likelihood ratio test for structural models. Econometrica, 71, 1027-1048.

Panzar J. and R. Willig, 1977. Economies of scale in multi-output production. *Quarterly Journal of Economics*, 91, 481-493.

Perloff J., L. Karp, and A. Golan, 2007. Estimating market power and strategies. (Cambridge: Cambridge University Press)

Perloff, J. and E. Shen, (2001). “Collinearity in Linear Structural Models of Market Power,” (working paper).

Pham H., P. Ginsburg, and J. Verdier, 2009. Medicare governance and provider payment policy. *Health Affairs,* 28, 1382-1394.

Puller S., 2007. Pricing and firm conduct in California’s deregulated electricity market. *The Review of Economics and Statistics*, 89, 75-87.

Reinhardt, W., 1972. A production function for physician services. *Review of Economics and Statistics*, 54, 55-66.

Roller L.-H. and R.C. Sickles, 2000. Capacity and product market competition: measuring market power in a 'puppy-dog' industry. *International Journal of Industrial Organization*, 18, 845-865.

Sarma S., R. Devlin, and W. Hogg, 2010. Physician’s production of primary care in Ontario, Canada. *Health Economics*, 19, 14-30.

Sickles R.C. and P. Taubman, 1997. Mortality and morbidity among adults and the elderly, In M. Rosenzweig and O. Stark *Handbook of Population and Family Economics*. (Amsterdam: North-Holland).

Sickles R.C. and A. Yazbeck, 1998. "On the dynamics of demand for leisure and production of health: evidence from the retirement history survey," *Journal of Business and Economic Statistics*, 16, 187-197.

Steen F. and K. Salvanes, 1999. Testing for market power using a dynamic oligopoly model. *International Journal of Industrial Organization*, 17, 147-177.

Stock, J. and M. Yogo, 2005. Testing for weak instruments in linear IV regression. In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, ed. D. Andrews and J. Stock, 80-108. Cambridge: Cambridge University Press.

Thurston N. and A. Libby, 2002. A production function for physician services revisited. *The Review of Economics and Statistics*, 84, 184-191.

Uzawa H., 1962. Production functions with constant elasticities of substitution. *Review of Economic Studies*, 29, 291-299.

Vita M., 1990. Exploring hospital production relationship with flexible functional forms. *Journal of Health Economics*, 9, 1-21.

Wolfram C., 1999. Measuring duopoly power in the British electricity spot market. *American Economic Review*, 89, 805-826.

Wong, H., 1996. Market structure and the roleof consumer information in the physician services industry: An empirical test. *Journal of Health Economics*, 15, 139-160.

Zuckerman S., Welch W. and G. Pope, 1990. A geographic index of physician practice costs. *Journal of Health Economics*, 9, 39-69.

TABLE 1 – SUMMARY OF DATA

Variable Name	Variable Description	Mean
Total Cost	Sum of total practice costs (rent, insurance, and labor for non-physicians)	$270,972
Annual Labor Hours	Total annual hours worked by the physician	2,336
Office Visits w/Est. Patients (Y1)	Total annual appointments by the physician with patients that have previously visited the physician	4,174
Office Visits w/New Patients (Y2)	Total annual appointments by the physician with patients that have not previously visited the physician	637
ER Visits (Y3)	Total annual ER visits by the physician	243
Hospital Visits (Y4)	Total annual hospital visits by the physician	693
Non-physician Labor Price (W1)	Non-physician input price component of the GPCI index – a normalized physician input price index	1.02
Office Price (W2)	Office rent input price component of the GPCI index – a normalized physician input price index	1.07
Malpractice Price (W3)	Insurance input price component of the GPCI index – a normalized physician input price index	1.14
Metropolitan (Geography)	Binary variable – 0 for non-metropolitan practice and 1 for metropolitan practice	0.83
Number of Physicians	Number of physicians in the practice	3.08
Medicaid	Percentage of patients paying with Medicaid	0.12
Board Certified School	Binary variable – 0 for non-certified school and 1 for certified school	0.79
Age	Years of age	52.1
Experience	Years of experience	19.5
Gender	Binary variable – 0 for male and 1 for female	0.15
Price of General Visit	Average revenue collected for a general office visit.	$65.30
General Practice (SPEC1)	Binary variable – 1 if physician is in general practice, 0 otherwise	0.25
Medical Specialty (SPEC2)	Binary variable – 1 if physician is in a non-surgical medical specialty, 0 otherwise	0.61
Surgical Specialty (SPEC3)	Binary variable – 1 if physician is primarily a surgeon, 0 otherwise	0.07
Other Specialty (SPEC4)	Binary variable – 1 if physician specialty does not fall in other three categories, 0 if physician does	0.07

*The SMS asks the physician to select the range that their age and years of experience fall within. For example, our age variable reports a “1” for 1-10 years, “2” for 11-20 years, and so on. Rather than employing a number of dummy variables, we instead use the mid-point of the interval to estimate age and experience.

TABLE 2 – PARAMETER ESTIMATES FOR COST AND PHYSICIAN LABOR EQUATION
(SEE MNEMONIC DEFINITIONS IN TABLE 1)

	Cost	Physician Labor
Labor	-52.89 (35.866)	-
W1	-876524.7 (769972)	-4016.1 (3633.3)
W2	222960 (235936)	72.28 (1133.8)
W3	9769 (33376)	283.45* (154.05)
W1Y1	-187.35 (970.2)	2.70 (4.62)
W2Y1	83.7 (900.5)	2.96 (4.29)
W3Y1	-5.49 (20.1)	-0.054 (0.096)
W1W2Y1	120.9 (1866)	-5.56 (8.89)
W1W3Y1	309.5* (187.4)	0.014 (0.896)
W2W3Y1	-309.56* (172.2)	0.027 (0.825)
W1Y2	-9108.9* (4976)	-24.22 (23.33)
W2Y2	-5810.1 (4369)	-17.83 (20.66)
W3Y2	23.7 (126)	-0.191 (0.604)
W1W2Y2	15155* (9302)	42.64 (43.79)
W1W3Y2	1158.7 (1084.7)	3.30 (5.14)
W2W3Y2	-1349 (960.2)	-3.56 (4.54)
W1Y3	11310** (5113)	30.50 (23.73)
W2Y3	8985* (4818)	27.66 (22.52)
W3Y3	139.8 (174.2)	-0.593 (0.828)

W1W2Y3	-20109.1** (9858)	-58.42 (45.90)
W1W3Y3	-308.4 (1273.2)	-1.13 (6.09)
W2W3Y3	-7.72 (1139)	2.18 (5.45)
W1Y4	-1786.4 (2205.4)	-7.02 (10.46)
W2Y4	-767.7 (2121)	-6.43 (10.10)
W3Y4	-13.7 (72.8)	-0.137 (0.348)
W1W2Y4	2584.6 (4315)	13.83 (20.51)
W1W3Y4	668.3 (536.7)	-0.448 (2.56)
W2W3Y4	-644.8 (536.7)	0.596 (2.13)
W1Y1Y1	-0.023 (0.015)	-0.00006 (0.00007)
W2Y1Y1	0.013 (0.016)	0.00011 (0.00008)
W3Y1Y1	0.009 (0.009)	-0.00005 (0.00004)
W1Y2Y2	-0.174 (0.178)	-0.00088 (0.00084)
W2Y2Y2	0.124 (0.248)	0.00106 (0.00117)
W3Y2Y2	0.010 (0.121)	-0.00022 (0.00058)
W1Y3Y3	-0.059 (0.343)	-0.00212 (0.0016)
W2Y3Y3	0.131 (0.484)	0.00228 (0.00227)
W3Y3Y3	-0.076 (0.178)	-0.00071 (0.00085)
W1Y4Y4	0.069 (0.063)	0.00032 (0.0003)
W2Y4Y4	-0.081 (0.088)	-0.00041 (0.00042)
W3Y4Y4	0.007 (0.037)	0.00007 (0.00018)

W1Y1Y2	0.141*** (0.054)	0.00022 (0.00026)
W1Y1Y3	-0.057 (0.055)	-0.0004 (0.0003)
W1Y1Y4	-0.004 (0.034)	0.0003** (0.00015)
W1Y2Y3	-0.155 (0.341)	0.0037** (0.0015)
W1Y2Y4	0.330* (0.195)	-0.0012 (0.0009)
W1Y3Y4	0.082 (0.119)	0.00043 (0.00056)
W2Y1Y2	-0.129*** (0.050)	-0.00024 (0.00024)
W2Y1Y3	0.054 (0.050)	0.000354 (0.00023)
W2Y1Y4	0.003 (0.031)	-0.0003** (0.00014)
W2Y2Y3	0.218 (0.306)	-0.0035*** (0.00133)
W2Y2Y4	-0.392** (0.175)	0.00103 (0.0008)
W2Y3Y4	-0.053 (0.122)	-0.00042 (0.00058)
W3Y1Y2	0.002 (0.006)	0.00002 (0.00003)
W3Y1Y3	-0.005 (0.008)	0.000001 (0.00038)
W3Y1Y4	0.003 (0.005)	-0.000003 (0.0002)
W3Y2Y3	0.004 (0.036)	0.00018 (0.00017)
W3Y2Y4	0.023 (0.025)	0.00018 (0.00012)
W3Y3Y4	-0.007 (0.024)	-0.00003 (0.0001)
SPEC1	84785 (586191)	-38.94 (87.69)
SPEC2	965699* (588051)	78.60 (80.87)
SPEC3	886480 (587972)	96.84 (109.1)
SPEC4	888689	-

	(587972)	
METRO	-24222 (15921)	2.76 (76.4)
DOCNUM	1838.3 (1515)	-8.71 (7.13)
MEDCAD	-117.7 (310)	-0.803 (1.48)
CERT	2112.3 (11082)	-97.04* (53.62)
AGE	-	25.52* (15.98)
AGESQ	-	-.2939 (.221)
EXP	-	-3.80 (36.82)
EXPSQ	-	.1697 (.223)
GENDER	-	-0.799 (57.51)
CONSTANT	-	5463.8 (3232.6)

Robust standard errors appear in parentheses
*p<0.10
**p<0.05
***p<0.01

TABLE 3 – PARAMETER ESTIMATES FOR DEMAND EQUATION

	Demand Equation
Price	-94.95** (44.6)
Price squared	-0.109 (0.271)
Experience	64.69 (117.78)
Experience Squared	-.3917 (.835)
Gender	-142.3 (307.2)
Medicaid	-9.66 (7.85)
Metropolitan	356.5 (300.49)
Specialty 1	-1285*** (450)
Specialty 2	-182.7 (421.03)
Specialty 3	-55.14 (596.2)
Specialty 4	-
Constant	9805 (6853)

Robust standard errors in parentheses
*p<0.10
**p<0.05
***p<0.01

TABLE 4 – MARGINAL COST ESTIMATES FOR PHYSICIAN LABOR AND OFFICE VISITS (CALCULATED AT THE MEAN)

Outputs	**Marginal Cost**
Opportunity Cost of an hour of Physician Labor	\$52.87 (32.57)
Established Patient Office Visit	\$27.23*** (1.54)
New Patient Office Visit	\$75.97*** (3.26)
Emergency Room Visit	\$26.91*** (2.76)
Hospital Visit	\$16.32*** (1.79)

Robust standard errors are in parentheses.
*p<0.10
**p<0.05
***p<0.01

TABLE 5 – ELASTICITIES OF DEMAND AND COMPETITION PARAMETER RESULTS (θ) BY PHYSICIAN SPECIALTY

Specialties	Elasticity of Demand	Competition Parameter (θ)
General Practice	-2.35*** (0.20)	-1.87*** (0.24)
Medical Specialties	-1.76*** (0.25)	-1.19*** (0.32)
Surgical Specialties	-1.75*** (0.20)	-1.04*** (0.19)
Other	-1.75*** (0.26)	-1.11*** (0.23)

Robust standard errors are in parentheses and were calculated using the Delta Method.
*p<0.10
**p<0.05
***p<0.01

TABLE 6 – OWN-PRICE AND CROSS-PRICE ELASTICITIES OF SUBSTITUTION FOR GEOGRAPHIC PRACTICE COST INDEX INPUTS

INPUTS	NON-PHYSICIAN WAGES	OFFICE RENT	MALPRACTICE
NON-PHYSICIAN WAGES	-0.132***	0.224***	0.058**
OFFICE RENT	0.052	-0.282***	0.080
MALPRACTICE	1.578	-1.794	0.106

*p<0.10
**p<0.05
***p<0.01

TABLE 7 – ALLEN-UZAWA OWN-PRICE AND CROSS-PRICE ELASTICITIES OF SUBSTITUTION FOR GEOGRAPHIC PRACTICE COST INDEX INPUTS

INPUTS	NON-PHYSICIAN WAGES	OFFICE RENT	MALPRACTICE
NON-PHYSICIAN WAGES	-0.880***	0.593***	0.628**
OFFICE RENT	-	-0.746***	0.866
MALPRACTICE	-	-	1.147

*p<0.10
**p<0.05
***p<0.01