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Measuring Physicians' Response to Incentives: Evidence on Hours Worked and Multitasking

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Abstract

We measure the response of physicians to monetary incentives using matched administrative and time-use data on specialists from Québec (Canada). These physicians were paid fee-for-service contracts and supplied a number of different services. Our sample covers a period during which the Québec government changed the prices paid for clinical services. We apply these data to a multitasking model of physician labour supply, measuring two distinct responses. The first is the labour-supply response of physicians to broad-based fee increases. The second is the response to changes in the relative prices of individual services. Our results confirm that physicians respond to incentives in predictable ways. The own-price substitution effects of a relative price change are both economically and statistically significant. Income effects are present, but are overridden when prices are increased for individual services. They are more prominent in the presence of broad-based fee increases. In such cases, the income effect empirically dominates the substitution effet, which leads physicians to reduce their supply of clinical services.

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1 Introduction

Measuring how physicians react to incentives has important implications for health-care policies in the face of changing demand. At least two basic issues are at stake for a given number of physicians. First, beginning with Feldstein (1970), Rizzo and Blumenthal (1994) and Baltagi, Bratberg, and Holmas (2005), much attention has been paid to characterizing the shape of physician labour-supply curves – in particular whether or not they are backward bending at high levels of the wage rate – and the resulting implications for policies aimed at increasing the total supply of services (*e.g.*, Sloan, 1975). A second concern is whether a change in the relative fees paid for a particular service leads physicians to reallocate their hours of work to increase the supply of that service. For instance, an ageing population is likely to increase the demand for certain services: cardiovascular treatments, cataract surgeries, and hip replacements are examples. Since training more physicians takes time, monetary incentives can provide the government with a policy tool to meet demand changes in the short run.

Relatively little is known about how physicians react to relative fee changes, particularly with respect to the relative sizes of income and substitution effects. Some studies have looked at the supply of isolated services in response to variation in remuneration rates. For example, Allin, Baker, Isabelle, and Stabile (2015) found that the propensity to deliver babies by Cesarean section across Canadian provinces was sensitive to the relative price paid to physicians for completing that service.[1] The natural-experiment empirical approach exploited by the authors provides robust evidence of the total reaction to incentives, but does not distinguish income from substitution effects (see Blundell and Macurdy, 1999). Other studies have relied on geographically-aggregated service data, often with mixed results. Hurley and Labelle (1995) considered how changes in the relative fee paid for given services affected the completion rates of those services in Canadian provinces. They found little consistency in results across services, either in terms of the statistical significance of the relative fee as a determinant of the utilization rate, or in the direction of the effect.

This paper develops and estimates an economic model which fully characterizes physicians' response to incentives. We analyse physician choices over the total hours they spend seeing patients and the manner in which those hours are allocated to different ser-

[1] Gruber and Owings (1996) found that the propensity to complete Cesarean sections across American states was inversely related to negative income shocks such as a decline in fertility rates, consistent with physician-induced demand (Evans, 1974).

vices, which we refer to as multitasking.[2] We also specify the complete production process that transforms hours devoted to a particular service into the supply of services. We use our model to estimate the income and substitution effects resulting from changes in relative prices as well as from broad-based increases in the fees paid for services. We specify a CES utility function for physicians, defined over income and leisure. CES preferences have a rich history of use in empirical labour-supply models, beginning with Stern (1976) and Zabalza (1983). This function is general enough to permit unrestricted responses to incentives, and to identify both income and substitution effects, yet it is parsimonious in parameters, allowing for simple and direct interpretations of the results.[3]

Our model generates a wage index that measures the marginal return to an hour worked when that hour is optimally allocated across different services. The wage index is a non-linear function of the prices of different services and the elasticity of substitution between those services. As relative prices change, physicians adjust their behaviour, reallocating hours across services through substitution and income effects.

The substitution effects associated with a change in relative prices operate through two separate channels. First, as prices change, physicians alter their supply of services to maximize income for any given number of hours worked. Second, the optimal reallocation of hours across services increases the marginal return to an hour of work causing total hours to increase. Income effects are also present. The optimal allocation of time implies that the price-weighted marginal utility of each service is equated across services. Income effects therefore operate only through total hours worked – they do not affect the relative supply of different services.

Explaining the variation in hours worked and identifying income effects, requires modeling the choice of hours by individual physicians. We do so assuming that physicians choose hours to maximise their utility. Our model is non linear, without a closed form solution for optimal hours. We therefore use numerical methods and the simulated method of moments. We estimate the model taking account of billing ceilings and income taxes.

Our data follow specialist physicians, working in the province of Québec, over a seven year period – between 1996 and 2002. They include detailed information on the number of services provided per quarter by individual physicians, the prices paid for these services

[2]This is a variation on the classic multitasking model of Holmstrom and Milgrom (1991) in which workers supply effort across different tasks within an agency framework. Here physicians allocate time across different tasks, producing different services.

[3]Stern (1986) provides an excellent discussion of the properties of CES and other utility functions and their uses in labour-supply models.

and physician earnings. These data were matched to time-use survey data provided by the physicians which include information on the number of hours worked per week. The prices for services are set by the government and apply to all physicians in our sample. One important advantage of this feature for the econometrician is that it is reasonable to assume that these prices are exogenous at the physician level. In addition, the Quebec government altered the fee schedule in 2001, changing the relative prices paid for different services. We exploit this variation in prices and incentives to identify our model. To render the model empirically tractable, we apply Hick's composite commodity theorem to aggregate services whose prices moved in parallel across time. We take the group of services provided by each physician as given and estimate the model conditional on that group. This gives sets of physicians distinguished by the number of aggregate services provided: two, three or four.

Our results suggest that physicians do react to incentives. The own-price elasticities vary across services, but are positive and statistically significant for all services. Following the two issues raised above, we highlight both the difference in reaction to changes in the fees for individual services and to broad-based fee increases. Changes in the fees for individual services have positive effects on the supply of those services as substitution effects outweigh income effects. However, broad-based fee increases have negative effects on the supply of services as the income effect dominates. This result is consistent with a developing consensus on the importance of income effects in determining physician behaviour[4]. We discuss the policy implications of our results for using the compensation system to meet short-term demand shocks in health care. We also simulate the effects of the recent decision of the Québec government to increase all fees by 30%. Our simulations point to a this increase leading to a reduction in services of between 1.44% and 2.20%.

The rest of the paper is organized as follows. The next Section describes the institutional setting related to physician compensation in Quebec and the sources of our data. Section 3 develops the empirical model. Section 5 presents our aggregation strategy, the variables and the descriptive statistics. Section 7 presents our estimation results, while Section 8 discusses policy simulations and the last section discusses possible extensions to the model and concludes.

[4] McGuire and Pauly (1991) provide an overview of early evidence.

2 Institutional details and data description

2.1 Physician payment system in Quebec

In Québec, medical service fees are fixed by the government and applied through the public insurance corporation, known as the *Régie de l'assurance maladie du Québec*[5] (RAMQ). Most doctors participate in the public health care system, which means that they receive the totality of their income from the RAMQ – patients pay nothing for their treatment.

Quebec physicians have traditionally been paid according to a fee-for-service system (FFS).[6] Under this system, physicians receive a fee for each service provided. In 1999, the Québec government introduced a Mixed Remuneration (MR) scheme. Under the MR system, physicians received a fixed wage and a reduced fee (relative to the FFS contract) for services provided. Takeup of the MR system was optional. In 2000, approximately 70% of specialists remained on the FFS system.

Our study concentrates on FFS physicians. These are physicians who did not switch to the MR system. Restricting our analysis to FFS physicians simplifies the empirical analysis. It allows us to concentrate on measuring the reaction of incentives without modelling the selection of a compensation system.[7]

In 2001, the government revised the fee schedule paid to physicians for services completed. Fees for individual services increased by between 5% and 25%, changing the relative prices for services completed and changing the incentives of physicians to complete different services.

2.2 Data Description and sample construction

The data used for this study contain information on specialist physicians practicing in Quebec between 1996 and 2002. These data are derived from two sources: the Quebec College of Physicians (CMQ) and the RAMQ. During this time, the CMQ conducted an annual time-use survey of its members. This survey contained information on labour supply behaviour, captured by time spent at work, measured as the average (over the whole year) number of hours per week and time devoted to seeing patients. Our second source of data comes from the RAMQ administrative files used to pay physicians. These files

[5] Free translation: Quebec Insurance Medical Board.

[6] Prior to 1999, around 92% of specialist physicians were paid FFS.

[7] There is a potential for selection bias due to physicians endogenously selecting a compensation system. This issue is treated extensively in Fortin, Jacquemet, and Shearer (2017). Extending our model in this direction represents an interesting area for future research.

give information on the medical fees paid to physicians for services completed, and the number of services performed by each physician. These data are available on a quarterly basis for each physician. The data from the CMQ and from RAMQ were matched on the basis of an anonymous payroll number attributed to each physician.

We restrict our sample to specialists who were present both before and after 2001, the year in which prices were changed. This restriction leads us to eliminate 3808 physicians of the 5904 in the initial database. At the same time, we eliminate 183 medical services which were only completed by eliminated physicians. Restricting attention to physicians who remained under the FFS system for the whole sample period eliminates another 590 specialists and 41 services. We also removed services for which prices increased between the years 1996 and 2000. There were 85 such services. We suspect these price changes reflect technological changes and are hence endogenous. Each physician conducts a large number of medical services. To render our empirical model tractable, we aggregated services. With this in mind, we dropped medical services which are not present over the whole sample period – 98 services are concerned. Finally, we dropped the following specialities: electroencephalography, urology, pneumology, rheumatology, physiatry and plastic surgery which represented each between 0.4% and 2% of the sample. This removed another 277 specialists and 123 services, leaving 1231 physicians who performed 221 services over a period of 7 years. All services included had fees that remained constant prior to 2001, but increased afterwards. Note that the increase was not immediate in all cases. For some services the agreement between the government and *la Fédération des médecins spécialistes du Québec (FMSQ)* induced a gradual increase between 2001 and 2002. The specialties include: cardiac and vascular surgery (19 physicians), nephrology (54 physicians), radio-oncology (6 physicians), anesthesiology (41 physicians), endocrinology (30 physicians), gastroenterology (74 physicians), cardiology (149 physicians), pediatrics (93 physicians), internal medicine (127), neurology (63 physicians), general surgery (97 physicians), dermatology (76 physicians), gynecology and obstetrics (127 physicians) , orthopedics surgery (84 physicians) and otorhinolaryngology (62 physicians).

3 Empirical Model

We develop a model of physician behaviour under linear contracts and multitasking. We focus on the supply side of physician services, explaining differences in the volume of services completed through changes in hours worked, the manner in which those hours are allocated across different services, and supply shocks that render individual physicians more or less productive. We ignore demand as a determinant of the number of services completed, assuming that physicians can supply as much or as little of each service as they wish. We feel this is a good first approximation to the health-care market in Canada where health services are paid for by the government and waiting lines exist for most services.[8]

The production of service j by a physician k is assumed to be a function of hours devoted to it $h_{k,j}$, a service-specific parameter b_j, and a production shock $\epsilon_{k,j}$. The production shock captures random elements that can be specific to the physician (such as state of health), or the task, and that affect his/her productivity. The output of the physician k in service j is:[9]

$$A_j = b_j h_j^{\delta} \epsilon_j, \quad \epsilon_j > 0,\ b_j > 0, \tag{1}$$

where $\delta \in (0,1)$ represents the marginal return to time spent by the physician to provide service j. This form of production function exhibits decreasing returns to hours spent in providing services.[10]

Physician utility is defined over consumption M, pure leisure, denoted by ℓ_p, and "on-the-job" leisure, ℓ_o. The latter includes all work-related activities apart from seeing patients, including: teaching, research and administrative tasks. These activities are not remunerated under a FFS scheme.[11] Physician preferences are assumed to be CES (with equal shares), which is general enough to permit unrestricted responses to incentives, yet parsimonious in parameters, allowing for simple and direct interpretations of the results:

$$U(M, \ell_o, \ell_p) = \left(M^{\rho} + \ell_o^{\rho} + \ell_p^{\rho}\right)^{\frac{1}{\rho}}, \quad \rho < 1. \tag{2}$$

Here $\ell_o = h_t - h_s$, h_t is total hours spent at work and h_s, denotes time spent providing services. Pure leisure is $\ell_p = T - h_t$ with T the maximum amount of time available.

We present the model for the case of J services, which we take as fixed (see assumption

[8]We also ignore institutional constraints (such as access to services or operating rooms) as determinants of the number of services completed. We have no information on the particular constraints in place for different hospitals, nor do we have information on the hospital at which a given physician is working.

[9]To simplify notation, we suppress the physician's subscript k, until Section 7 on estimation.

[10]The assumption of decreasing returns ensures that a finite, interior solution exists for hours worked but rules gains from specialization in the completion of certain services. One way to incorporate such effects is to allow b_j to depend on past experience. Somé (2016) estimates such a model and discusses its policy implications for long-term supply and training physicians.

[11]Since such activities do not generate income, we assume that they increase utility, as in Fortin, Jacquemet, and Shearer (2017). For example, performing teaching or research activities may increase a physician's influence and prestige.

A1, below). The budget constraint is given by:

$$M = \sum_{j=1}^{J} \alpha_j A_j + y, ^{12} \tag{3}$$

where α_j represents the fee paid for service A_j and y is the non-labour income. Substituting (3) into (2), taking account of (1) and the definition of leisure, we rewrite utility as:

$$U = \left[\left(\sum_{j=1}^{J} \alpha_j b_j h_j^{\delta} \epsilon_j + y \right)^{\rho} + (h_t - h_s)^{\rho} + (T - h_t)^{\rho} \right]^{\frac{1}{\rho}}, \tag{4}$$

where

$$\sum_{j=1}^{J} h_j = h_s. \tag{5}$$

We list the key assumptions that we impose to simplify the model's resolution and the empirical analysis:

A1. **Exogenous Service Mix:** A key assumption of the model is that the group of services that a particular physician provides is exogenously fixed. This is equivalent to assuming that each physician is trained to provide a fixed number J of services. It allows us to search for interior solutions that examine how the supply of those services varies as prices change, ignoring services outside of this set. We ignore the decision to provide certain services and not others.[13]

A.2 **Common Shocks:** We assume common shocks across services for a given physician: $\epsilon_j = \epsilon_i = \epsilon$ for $i, j = \{1, 2, \ldots, J\}$. As such, we interpret the production shock purely in terms of elements that affect the physician and his/her productivity across all services. This can be due to elements affecting a physician's personal health. It can also reflect physician ability (or inherent productivity) which is constant across periods. Common shocks simplify the estimation as they drop out of the optimization

[12] Note that this budget constraint accounts only for FFS contracts. An interesting extension of the model would be to have a budget constraint general enough to account for both FFS and Mixed remuneration contracts.

[13] A more general model would examine the choice of which services to provide and allow for corner solutions – possibly due to demand shocks – to explain the fact that certain services are not provided.

problem for allocating time across services. Since the shock affects physician productivity independent of the service completed, only hours worked decisions are affected by the shock. An alternative would be to allow for demand shocks that vary across services.[14]

A.3 **Perfectly Elastic Demand for Services:** We rule out any demand shocks as determinants of the observed number of services provided. This is a strong assumption, but one that allows us to focus completely on physician behaviour.

A.4 **Full Information for physicians:** The physician observes ϵ, the price of each service, and the technology parameters b_j, before choosing hours. Given the restriction to common shocks that represent physician health or ability, it seems reasonable to assume that the physician observes the value of the shock before selecting hours of work.

A.5 **Stationary distribution of shocks:** The mean and variance of the distribution of shocks are constant over time. Our data takes the general form of a before-after natural experiment. Given prices are revised annually, any change in unobservable shocks is not separately identified from the effect of the change in prices. Given our interpretation of the shocks as a health shock, drawn across a relatively broad population of physicians, we feel comfortable in assuming that its general characteristics do not change over time.

A.6 **Absence of technological change:** We assume that the b_j parameters are constant through time, ruling out technological change. Again, the before-after nature of our data requires ruling out changes in elements that might be correlated with prices. This step is also necessary for aggregation as it allows us to estimate a constant aggregate $\tilde{b}$ that is common to all services within the aggregated group. While this is obviously an approximation, given the relatively short panel – and the benefits that it accords in terms of aggregation – we feel that this step is justified.

A.7 **Exogenous Participation:** We assume that participation decisions are independent of potential physician productivity, ϵ. This allows us to ignore modelling the participation decision in estimating the model, focussing solely on the choice of hours worked and services provided.

[14]An agency interpretation would allow for service-specific shocks, perhaps due to the complexity of individual cases and asymetric information. Physicians could then hide low effort levels behind low values of production shocks, generating agency costs. We discuss this, and other possible extensions, further in the conclusion of the paper.

The physician chooses total time at work, h_t, hours devoted to providing services, h_s, and the manner that those hours are allocated across different services, h_j, after having observed the value of the productivity shock ϵ.

To solve the model, we note that hours devoted to service j only enter (4) through the first term (income) while total time at work h_t only enters the second and the third terms. Optimizing over these variables, for a fixed h_s, gives closed-form solutions. We therefore proceed conditionally. We fix h_s and maximize with respect to h_j and h_t. We denote these solutions $\hat{h}_j(h_s), \hat{h}_t(h_s)$. We then substitute the optimal values, $\hat{h}_j(h_s)$ and $\hat{h}_t(h_s)$ into (4) to concentrate utility as a function of h_s, which we can maximize to find optimal hours devoted to services.

To maximize (4) with respect to h_1, we substitute the constraint (5) into (4). The first-order condition for h_1 is:

$$\alpha_1 b_1 h_1^{\delta-1} - \alpha_J b_J (h_s - h_1 - h_2 - \dots h_{J-1})^{\delta-1} = 0 \tag{6}$$

Standard algebra shows that, conditional on clinical hours h_s, the optimal time spent providing service j is:

$$\hat{h}_j(h_s) = \frac{\widetilde{P}_j}{\sum_{i=1}^{J} \widetilde{P}_i} h_s, \tag{7}$$

where

$$\widetilde{P}_j = (\alpha_j b_j \epsilon_j)^{\frac{1}{1-\delta}}.$$

Maximizing with respect to h_t, we have the following first-order condition:

$$(h_t - h_s)^{\rho-1} - (T - h_t)^{\rho-1} = 0,$$

which gives

$$\hat{h}_t(h_s) = \frac{T + h_s}{2}. \tag{8}$$

Substituting from (7) and (8) back into (4) gives the (conditional) indirect utility as a function of h_s:

$$V(h_s) = \left[(w h_s^{\delta} \epsilon + y)^{\rho} + 2^{1-\rho}(T - h_s)^{\rho}\right]^{\frac{1}{\rho}}, \tag{9}$$

where

$$w = \left(\sum_{j=1}^{J} \widetilde{P}_j \right)^{1-\delta} \tag{10}$$

determines the marginal return to an hour worked when that hour is optimally allocated across services, given relative prices. It is important to note that w is not a wage in the traditional sense, but a wage index. Earnings are not linear in hours worked. Rather hours are an input to the production of services and hence have decreasing marginal productivity. Notice as well, each hour worked is replicated and distributed across different services. This reflects the decreasing returns to the production of any given service and common shocks giving rise to interior solutions within the set of services that the physician provides – in the absence of increasing returns there are no gains to specialization among services.

The physician's optimal hours spent seeing patients, h_s^* solves

$$w\delta {h_s^*}^{\delta-1}\epsilon(w{h_s^*}^{\delta}\epsilon + y)^{\rho-1} - 2^{1-\rho}(T - h_s^*)^{\rho-1} = 0. \tag{11}$$

The second-order condition is

$$\begin{aligned} V_{h_s h_s} = w\delta(\delta-1){h_s^*}^{\delta-2}(w{h_s^*}^{\delta} + y)^{\rho-1} + (\rho-1)(w\delta {h_s^*}^{\delta-1})^2(w{h_s^*}^{\delta} + y)^{\rho-2} \\ +2^{1-\rho}(\rho-1)(T - h_s^*)^{\rho-2} < 0 \end{aligned} \tag{12}$$

since $\delta \in (0,1)$ and $\rho < 1$.

While (11) does not give rise to an explicit functional form for h_s^*, it can be solved numerically. Upon doing so, the optimal values of $h_j^* = \hat{h}_j(h_s^*)$ can be solved by evaluating equations (7), at h_s^*. With common shocks (Assumption A.2), the optimal number of services is given by

$$A_j^* = b_j \left[\frac{P_j}{\sum_{i=1}^{J} P_i} \right]^{\delta} {h_s^*}^{\delta}\epsilon, \tag{13}$$

where

$$P_j = (\alpha_j b_j)^{\frac{1}{1-\delta}}$$

represents the non-random counterpart of $\widetilde{P}_j$.

4 Comparative statics

A physician's reaction to incentives can be analyzed using comparative techniques. Fees changes imply income and substitution effects for the supply of services. These effects operate through the time allocated to different services within the context of our model. They operate through multiple channels since physicians choose the number of hours to devote to services and the manner in which those hours are allocated across services. We present the relevant equations in the text. Complete derivations are given in the Appendix A.1.

4.1 Own-price elasticities

The own-price elasticity captures how physicians alter the supply of service j in response to a change in its price relative to the prices of the other services. We concentrate on the elasticity of hours devoted to service j.[15] This is given by

$$\eta_{h_j,\alpha_j} = \underbrace{\left[\frac{1}{(1-\delta)} \frac{\sum_{i \neq j} P_i}{\sum_i P_i} - \frac{\alpha_j A_j \delta M^{\rho-1}}{h_s^2 F_{h_s}} \right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_j A_j}{y} \eta_{h_s,y}}_{\text{Income effect}} \tag{15}$$

The first term represents the substitution effect which is positive – since F_{h_s} is negative from the second-order condition – and the second term represents the income effect, which is negative. The substitution effect is composed of two parts. First, conditional on hours, h_s, physicians allocate more time towards those services for which the price has risen. From (7),

$$h_j = \frac{P_j}{\sum_i P_i} h_s,$$

hence (holding h_s constant)

$$\left. \frac{\alpha_j}{h_j} \frac{dh_j}{d\alpha_j} \right|_{h_s} = \frac{1}{(1-\delta)} \frac{\sum_{i \neq j} P_i}{\sum_i P_i} > 0$$

[15] The elasticity for services is proportional to the elasticity for hours:

$$\eta_{A_j,\alpha_j} = \delta \eta_{h_j,\alpha_j}. \tag{14}$$

the first term of the substitution effect.

The second component of the substitution effect results from the wage index increasing (through the reallocation of hours across services subsequent to the change in relative prices) which increases the marginal return to an hour of work. These additional hours are then allocated across different services optimally, including the service whose price has changed. This term depends on ρ which determines how total hours adjusts.

4.2 Cross-price elasticities

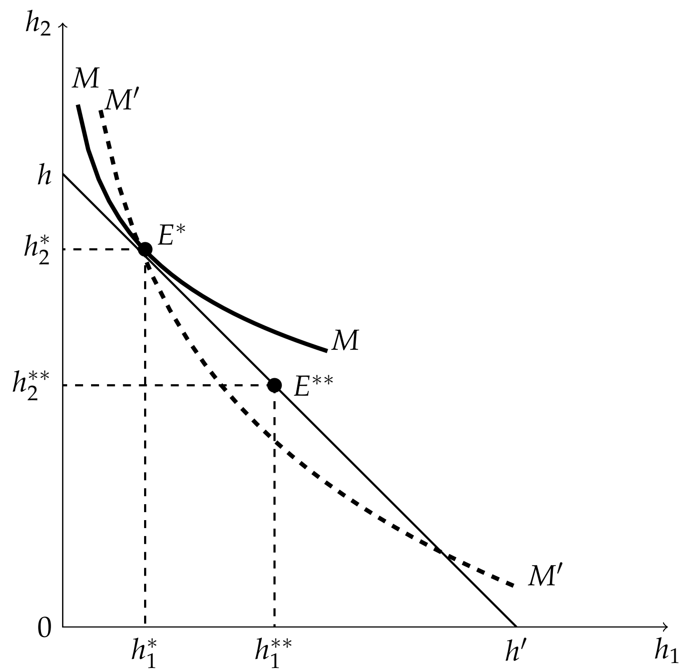
The expression for the cross-price elasticity is

$$\eta_{h_j,\alpha_i} = \underbrace{-\left[\frac{1}{(1-\delta)}\frac{P_i}{\sum_\iota P_\iota} + \frac{\delta\alpha_i A_i M^{\rho-1}}{h_s^2 F_{h_s}}\right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_i A_i}{y}\eta_{h_j,y},}_{\text{Income effect}} \tag{16}$$

$$\eta_{A_j,\alpha_i} = \delta\eta_{h_j,\alpha_i} \tag{17}$$

for $\iota = \{1, 2, \ldots, J\}$. Again the substitution effect has two components. The change in relative prices causes physicians to substitute away from services whose relative price has decreased, but the resulting increase in w leads to an increase in hours worked which is distributed across all services, including those with lower prices. The overall cross-price substitution effect is ambiguous. Notice, as well, the substitution effects are not symmetric, even conditional on h_s. This is due to the nonlinearities in the production of services that enter the budget constraint (*e.g.*, Kalman and Intriligator, 1973; Blomquist, 1989). Changes in prices cause first and second-order effects that determine the elasticity of substitution. These effects are shown in Figure 1. The figure shows the substitution effects, for a given level of h_s. The physician chooses h_1 and h_2 to maximize income along hh'. Iso-income lines are convex due to decreasing returns of h_i devoted to any service. A change in relative prices rotates the isoincome line, but also alters its convexity. The substitution effect is then completed by an adjustment of h_s as w changes with the change in prices. The homogeneity of the iso-income curves ensures a constant relative supply of h_1 and h_2 through this second phase.

Figure 1: Iso-income maps for h_1 and h_2



4.3 Wage index elasticities

As discussed in the introduction, a major concern of our paper is to analyse the impact of a change in a proportional increase in all prices on a physician labour supply. From (11), this can be approximated by the effect in the wage index on clinical hours worked, as given by:

$$\eta_{h_s,\omega} = \frac{\omega}{h_s}\Bigg[\underbrace{-\frac{\delta h_s^{\delta-1}(\omega h_s^{\delta}+y)^{\rho-1}}{F_{h_s}}}_{\text{Substitution Effect}} + \underbrace{\frac{(1-\rho)\delta\omega h_s^{2\delta-1}(\omega h_s^{\delta}+y)}{F_{h_s}}}_{\text{Income Effect}}\Bigg] \tag{18}$$

where

$$F_{h_s} = w\epsilon\delta(\delta-1)h_s^{\delta-2}M^{\rho-1} + (\rho-1)(w\delta h_s^{\delta-1}\epsilon)^2 M^{\rho-2} + 2^{1-\rho}(\rho-1)(T-h_s)^{\rho-2} < 0. \tag{19}$$

The substitution effect is positive and reflects the compensated effect of a change in the wage index on total clinical hours, while the income effect is negative as (pure and on-the-job) leisure is a normal good.

Using (7), the effect of an increase in ω on hours devoted to a given service can be calculated as:

$$\frac{\partial h_j}{\partial \omega} = \frac{P_j}{\sum_{i=1}^{I} P_i} \frac{\partial h_s}{\partial \omega}. \tag{20}$$

Here the first term is homogeneous of degree 0 in prices and hence unaffected by a broad increase in all prices. In consequence, the elasticity of h_j with respect to ω is the same as the elasticity of h_s with respect to ω:

$$\frac{\partial h_j}{\partial \omega} \frac{\omega}{h_j} = \frac{P_j}{\sum_{i=1}^{I} P_i} \frac{\partial h_s}{\partial \omega} \frac{\omega}{\frac{P_j}{\sum_{i=1}^{I} P_i} h_s} \tag{21}$$

$$= \frac{\partial h_s}{\partial \omega} \frac{\omega}{h_s} \tag{22}$$

Similarly,

$$\frac{\partial A_j}{\partial \omega} \frac{\omega}{A_j} = \delta \frac{\partial h_s}{\partial \omega} \frac{\omega}{h_s}. \tag{23}$$

5 Aggregation and Variable Construction

Conditional on h_s, only relative prices matter for determining the amount of time devoted to a particular service, hence the supply of services for which the relative price is constant through time will not change with respect to each other. They can therefore be treated as one service, the price of which is their price increase through time and the aggregate is the income generated by the supply of those services. Formally, we apply the Hick's composite-commodity theorem – the derivation within our context is in the Appendix A.2. As shown in Section A.2.1 of the appendix, the productivity parameters b of the aggregated services represent weighted averages of the individual service parameters. The weights being the base-period prices.

Our data cover a period during which the Quebec government changed the relative prices paid to physicians for the completion of medical services. To aggregate services, we considered the (geometric) average price increase of each service between the years

2000 and 2002, rounded to the nearest 5%. This provides six groups of services, whose prices increased (on average) by 0, 5, 10, 15, 20 and 25 percent.

Let α_j^t be the nominal price of service j in year t, for t =1996, 1997, 1998, 1999, 2000, 2001, 2002. Since prices are constant between 1996 and 2000, we treat 2000 as the base year. We calculate θ based on the geometric average growth rate of the price of service j between $t = 2000$ and $t = 2002$ (see Appendix A.2 for more details). Denote this geometric average by λ, then

$$\lambda_j = Round_{0.05}\left[\left(\frac{\alpha_j^{2002}}{\alpha_j^{2000}}\right)^{0.5} - 1\right]$$

where $Round_{.05}$ denotes the rounding operator. All services with the same λ were aggregated into the same group. This provides six groups of services, whose prices increased by 0, 5, 10, 15, 20 and 25 percent. If there are $m > 2$ services with the same λ, their composite service volume – provided by physician i – is calculated as $\sum_{j=1}^{m} \alpha_j^{2000} A_{ij}^t$, where A_{ij}^t is the number of services j performed by physician i at time t. The nominal price of composite service j after one period (in the year 2001) is then $\theta_{j,01} = \lambda_j + 1$. The nominal price in year 2002 is $\theta_{j,02} = \lambda_j^2 + 1$. We then convert nominal prices to real prices for each period, by dividing by a price index.

Table 1: Distribution of composite services

Composite service	Average price increase (%)	% of Services	Number of acts
1	0%	59.38%	57
2	5%	29.17%	28
3	10%	7.29%	7
4	15%	2.08%	2
5	20%	1.04%	1
6	25%	1.04%	1
Total		100.00%	96

The distribution of composite services is presented in Table 1. Our composite service 1 is an aggregation of medical acts for which the price remained constant for the whole sample period. This group contains 59.38% of services . The composite service 2 contains services whose prices increased by 5% between 2000 and 2002. This amounts to 29.17% of services. Composite service 3 contains services whose prices rose by 10% and represents 7.3% of services. The composite service 4 is the group of medical services whose prices increased by 15%. This represents 2.08% of services. The composite service 5 represents services whose prices increased by 20%. It represents 1% of services. The composite service 6 represents services whose prices increased by 25%. It represents 1% of services.

5.1 Earnings

Each physician's earnings are calculated as the sum of (aggregate) services that the physician provided in a given year multiplied by the price of those aggregate services. In our sample each physician did not necessarily provide each of the 6 aggregate services. In line with assumption A1, we take the set of aggregate services provided by a given physician as fixed.[16] We then classify physicians into groups, depending on the set of medical services provided. This gives 3 disjoint groups of physicians: physicians who provided 2 services, physicians who provided 3 services and physicians who provided 4 services.[17],[18] A complete description of the construction of earnings is given in the Appendix A.3.

6 Descriptive Statistics

Table 2 shows summary statistics on the main variables of interest for our model: hours worked, prices and earnings. We provide statistics on each for each period of the sample data, separated by the number of services provided. Hours worked are reported on a weekly basis. Earnings are annual and in thousands of dollars.

The prices of all goods are the same before the price increases in the year 2000. This reflects the fact that these are the prices of the aggregate services (measured by the revenue generated from those services). Under the aggregation theorem, their prices are equal to the rate of increase of the prices within the relevant group of services. As all prices were stable before the year 2000, their nominal prices are equal to one for those years. The variation across years reflects changes in the rate of inflation. The price increases are evident in years 2001-2002, raising average earnings in the process. Subsequent to the fee changes, physician incomes increased (21% for those providing 2 services , 6.9% for those providing 3 services and 21.2% for those providing 4 services). There is a slight decrease in clinical hours worked between the years 2000 and 2002, in the order of 3.5% for those

[16]One interpretation of this is as a short-term phenomenon. Physicians are trained to perform a certain number of services and we take the set of those services as fixed.

[17]Grouping physicians avoids censored data that would arise from physicians not providing some services.

[18]Note that within each group, however, each physician does not necessarily provide the same services. For example, within the group of physicians who provided 2 services are found physicians who provided services 1 and 2 as well as physicians who provided services 1 and 3.

Table 2: Descriptive statistics : Prices, Earnings and Hours

Physicians providing 2 services										
Year	Obs	Prices						Annual Earnings	Clinical Hours	Weeks
		1	2	3	4	5	6	(000's)	(weekly)	
1996	197	1.104	1.104	1.104	–	–	–	96.27	42.02	45.74
1997	201	1.087	1.087	1.087	–	–	–	93.68	46.47	46.16
1998	188	1.057	1.057	1.057	–	–	–	96.55	43.12	46.06
1999	192	1.035	1.035	1.035	–	–	–	95.75	44.74	–
2000	189	1.017	1.017	1.017	–	–	–	93.32	44.98	–
2001	168	1.005	1.055	1.106	–	–	–	106.94	44.15	–
2002	165	1.000	1.103	1.21	–	–	–	112.94	43.39	45.82
Physicians providing 3 services										
Year	Obs	Prices						Annual Earnings	Clinical Hours	Weeks
		1	2	3	4	5	6	(000's)	(weekly)	
1996	191	1.104	1.104	1.104	–	1.104	1.104	151.35	41.24	46.20
1997	180	1.087	1.087	1.087	–	1.087	1.087	153.82	45.91	46.64
1998	177	1.057	1.057	1.057	–	1.057	1.057	151.88	42.40	46.38
1999	190	1.035	1.035	1.035	–	1.035	1.035	140.65	43.07	–
2000	191	1.017	1.017	1.017	–	1.017	1.017	141.98	43.74	–
2001	179	1.005	1.055	1.106	–	1.206	1.256	149.43	44.22	–
2002	175	1.000	1.103	1.210	–	1.440	1.563	151.81	42.59	46.25
Physicians providing 4 services										
Year	Obs	Prices						Annual Earnings	Clinical Hours	Weeks
		1	2	3	4	5	6	(000's)	(weekly)	
1996	197	1.104	1.104	1.104	1.104	1.104	–	82.86	42.40	45.25
1997	201	1.087	1.087	1.087	1.087	1.087	–	81.18	48.84	45.48
1998	188	1.057	1.057	1.057	1.057	1.057	–	81.30	44.97	45.04
1999	192	1.035	1.035	1.035	1.035	1.035	–	79.61	48.17	–
2000	189	1.017	1.017	1.017	1.017	1.017	–	78.72	49.27	–
2001	168	1.005	1.055	1.106	1.156	1.206	–	89.81	48.80	–
2002	165	1.000	1.103	1.210	1.323	1.440	–	95.48	45.90	44.2

providing 2 services, 2.6% for those providing 3 services and 6.8% for those providing 4 services. These reductions are consistent with the presence income effects. Physicians spend part of the fee increase on consuming extra leisure.

Given earnings are reported on an annual basis and hours on a weekly basis, we convert earnings to weekly values by dividing by reported annual weeks worked. This is somewhat problematic due to the fact that annual weeks worked is not reported for three years of the survey. In an effort to keep as much data as possible, we therefore divide annual earnings by the average number of weeks worked during the years for which weeks are observed: 45.95.[19]

7 Estimation

To estimate the parameters, we match the first moments of log earnings earned on each service, the first moment of the log hours in each period and the second moment of the log total earnings. The log earnings from service j for physian k in period t are given by

$$\ln \mathcal{E}_{k,j,t} = \ln(P_{j_t}) - \delta \ln(\sum_j P_{j,t}) + \delta \ln h_{k,t} + \epsilon_{k,t}; \tag{24}$$

where $P_{j_t} = \left(b_j \alpha_{j_t}\right)^{\frac{1}{1-\delta}}$. The log total earnings in period t for a physician providing J services are

$$\ln \mathcal{E}_{k,t} = \ln \omega_t + \delta \ln h_{k,t} + \epsilon_{k,t}; \tag{25}$$

where $\omega_t = \left(\sum_{j=1}^{J} P_{j,t}\right)^{(1-\delta)}$.

We allow the productivity parameters of the services that all physicians offer to differ, depending on the mixture of services the physician provides. For example, for physicians providing 2 services, all physicians provide service 1 and either service 2 or service 3. We let $b_{1,12}$ denote the parameter b_1 among physicians providing services 1 and 2, and $b_{1,13}$ denotes the parameter b_1 among physicians providing services 1 and 3. The moment equations on earnings identify the parameters the service-specific productivity parameters b_j, the substitution parameter δ, and the variance of shocks σ_ϵ^2. No information on the parameter ρ is available from earnings.

[19] To investigate the accuracy of this approximation, we compared the earnings per week so constructed, with actual earnings per week for those years that the actual weeks worked was available. We then regressed the two measures to see how closely our approximate measure predicts the actual earnings per week in those years. The slope coefficient is estimated to be .978 and a test of the hypothesis that the coefficient equals one is not rejected at the 5% significance level.

We add the hours equation (11) to explain observed variation in hours worked in each period and identify ρ. We use numerical methods to solve for hours, setting non-labour income to zero.[20] We use * to denote values that are generated within the model and we note that h_s^* solves

$$w\delta h_s^{*\delta-1}\epsilon(h_s^{*\delta}\epsilon)^{\rho-1} - 2^{1-\rho}(T-h_s^*)^{\rho-1} = 0, \tag{26}$$

which depends on a vector of service prices $\mathcal{P}$ (through ω), the random shock ϵ, and unknown parameters, which we denote Γ_J, indexed by the total number of services provided:

$$\begin{aligned} \Gamma_2 &= (\rho, b_{1,1j}, b_j, \delta, \sigma_\epsilon^2) && \text{for } j = 2,3; \\ \Gamma_3 &= (\rho, b_{1,12j}, b_{2,12j}, b_j, \delta, \sigma_\epsilon^2) && \text{for } j = 3,4; \\ \Gamma_4 &= (\rho, b_{1,123j}, b_{2,123j}, b_{3,123j}, b_j, \delta, \sigma_\epsilon^2) && \text{for } j = 4,5. \end{aligned}$$

We estimate the model using simulated method of moments (SMM), generating ϵ from a lognormal distribution. Let $h_{s,t,r}^*(\Gamma, \mathcal{P}_t, \epsilon_r)$, denote the hours worked that solves (26), given period t prices, $\mathcal{P}_t$, and a particular draw of ϵ_r. Similarly, $\mathcal{E}_{j,r}^*(\Gamma, \mathcal{P}_t, \epsilon_r)$ represents the resulting implied earnings on services j. Given N_t observations in period t and given N_r repeated draws: $\epsilon_1, \epsilon_2, \ldots \epsilon_{N_r}$, we calculate the simulated period-t moments, conditional on period-t prices, as

$$\begin{aligned} \overline{\ln h_t^*}(\Gamma, \mathcal{P}_t) &= \frac{1}{N_t N_r}\sum_{k=1}^{N_t}\sum_{r=1}^{N_r} \ln h_{k,r,t}^*(\Gamma, \mathcal{P}_t, \epsilon_r), \\ \overline{\ln \mathcal{E}_t^*}(\Gamma, \mathcal{P}_t) &= \frac{1}{N_t N_r}\sum_{k=1}^{N_t}\sum_{r=1}^{N_r} \ln \mathcal{E}_{k,r,t}^*(\Gamma, \mathcal{P}_t, \epsilon_r) \\ \overline{\ln \mathcal{E}_{t,j}^*}(\Gamma, \mathcal{P}_t) &= \frac{1}{N_t N_r}\sum_{k=1}^{N_t}\sum_{r=1}^{N_r} \ln \mathcal{E}_{k,j,r,t}^*(\Gamma, \mathcal{P}_t, \epsilon_r) \\ \overline{(\ln \mathcal{E}_t^*(\Gamma, \mathcal{P}_t))^2} &= \frac{1}{N_t N_r}\sum_{k=1}^{N_t}\sum_{r=1}^{N_r} (\ln \mathcal{E}_{k,r,t}^*(\Gamma, \mathcal{P}_t, \epsilon_r))^2 \end{aligned}$$

for services $j = 2, \ldots, J$.

We then choose the parameter vector to match the simulated moments for each year to their observed counterparts. Let $\overline{\ln h_t{}^o}$, $\overline{\ln \mathcal{E}_t^o}$, $\overline{\ln \mathcal{E}_{t,j}^o}$, and $\overline{(\ln \mathcal{E}_t^o)^2}$, be the observed average

[20] Attempts to identify parameters of non-labour income have proved unsuccesful.

values of: the natural logarithm of hours worked by physicians in year t, the natural logarithm of earnings in year t, the natural logarithm of earnings on service j in year t, and the square of natural logarithm of total earnings, respectively.

Given 6 aggregate services, there are $\binom{6}{J}$ possible service mixtures among physicians providing J services. Yet only a subset J^o of these are observed in the sample. Let $q^J_{j^o}$ denote the observed service mix j^o among physicians providing J services. Also, let $Q_J = \cup_{j^o \in J} q^J_{j^o}$ be the set of service mixtures that is observed for physicians providing J services. Note that Q_J has J^o elements. [21]

For physicians providing J services, the $(J+2)$ vector of moments for physicians providing service mix $q^J_{j^o} \in Q_J$, in year t, is given by:

$$m^*_J(\Gamma_J)_{t,\, q^J_{j^o}} = \begin{bmatrix} \overline{\ln h_{t,q^J_{j^o}}}^{\,o} & - & \overline{\ln h_t}^{*}(\Gamma, \mathcal{P}_t) \\ \overline{\ln \mathcal{E}^o_{t,q^J_{j^o}}} & - & \overline{\ln \mathcal{E}^*_t}(\Gamma, \mathcal{P}_t) \\ \overline{\ln \mathcal{E}^o_{j,t,q^J_{j^o}}} & - & \overline{\ln \mathcal{E}^*_{j,t}}(\Gamma, \mathcal{P}_t) \\ \overline{(\ln \mathcal{E}^o_{t,q^J_{j^o}})^2} & - & \overline{(\ln \mathcal{E}^*_t}(\Gamma, \mathcal{P}_t))^2 \end{bmatrix} \qquad j = 2, \ldots, J. \tag{27}$$

Let $m^*_J(\Gamma_J)$ be the $((J+2) \times J^o \times T)$ vector of stacked moments for the sample of physicians providing J services. The estimator solves

$$\widehat{\Gamma_J} = \arg\min_{\Gamma_J} m^*_J(\Gamma_J)' \Omega_J^{-1} m^*_J(\Gamma_J), \tag{28}$$

where Ω_J represents a $((J+2) \times J^o \times T) \times ((J+2) \times J^o \times T)$ symmetric weighting matrix for physicians providing J services.

We estimate the model in two steps. In the first step, we set Ω to be the variance-covariance matrix of observed sample moments. We allow for correlation between moments within a given period among physicians providing the same services, but impose

[21] Among physicians providing J services, there is a different moment vector for each set of services provided. For example, for physicians providing 2 services, there is one vector for physicians providing services 1 and 2 and another vector for services providing services 1 and 3. $Q_2 = \{(1,2),(1,3)\}; Q_3 = \{(1,2,3),(1,2,5),(1,2,6)\}; Q_4 = \{(1,2,3,4),(1,2,3,5)\}$.

independence across periods and across $q^J_{j^o}$: Ω is block diagonal, with block t, q_{j^o} given by

$$\Omega^J_{t,q_{j^o}} = \frac{1}{N_{t,q_{j^o}}}\begin{bmatrix} \hat{\sigma}^2_{\mathcal{E}_{t,q_{j^o}}} & \hat{\sigma}_{\mathcal{E}_{t,q_{j^o}},H_{t,q_{j^o}}} & \hat{\sigma}_{\mathcal{E}_{t,q_{j^o}},(\mathcal{E})^2_{t,q_{j^o}}} & \hat{\sigma}_{\mathcal{E}_{t,q_{j^o}},\mathcal{E}_{2,t,q_{j^o}}} & \cdots & \hat{\sigma}_{\mathcal{E}_t,\mathcal{E}_{J,t,q_{j^o}}} \\ & \hat{\sigma}^2_{H_{t,q_{j^o}}} & \hat{\sigma}_{H_{t,q_{j^o}},(\mathcal{E})^2_{t,q_{j^o}}} & \hat{\sigma}_{H_{t,q_{j^o}},\mathcal{E}_{2,t,q_{j^o}}} & \cdots & \hat{\sigma}_{H_{t,q_{j^o}},\mathcal{E}_{J,t,q_{j^o}}} \\ & & \hat{\sigma}^2_{(\mathcal{E})^2_{t,q_{j^o}}} & \hat{\sigma}_{(\mathcal{E})^2_{t,q_{j^o}},\mathcal{E}_{2,t,q_{j^o}}} & \cdots & \hat{\sigma}_{(\mathcal{E})^2_{t,q_{j^o}},\mathcal{E}_{J,t,q_{j^o}}} \\ & & & \hat{\sigma}^2_{\mathcal{E}_{2,t,q_{j^o}}} & \cdots & \hat{\sigma}_{\mathcal{E}_{2,t,q_{j^o}},\mathcal{E}_{J,t,q_{j^o}}} \\ & & & & \ddots & \vdots \\ & & & & & \hat{\sigma}^2_{\mathcal{E}_{J,t,q_{j^o}}} \end{bmatrix}.$$

Here, $\hat{\sigma}^2_{x_{t,q_{j^o}}}$ represents the sample variance of $\ln x$ in period t, among physicians supplying services in group j^o. Similarly, $\hat{\sigma}_{x_{t,q_{j^o}},y_{t,q_{j^o}}}$ represents the sample covariance between $\ln x$ and $\ln y$. We denote the resulting estimator $\widehat{\Gamma}_1$. Similar to pooled estimators, correlation across periods due to random individual-specific effects is ignored and causes an efficiency loss. Notice, however, that individual-specific effects will be captured in ϵ; any correlation with hours will be accounted for through (26). The resulting estimators are consistent but inefficient.

In the second step, we use $\widehat{\Gamma}_1$ to construct the weighting matrix of moments across periods, allowing for correlation across periods due to random individual-specific effects. Let $\hat{e}_{q,1}$ denote the $((J+2)T_k \times 1)$ residual vector for individual k, from the first-stage estimates. T_k is the number of periods in which individual k worked. Assuming the residual can be decomposed into a term that is independent across time $e_{x,k,t}$ and an individual-specific term, η_k, that is constant across periods but independent across individuals, the covariance between moments $\bar{x}$ in period t and $\bar{y}$ in period s is:

$$Cov(\bar{x}_t, \bar{y}_s) = \frac{n_{t,s}\sigma^2_\eta}{n_t n_s} \tag{29}$$

where σ^2_η is the variance of the individual-specific effect, n_t, n_s represent the number of observations periods t and s respectively, and $n_{t,s}$ is the number of physicians who worked in both periods.

7.1 Income Taxes and Billing Ceilings

In order to estimate the model we take account of the institutional incentives imposed on physicians by the government through income ceilings and taxes. These affect the budget constraint and hence hours worked. We describe briefly here the institutions and method. Details are also presented in the Appendix; see also Somé (2016). Note, given we observe gross earnings, we solve for optimal hours given the tax rates and income ceilings. We then match the implied gross earnings that optimal hours implies to observed earnings.

Billing Ceilings:

Prior to 1999, the government of Quebec imposed half-yearly billing ceilings[22] on physicians. Payment for billed services, beyond the ceiling, was reduced by 75%.

Let $\overline{E}_{w,c}$ denote the weekly income ceiling.[23] The weekly earnings derived from seeing patients,

$$\mathcal{E} = wh_s^{\delta}\epsilon$$

allows us to calculate the number of weekly hours needed to obtain $\overline{E}_{w,c}$,

$$\overline{h}_{s,c} = \left(\frac{\overline{E}_{w,c}}{w\epsilon}\right)^{1/\delta}. \tag{30}$$

Let $\tau_c = 0.75$ be the penalty for exceeding the billing ceiling. The potential earnings (or budget constraint) of the physician is then given by

$$\text{Earnings} = \begin{cases} wh_s^{\delta}\epsilon & \text{if} \quad h_s \leq \overline{h}_{s,c} \\ (1-\tau_c)wh_s^{\delta}\epsilon & \text{if} \quad h_s > \overline{h}_{s,c}. \end{cases} \tag{31}$$

The penalty implies a kink in potential earnings at $\overline{h}_{s,c}$ which depends on both δ and ϵ.

Income Taxes: The budget constraint becomes more complex when taking account of income taxes. We calculated the marginal tax rates, including both provincial and federal

[22]The income ceilings for specialists was set at 150 thousand CAN dollars per semester between 1996 and 1999, except for neurologists, the ceiling was 142.5 thousand CAN dollars per semester.

[23]We convert to a weekly ceiling by dividing the annual income ceiling by the average weeks worked per year in the sample. The average weeks worked per year is 45.83 for physicians providing 2 services, 45.70 for physicians providing 3 services and 44.2 for physicians providing 4 services.

income taxes. For example, in 2001 the tax structure is:

$$\text{Tax rate} = \begin{cases} \tau_1 = 33\% & \text{if} \quad 0 \leq E < 26,000 \\ \tau_2 = 37.25\% & \text{if} \quad 26,000 \leq E < 30,754 \\ \tau_3 = 43.25\% & \text{if} \quad 30,754 \leq E < 52,000 \\ \tau_4 = 46.5\% & \text{if} \quad 52,000 \leq E < 61,509 \\ \tau_5 = 50.5\% & \text{if} \quad 61,5090 \leq E < 100,000 \\ \tau_6 = 53.5\% & \text{if} \quad E \geq 100,000. \end{cases}$$

Since the marginal tax rate depends on income, it will depend on hours worked (and ϵ). We proceed by calculating the virtual budget constraints associated with each marginal tax rate, ignoring at first any billing ceilings. For example, let $\overline{h_{s,1}}$ be the maximum number of hours a physician can work and still be in the lowest income-tax bracket, taxed at τ_1. Then, for $h_s > \overline{h_{s,1}}$, we solve for virtual income, $\overline{B_2}$, that equates

$$\begin{aligned} \overline{B}_2 + (1-\tau_2) w \overline{h}_{s,1}^{\delta} \epsilon =& (1-\tau_1) w \overline{h}_{s,1}^{\delta} \epsilon \\ \Leftrightarrow \overline{B}_2 =& (\tau_2 - \tau_1) w \overline{h}_{s,1}^{\delta} \epsilon \\ =& (\tau_2 - \tau_1) \overline{E}_{w,1}. \end{aligned}$$

This generalizes easily to find the virtual income that equates earnings at between the j^{th} and $j-1^{th}$ income-tax bracket:

$$\overline{B}_j = \sum_{k=1}^{j-1} (\tau_{i+1} - \tau_i) \overline{E}_{w,i}.$$

Billing ceilings are easily added by noting that physicians are taxed on income received. Once the billing ceiling is attained, after tax earnings become

$$(1-\tau_j)(1-\tau_c) w h^{\delta} \epsilon$$

where τ_j is the marginal tax rate. To calculate the optimal hours in this context we proceed piecewise throughout the composite budget constraint following Hausman (1979) and Moffitt (1990). Given the kink points, $\bar{h}_{s,c}$ depend on ϵ, the program must be solved for each draw of ϵ, for each individual.

7.2 Estimation Results

The estimates are given in Table 3. The case of physicians providing 2 services is given in the first column. The estimated value of δ is equal to 0.625 and the value of ρ is equal to -0.139. The case of physicians providing 3 services is given in the second column. The value of δ is equal to 0.649 and the value of ρ is equal to $-.112$. The results for physicians providing 4 services are given in the third column.[24] The value of δ is 0.684 and the value of ρ is -0.174.

7.3 Model Fit

The model fit is presented for each set of physicians in Figures 2 – 4. In each case we concentrate on the predicted and observed aggregate first moments of log earnings and log hours. Predicted moments are given by the hollow symbols and observed moments, the solid symbols. While a statistical test, such as one based on the value of the overidentification statistic, is technically rejected by the data, it is clear that the model replicates the observed moments quite well. However, in all cases there is a tendency to overestimate both hours and earnings in year 4.

7.3.1 Incentive Effects

Estimation of the structural model allows us to provide a complete characterization of the reaction of physicians to monetary incentives. We use our estimates to calculate the income and substitution effects of price changes on total hours providing services, h_s and services supplied. These are presented in Tables 4, 5, 6, and 7, for the cases of physicians providing two, three and four services, respectively. In each case, we report the overall effect of the price change, along with its income and substitution effect. In table 4 the different rows present the induced changes in total clinical hours providing services among physicians providing services 1 and 2, total clinical hours providing services among physicians providing services 1 and 3, the elasticity of service 1 among physicians providing services 1 and 2, the elasticity of service 1 among physicians providing services 1 and 3, the elasticity of service 2, and the elasticity of service 3. The other tables follow the same format. The tables present the elasticity with respect to the relevant price (given

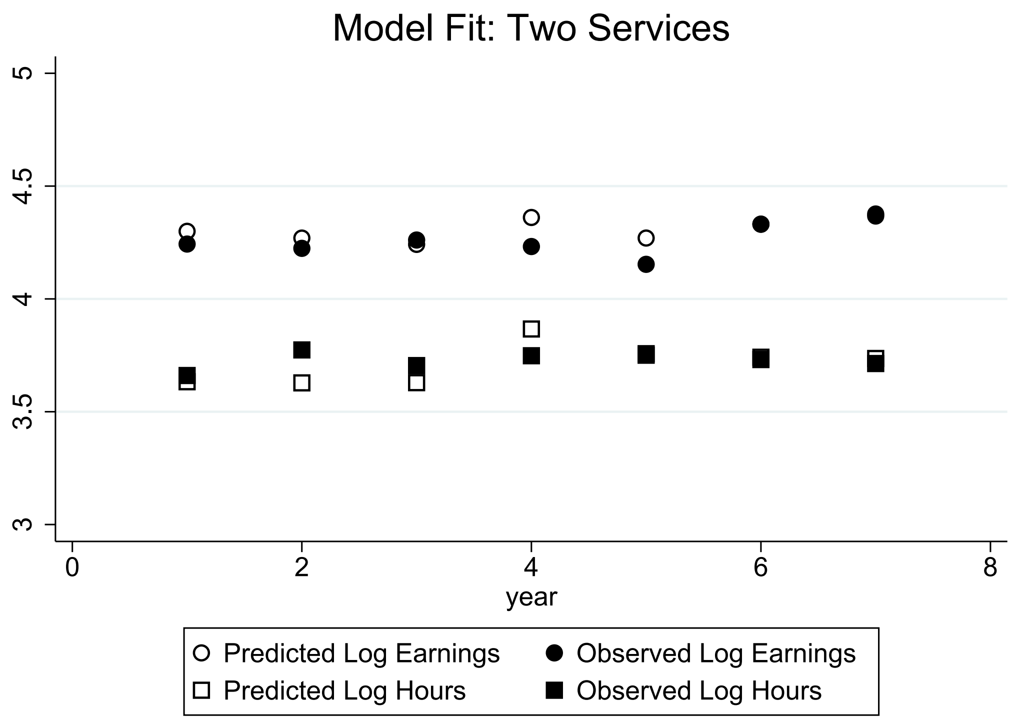
[24]These estimates are based on a restricted sample, including only physicians providing services $1, 2, 4$ and 5. There were only 116 physicians providing services $1, 2, 3$ and 4, which led to numerical problems and a non-positive definite variance-covariance matrix of the moments in the second stage estimation process.

Table 3: Estimation Results

Parameter	2 services	3 services	4 services
ρ	-0.139 *** (0.013)	–0.112*** (0.009)	-0.174 *** (0.013)
δ	0.625*** (0.018)	0.649*** (0.011)	0.684*** (0.013)
$\tilde{b}_1$	4.172*** (0.262)	8.614*** (0.390)	2.914*** (0.103)
$\tilde{b}_2$	7.897*** (0.590)	9.046*** (0.568)	3.931*** (0.160)
$\tilde{b}_3$	3.449*** (0.211)	11.205*** (0.579)	– –
$\tilde{b}_4$			3.777*** (0.169)
$\tilde{b}_5$		3.674*** (0.160)	3.239*** (0.121)
$\tilde{b}_6$		1.750*** (0.075)	
$\tilde{b}_{1,3}$	-2.361*** (0.249)		
$\tilde{b}_{1,125}$		-2.289*** (0.398)	
$\tilde{b}_{1,126}$		-0.645* (0.370)	
$\tilde{b}_{2,125}$		4.555*** (0.621)	
$\tilde{b}_{2,126}$		-6.692*** (0.557)	
σ	0.762*** (0.026)	0.436*** (0.013)	0.339*** (0.017)
Observations	1,300	1,283	472

Standard errors in parentheses
***, **, denote signficance at 1% and 5%, respectively.

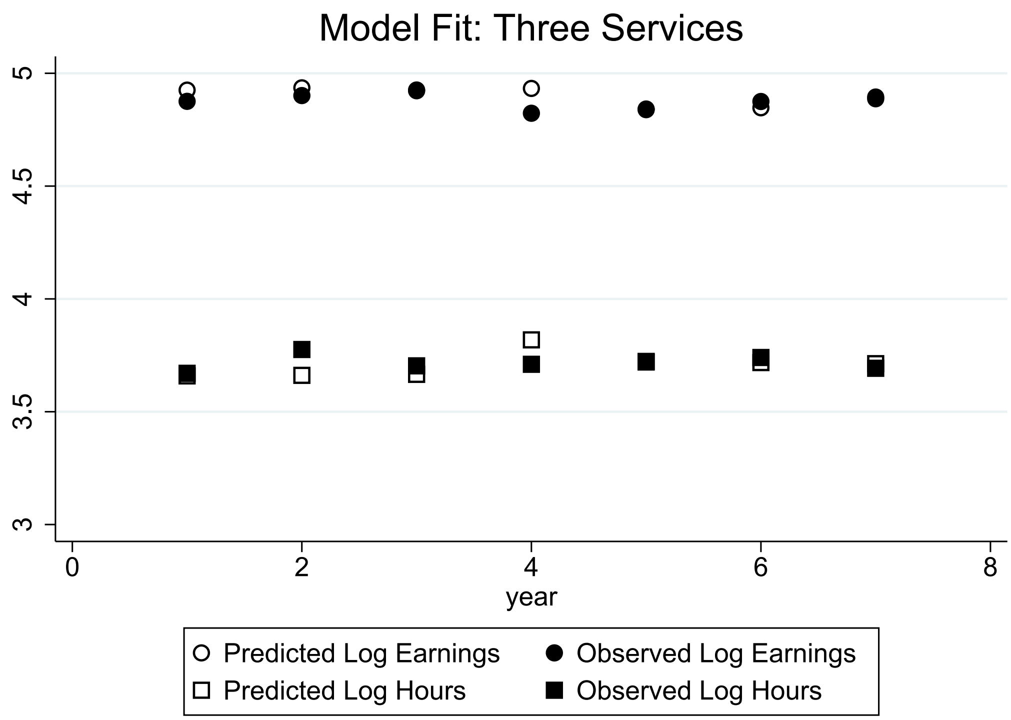
Figure 2



at the top of each column), as well as the 95% confidence interval, based on 99 draws of the parameter vector from its asymptotic normal distribution.

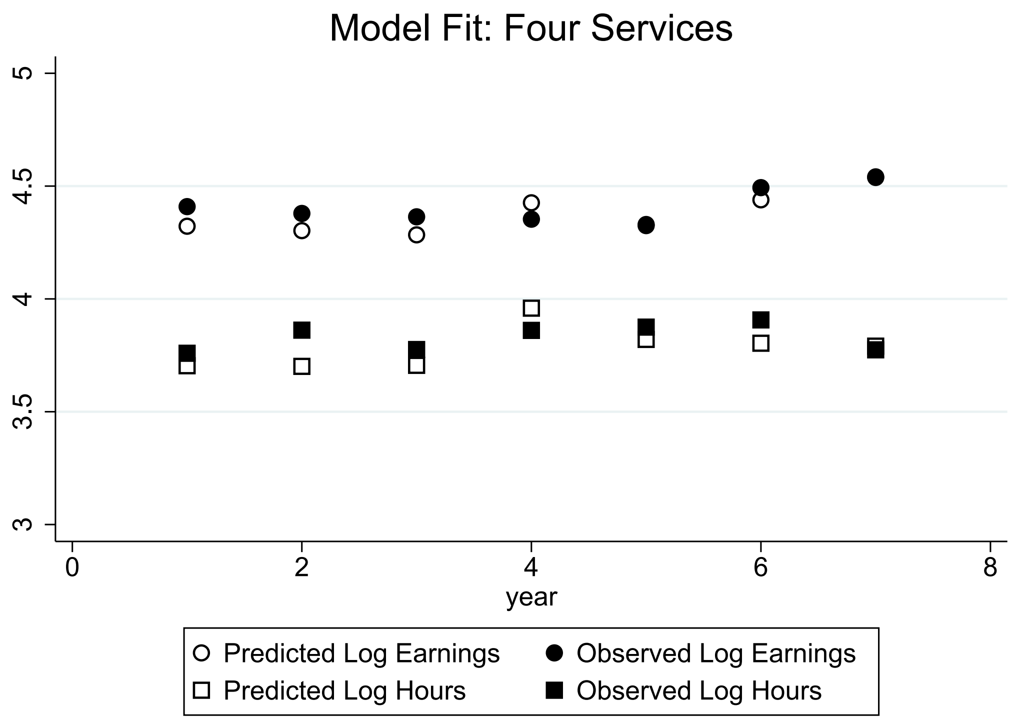
The results vary across specifications, but general patterns are evident. All specifications display negative income effects, for both total hours devoted to services and specific services. Given an increase in outside income, physicians reduce their supply of clinical services and their supply of services. The price changes induce positive own-price effects on services, suggesting that the substitution effects outweigh the income effects, and negative cross-price effects. The effects are all significant at the 5% level as the confidence intervals do not cover zero. The effects of price increases on clinical hours is negative. For example, from Table 4, an increase in the price of service 1 induces physicians who provide services 1 and 2 to reduce their total clinical hours (the elasticity is -.041). Yet, they increase their supply of service 1 (the elasticity is 1.409) as a larger proportion of the hours supplied are allocated to service 1 to take advantage of the higher price. The presence of

Figure 3



positive and non-symmetric cross-price substitution effects are also noted (between services 1 and 3, for example) confirming the possibility suggested by (16).

Figure 4



8 Policy simulations

Estimation of the structural model allows us to predict how physicians would respond to policy changes by the government. As the data are historic, we can take advantage of past price increases enacted by the government and compare the model's predictions to reported actual responses . Between 2007 and 2011, the Quebec government increased the prices paid for physician services by 30%. Contandriopoulos and Perroux (2013) presented aggregate evidence that this increase led physicians to reduce their supply of services.

We calculated (18) at the estimated parameter values. The results are presented in Table 8. For all cases, hours worked and the volume of all services are predicted to decrease. The elasticities are all of a similar order of magnitude: between 0.074 and 0.107. Multiplying by 30 and by the relevant estimate of δ gives estimates of the percent service response

Table 4: Elasticities: 2 Services

	P_1	P_2	P_3
Weekly clinical hours (h_{s12})	-.041	-.041	–
95% Confidence Interval	[-.048, -.035]	[-.048, -.035]	–
Income Effect	-.339	-.338	–
Substitution Effect	.297	.297	–
Weekly clinical hours (h_{s13})	-.096	–	-.096
95% Confidence Interval	[-.111, -.079]	–	[-.110, -.079]
Income Effect	-.789	–	-.787
Substitution Effect	.693	–	.691
$A_{1,2}$	1.409	-1.461	–
95% Confidence Interval	[1.252, 1.603]	[-1.655, -1.310]	–
Income Effect	-.212	-.211	–
Substitution Effect	1.622	-1.249	–
$A_{1,3}$	1.387	–	-1.507
95% Confidence Interval	[1.234, 1.604]	–	[-1.722, -1.351]
Income Effect	-.494	–	-.493
Substitution Effect	1.881	–	-1.014
A_2	-.276	.225	–
95% Confidence Interval	[-.330, -.235]	[.182, .280]	–
Income Effect	-.212	-.212	–
Substitution Effect	-.064	.436	–
A_3	-.298	–	.179
95% Confidence Interval	[-.342, -.261]	–	[.138, .224]
Income Effect	-.494	–	-.493
Substitution Effect	.196	–	.672

to the 30% increase in all prices. This gives -1.73%, -1.44% and -2.20% for the cases of physicians providing 2, 3 and 4 services, respectively. These results contrast with those in which the price of single service is increased (see Tables 4, 6 and 7), which generally give large and positive own-price effects. The difference is due to the lack of a substitution effect on any specific service. A broad-based price increase does not change relative prices, but only affects the return to an hour's work (the wage index). It therefore introduces an income and substitution effect on hours devoted to services, which are then distributed

Table 5: Hours Elasticities: 3 Services

	P_1	P_2	P_3	P_4	P_5
Weekly clinical hours (h_{s123})	-0.018	-0.018	-0.018		
95% Confidence Interval	[-0.020, -0.016]	[-0.020, -0.016]	[-0.020, -0.016]		
Income Effect	-0.178	-0.178	-0.178		
Substitution Effect	0.161	0.160	0.160		
Weekly clinical hours (h_{s124})	-0.018	-0.018		-0.018	
95% Confidence Interval	[-0.020, -0.016]	[-0.020, -0.016]		[-.020, -.016]	
Income Effect	-0.181	-0.181		-0.181	
Substitution Effect	0.163	0.163		0.163	
Weekly clinical hours (h_{s125})	-0.033	-0.032			-0.033
95% Confidence Interval	[-0.037, -0.029]	[-0.037, -0.029]			[-0.037, -0.029]
Income Effect	-0.328	-0.328			-0.328
Substitution Effect	0.295	0.295			0.296

over all services.[25]

9 Discussion and Conclusion

We have developed and estimated a structural labour supply model that incorporates the production of medical services and the allocation of hours across services (multitasking) into the standard consumption/leisure trade-off. The equilibrium of the model gives rise to a wage index for clinical hours when those hours are optimally distributed across different medical services. The wage index captures physicians' ability to substitute between services and hence contains economically relevant information on physician response to incentives. Our model also provides an implicit function defining optimal clinical hours worked. We have applied our model to analyze the response of fee-for-service physicians to changes in fees using data from the Province of Quebec.

Our results suggest that physicians react to incentives in predictable ways. While income effects are present, and tend to reduce hours worked and services provided, substitution effects outweigh them when the price of a single service is changed. Changing

[25] This result is also consistent with a " target income hypothesis" Kantarevic, Kralj, and Weinkauf (2008); Rizzo and Blumenthal (1994); McGuire and Pauly (1991).

Table 6: Service Elasticities: 3 Services

	P_1	P_2	P_3	P_4	P_5
$A_{1,123}$ 95% Confidence Interval Income Effect Substitution Effect	1.438 [1.347, 1.555] -0.116 1.554	-0.502 [-0.578, -0.443] -0.116 -0.387	-0.971 [-1.048, -0.899] -0.116 -0.855		
$A_{1,124}$ 95% Confidence Interval Income Effect Substitution Effect	1.668 [1.569, 1.819] -0.118 1.786	-1.644 [-1.780, -1.545] -0.118 -1.527		-0.058 [-0.070,-0.049] -0.118 0.059	
$A_{1,125}$ 95% Confidence Interval Income Effect Substitution Effect	0.073 [0.063, 0.085] -0.213 0.286	-0.079 [-0.087, -0.072] -0.212 0.134			-0.057 [-0.063, -0.051] -0.213 0.156
$A_{2,123}$ 95% Confidence Interval Income Effect Substitution Effect	-0.419 [-0.495, -0.359] -0.116 -0.303	1.355 [1.241, 1.493] -0.116 1.471	-0.971 [-1.048, -0.899] -0.116 -0.855		
$A_{2,124}$ 95% Confidence Interval Income Effect Substitution Effect	-0.190 [-0.212, -0.170] -0.118 -0.072	0.213 [0.187, 0.245] -0.118 0.321		-0.058 [-0.070, -0.049] -0.118 0.059	
$A_{2,125}$ 95% Confidence Interval Income Effect Substitution Effect	-1.785 [-1.926, -1.669] -0.213 -1.571	1.778 [1.664, 1.922] -0.213 1.991			-0.057 [-0.063, -0.051] -0.213 0.156
A_3 95% Confidence Interval Income Effect Substitution Effect	-0.419 [-0.495, -0.359] -0.116 -0.303	-.502 [-0.578, -0.443] -0.116 -0.387	0.887 [0.823, 0.979] -0.116 1.003		
A_4 95% Confidence Interval Income Effect Substitution Effect	-0.190 [-0.212, -0.170] -0.118 -0.072	-1.644 [-1.780, -1.545] -0.118 -1.527		1.799 [1.691, 1.938] -0.118 1.917	
A_5 95% Confidence Interval Income Effect Substitution Effect	-1.785 [-1.926, -1.669] -0.213 -1.572	-0.079 [-0.087, -0.072] -0.213 0.134			1.801 [1.682, 1.948] -0.213 2.014

Table 7: Hours Elasticities: 4 Services

	P_1	P_2	P_3	P_5
Weekly clinical hours (h_{s1235})	-0.060	-0.060	-0.060	-0.060
95% Confidence Interval	[-0.066, -0.052]	[-0.066, -0.052]	[-0.066, -0.052]	[-0.066, -0.052]
Income Effect	-0.405	-0.405	-0.406	-0.405
Substitution Effect	0.345	0.346	0.346	0.345
$A_{1,1235}$	1.870	-0.774	-0.763	-0.497
95% Confidence Interval	[1.711, 2.076]	[-0.863, -0.706]	[-0.833,-0.699]	[-0.555, -0.458]
Income Effect	-0.277	-0.279	-0.278	-0.278
Substitution Effect	2.148	-0.496	-0.485	-0.220
$A_{2,1235}$	-0.312	1.409	-0.763	-0.497
95% Confidence Interval	[-0.349, -0.280]	[1.285, 1.566]	[-0.833, -0.699]	[-0.555, -0.458]
Income Effect	-0.277	-0.278	-0.278	-0.278
Substitution Effect	-0.035	1.687	-0.485	-0.220
$A_{3,1235}$	-0.312	-0.774	1.419	-0.530
95% Confidence Interval	[-0.349, -0.280]	[-0.863, -0.706]	[1.283, 1.577]	[-0.588, -0.485]
Income Effect	-0.277	-0.278	-0.278	-0.310
Substitution Effect	-0.035	-0.496	1.697	-0.220
A_5	-0.312	-0.774	-0.763	1.685
95% Confidence Interval	[-0.349, -0.280]	[-0.863, -0.706]	[-0.833, -0.699]	[1.548, 1.877]
Income Effect	-0.277	-0.278	-0.278	-0.278
Substitution Effect	-0.035	-0.496	-0.485	1.963

many prices in unison however, introduces a large income effect which reduces the supply of services. These results have policy implications for the provision of heath services. Governments (or other health care providers) who are faced with increased demand for particular medical services (and accompanying waiting times) can use price controls to increase the supply of those services. In general, our results highlight the fact that increasing individual fees will lead to a significant increase in the supply of those services. We note that, while our approach to modelling behaviour differs, our results pointing to the importance of the income effect are qualitatively consistent with those of Fortin, Jacquemet, and Shearer (2017) who used flexible functional forms to approximate the utility function and discretized the choice set over practice variables.

The simplicity of our model is one of its attractive features. It is parsimonious, leading to a relatively small number of estimated parameters and easily interpretable comparative

Table 8: Policy Analysis

Variable	Two Services	Three Services	Four Services
$hs_{1,2}$ 95% Confidence Interval Income Effect Substitution Effect	-0.092 [-0.103, -0.079] - 0.753 0.661		
$hs_{1,3}$ 95% C. I. Income Effect Substitution Effect	-0.094 [-0.106, -0.080] - 0.776 0.682		
$hs_{1,2,3}$ 95% C. I. Income Effect Substitution Effect		-0.074 [-0.084,-0.066] -0.746 0.672	
$hs_{1,2,4}$ 95% C. I. Income Effect Substitution Effect		-0.074 [-.084,-.067] -0.747 -0.672	
$hs_{1,2,5}$ 95% C. I. Income Effect Substitution Effect		-0.076 [-.085,-0.068] -0.760 0.684	
$hs_{1,2,4,5}$ 95% C. I. Income Effect Substitution Effect		– –	-0.107 [-0.117,-0.095] -0.724 0.618

statics. Yet it is powerful enough to predict physician behaviour, capturing both income and substitution effects. Nevertheless, the model is limited and it can be extended in various ways to allow for a richer analysis of physician behaviour.

While our sample only includes physicians who are present before and after the price changes, we have ignored participation in physician's labour-supply decision. Incorporating participation decisions into our model shifts attention to moments that are conditional on working. To the extent that participation decisions depend on potential productivity, this can affect the parameter estimates. We have also ignored observable heterogeneity among physicians. A natural way to incorporate this into the model is through the weighting parameter introduced into the preferences on hours worked. Heterogeneity also raises questions of possible instruments for hours worked and the relative benefits of limited-information estimation that conditions on hours worked. We leave an investigation of the importance of these issues for future work.

Part of the model's parsimony is due to the aggregation of services and the assumption of common shocks. Eliminating aggregation and introducing service-specific shocks would be an interesting extension, but would increase the numerical intensity of solving and estimating the model. Doing so would allow the incorporation of demand and technology shocks as determinants of the variation in observed services. It would also allow consideration of agency questions as service-specific shocks might be observed uniquely by the physician. This would allow the measurement of the extent of asymmetric information in the medical profession.

We have also assumed that the fee changes are exogenous and independent of physician productivity. This would be violated if, for example, the government changed fees in response to technological changes that reduced the time needed to perform certain services. While modelling the fee setting behaviour of the government in such situations poses no special problems from an econometric point of view – see Paarsch and Shearer (1999) for one possible approach – doing so imposes a certain level of economic rationality on the part of the government which may or may not be present. Developing models that allow for the detection of rational price setting on the part of the government is also worthy of future research.

Physician productivity may change over time, due, for example, to learning by doing. Extending the model in such a direction gives rise to dynamic issues of labour supply and health-care policy. For example, the government may want to induce young physicians to spend more time in the labour market in order to increase future productivity. See Somé (2016) for a discussion of these issues.

Finally, we have concentrated on evaluating the volume-increase response of physicians to fee increases. It would be interesting to extend this model to account for the quality of services provided. Estimating a model that takes account of the quality of care will require data on the health outcomes of patients and following patients through time.

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Appendix A1: Elasticities

Let

$$F(h_s, \alpha_1, \alpha_2, \ldots \alpha_J, y, \epsilon) = \omega \delta h_s^{\delta-1} \epsilon (\omega h_s^{\delta} \epsilon + y)^{\rho-1} - 2^{1-\rho}(T - h_s)^{\rho-1}, \tag{32}$$

where

$$\omega = \left[\sum_{J=1}^{I} \left(\alpha_j b_j \right)^{\frac{1}{1-\delta}} \right]^{(1-\delta)}$$

and note that optimal h_s^* solves

$$F(h_s^*, \alpha_1, \alpha_2, \ldots \alpha_J, y, \epsilon) = 0, \tag{33}$$

with the second-order condition

$$F_{h_s} \equiv \frac{\partial F(h_s^*, \alpha_1, \alpha_2, \ldots \alpha_J, y, \epsilon)}{\partial h_s} < 0. \tag{34}$$

By the implicit function theorem, we can write

$$h_s^* = \psi(\alpha_1, \alpha_2, \ldots \alpha_J, y, \epsilon). \tag{35}$$

Furthermore,

$$\frac{dh_s^*}{d\alpha_j} = -\frac{\frac{\partial F}{\partial \alpha_j}}{\frac{\partial F}{\partial h_s}}, \tag{36}$$

and

$$\frac{dh_s^*}{dy} = -\frac{\frac{\partial F}{\partial y}}{\frac{\partial F}{\partial h_s}}. \tag{37}$$

We use the following notation:

(i) $M = wh_s^{\delta}\epsilon + y$.

(ii) $\omega = \left[\sum_{j=1}^{J}\left(\alpha_j b_j\right)^{\frac{1}{1-\delta}}.\right]^{(1-\delta)}$

(iii) $P_j = \left(\alpha_j b_j\right)^{\frac{1}{1-\delta}}$.

We note

$$\frac{\partial w}{\partial \alpha_j} = b_j \left(\frac{P_j}{\sum_i P_i}\right)^{\delta} > 0. \tag{38}$$

We will use the following results which rely on the parameters satisfying the second-order condition, i.e., $\rho < 1$ and $\delta \in (0, 1)$.

$$\begin{aligned}
F_{h_s} =& w\epsilon\delta(\delta-1)h_s^{\delta-2}M^{\rho-1} + (\rho-1)(w\delta h_s^{\delta-1}\epsilon)^2 M^{\rho-2} + 2^{1-\rho}(\rho-1)(T-h_s)^{\rho-2} < 0, \\
F_y =& (\rho-1)w\delta h_s^{\delta-1}\epsilon M^{\rho-2} < 0, \\
F_{\alpha_j} =& \frac{\partial w}{\partial \alpha_j} h_s^{\delta-1}\epsilon\left[\delta M^{\rho-1} + h_s F_y\right] \quad \gtrless \quad 0.
\end{aligned}$$

Income elasticity, h_s

$$\frac{dh_s}{dy} = -\frac{F_y}{F_{h_s}} = \frac{(1-\rho)\omega\delta h_s^{\delta-1}\epsilon M^{\rho-2}}{F_{h_s}} < 0, \tag{39}$$

$$\eta_{h_s,y} = \frac{y}{h_s}\frac{(1-\rho)\omega\delta h_s^{\delta-1}\epsilon M^{\rho-2}}{F_{h_s}}. \tag{40}$$

Income elasticity, h_j

Recall,

$$h_j = \frac{P_j}{\sum_i P_i} h_s. \tag{41}$$

It follows that

$$\frac{dh_j}{dy} = \frac{P_j}{\sum_i P_i}\frac{dh_s}{dy} < 0, \quad \text{since } \frac{dh_s}{dy} < 0 \text{ from (39)}. \tag{42}$$

Using (41) we have

$$\eta_{h_j,y} = \eta_{h_s,y}.$$

Income elasticity, A_j

Recall,

$$A_j = b_j h_j^{\delta}\epsilon. \tag{43}$$

It follows that

$$\frac{dA_j}{dy} = \delta b_j h_j^{\delta-1}\frac{dh_j}{dy}\epsilon < 0, \quad \text{since } \frac{dh_j}{dy} < 0 \quad \text{from (42)}. \tag{44}$$

Using (43), we have the elasticity form

$$\eta_{A_j,y} = \delta\eta_{h_j,y} = \delta\eta_{h_s,y}.$$

Price elasticity, h_s

$$
\begin{aligned}
\frac{dh_s}{d\alpha_j} =& -\frac{F_{\alpha_j}}{F_{h_s}} \\
=& \frac{\partial w}{\partial \alpha_j} h_s^{\delta-1}\epsilon \left[-\frac{\delta M^{\rho-1}}{F_{h_s}} - h_s \frac{F_y}{F_{h_s}} \right] \\
=& \frac{\partial w}{\partial \alpha_j} h_s^{\delta-1}\epsilon \left[-\frac{\delta M^{\rho-1}}{F_{h_s}} + h_s \frac{dh_s}{dy} \right], \quad \text{from (39)} \\
=& -\frac{\partial w}{\partial \alpha_j} \frac{\delta h_s^{\delta-1}\epsilon M^{\rho-1}}{F_{h_s}} + h_s^{\delta}\epsilon \frac{\partial w}{\partial \alpha_j}\frac{dh_s}{dy} \\
=& -b_j \left(\frac{P_j h_s}{\sum_i P_i} \right)^{\delta} \frac{\delta \epsilon M^{\rho-1}}{h_s F_{h_s}} + b_j \left(\frac{P_j h_s}{\sum_i P_i} \right)^{\delta} \frac{dh_s}{dy}\epsilon, \quad \text{from (38)} \\
=& -b_j h_j^{\delta}\epsilon \frac{\delta M^{\rho-1}}{h_s F_{h_s}} + b_j h_j^{\delta}\epsilon \frac{dh_s}{dy} \\
=& -A_j \frac{\delta M^{\rho-1}}{h_s F_{h_s}} + A_j \frac{dh_s}{dy}. \qquad (45)
\end{aligned}
$$

To convert to elasticity terms, multiply by α_j/h_s. After adjusting the income effect, we get:

$$\eta_{h_s,\alpha_j} = -\frac{\delta \alpha_j A_j M^{\rho-1}}{h_s^2 V_{h_s h_s}} + \frac{\alpha_j A_j}{y}\eta_{h_s,y}.$$

Own-price elasticity, h_j

Recall,

$$h_j = \frac{P_j}{\sum_i P_i} h_s.$$

We then have:

$$\frac{\partial h_j}{\partial \alpha_j} = \frac{P_j}{\sum_i P_i} \frac{\partial h_s}{\partial \alpha_j} + h_s \frac{\partial}{\partial \alpha_j} \left[\frac{P_j}{\sum_i P_i} \right].$$

Using (45) and the fact that $\frac{\partial P_j}{\partial \alpha_j} = \frac{P_j}{(1-\delta)\alpha_j}$, we have:

$$\begin{aligned}
\frac{\partial h_j}{\partial \alpha_j} &= \frac{P_j}{\sum_i P_i} \left[-A_j \delta \frac{M^{\rho-1}}{h_s F_{h_s}} + A_j \frac{\partial h_s}{\partial y} \right] + \frac{P_j \sum_{j \neq i} P_j}{(\sum_i P_i)^2} \frac{h_s}{\alpha_j (1-\delta)} \\
&= \frac{P_j}{\sum_i P_i} \left[-A_j \delta \frac{M^{\rho-1}}{h_s F_{h_s}} + A_j \frac{\partial h_s}{\partial y} \right] + \frac{h_j}{\alpha_j (1-\delta)} \frac{\sum_{j \neq i} P_j}{\sum_i P_i}.
\end{aligned}$$

Using the fact that $h_j = \frac{P_j}{\sum_i P_i} h_s$ and rearranging gives:

$$\frac{\partial h_j}{\partial \alpha_j} \frac{\alpha_j}{h_j} = \left[\frac{1}{(1-\delta)} \frac{\sum_{i \neq j} P_i}{\sum_i P_i} - \alpha_j A_j \delta \frac{M^{\rho-1}}{h_s^2 F_{h_s}} \right] + \frac{\alpha_j A_j}{y} \frac{\partial h_s}{\partial y} \frac{y}{h_s}$$

Own-price elasticity, A_j

$$\begin{aligned}
A_j &= b_j h_j^{\delta} \epsilon \\
\frac{\partial A_j}{\partial \alpha_j} &= b_j h_j^{\delta-1} \delta \frac{\partial h_j}{\partial \alpha_j} \\
&= \frac{A_j}{h_j} \delta \frac{\partial h_j}{\partial \alpha_j} \\
&= \delta \frac{\alpha_j}{h_j} \frac{\partial h_j}{\partial \alpha_j}. \\
\eta_{A_j, \alpha_j} &= \delta \eta_{h_j, \alpha_j}.
\end{aligned}$$

Cross-price elasticity, h_j

$$\begin{aligned}\frac{\partial h_j}{\partial \alpha_i} =& \frac{P_j}{\sum_\iota P_\iota}\frac{\partial h_s}{\partial \alpha_i} + \frac{\partial}{\partial \alpha_i}\left[\frac{P_j}{\sum_\iota P_\iota}\right] h_s \\ =& \frac{P_j}{\sum_\iota P_\iota}\frac{\partial h_s}{\partial \alpha_i} - \frac{P_i P_j}{\alpha_i(1-\delta)(\sum_\iota P_\iota)^2} h_s.\end{aligned}$$

Using (45) and the fact that $h_j = \frac{P_j}{\sum_\iota P_\iota} h_s$ we have:

$$\begin{aligned}\frac{\partial h_j}{\partial \alpha_i} =& - \frac{P_j}{\sum_\iota P_\iota}\frac{A_i \delta M^{\rho-1}}{h_s F_{h_s}} + \frac{P_j}{\sum_\iota P_\iota} A_i \frac{\partial h_s}{\partial y} - \frac{h_i h_j}{h_s}\frac{1}{(1-\delta)\alpha_i} \\ =& - \left[\frac{h_j}{h_s^2}\frac{A_i \delta M^{\rho-1}}{F_{h_s}} + \frac{h_i h_j}{h_s}\frac{1}{(1-\delta)\alpha_i}\right] + \frac{P_j}{\sum_\iota P_\iota} A_i \frac{\partial h_s}{\partial y}.\end{aligned}$$

Finally, using $\frac{\partial h_j}{\partial y} = \frac{P_j}{\sum_\iota P_\iota}\frac{\partial h_s}{\partial y}$, we have:

$$\frac{\partial h_j}{\partial \alpha_i} = - \frac{h_j}{\alpha_i}\left[\frac{h_i}{h_s}\frac{1}{(1-\delta)} + \frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 F_{h_s}}\right] + A_i \frac{\partial h_j}{\partial y},$$

or in elasticity form,

$$\begin{aligned}\frac{\partial h_j}{\partial \alpha_i}\frac{\alpha_i}{h_i} =& - \left[\frac{h_i}{h_s}\frac{1}{(1-\delta)} + \frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 F_{h_s}}\right] + \frac{\alpha_i A_i}{y}\frac{\partial h_j}{\partial y}\frac{y}{h_j} \\ =& - \left[\frac{1}{(1-\delta)}\frac{P_i}{\sum_\iota P_\iota} + \frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 F_{h_s}}\right] + \frac{\alpha_i A_i}{y}\frac{\partial h_j}{\partial y}\frac{y}{h_j},\end{aligned}$$

where the last line uses the fact that $h_j = \frac{P_j}{\sum_\iota P_i} h_s$.

Cross-price elasticity, A_j

$$\begin{aligned}\frac{dA_j}{d\alpha_i} =& b_j h_j^{\delta-1}\delta \frac{dh_j}{d\alpha_i} \\ =& \frac{A_j}{h_j}\delta \frac{dh_j}{d\alpha_i},\end{aligned}$$

or in elasticity form,

$$\begin{aligned}\frac{dA_j}{d\alpha_i}\frac{\alpha_i}{A_j} =& \delta \frac{\alpha_i}{h_j}\frac{dh_j}{d\alpha_i} \\ \eta_{A_j,\alpha_i} =& \delta \eta_{h_j,\alpha_i}.\end{aligned}$$

10 Appendix A2: Composite Services

To aggregate services we use the hicks composite commodity theorem.[26]

Given n services that can be provided by a physician, the vector of service quantities is $(A_1, A_2, ..., A_n)$ and the associated price vector is $(\alpha_1, \alpha_2, ..., \alpha_n)$. Note, for example, if prices i and j move in the same proportion θ with respect to their base-period prices, denoted α_i^0, α_j^0, then we can write

$$\alpha_{i,t} = \theta_t \alpha_i^0 \quad \text{and} \quad \alpha_{j,t} = \theta_t \alpha_j^0.$$

The relative prices of services i and j are constant in each period:

$$\frac{\alpha_{it}}{\alpha_{jt}} = \frac{\alpha_i^0}{\alpha_j^0}.$$

Now let $q < n$ be the number groups of services with distinct changes in service prices. Let $\theta_1, \theta_2, ..., \theta_q$ denote those price changes and let Θ_j denote the group of services associated with each $\theta_j, \quad j \in \{1, 2, ..., q\}$.

Proposition : *If* $(A_1, A_2, \ldots, A_n)$ *solves*

$$\begin{aligned} \max_{\{M, h_1, h_2, \ldots h_n, h_t, h_s\}} U &= [M^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho]^{\frac{1}{\rho}} \qquad (46) \\ s.t. \quad (i) \quad M &= \sum_{j=1}^{n} \alpha_j A_j + y. \\ (ii) \quad A_j &= b_j h_j^\delta \epsilon, \quad j = 1, 2, ..., n. \\ (iii) \quad h_s &= \sum_{i=1}^{n} h_j. \end{aligned}$$

then medical services can be aggregated in $q < n$ *groups of services. The aggregate service vector is* $(\sum_{j \in \Theta_1} \alpha_j^0 A_j, \sum_{j \in \Theta} \alpha_j^0 A_j, ..., \sum_{j \in \Theta_q} \alpha_j^0 A_j)$ *and the associated price vector is* $(\theta_1, \theta_2, ..., \theta_q)$.

Proof: The indirect utility function is $V(w, y) = \left[(w h_s^\delta \epsilon + y)^\rho + 2^{1-\rho}(T - h_s)^\rho\right]^{\frac{1}{\rho}}$, where $w = \left[\sum_{j=1}^{n} (b_j \alpha_j)^{\frac{1}{1-\delta}}\right]^{1-\delta}$. The expenditure function, $e(w, u^0)$, is the amount of non labor income needed to set to $V(w, e(w, u^0)) = u^0$. This gives:

$$\begin{aligned} \left[(w h_s^\delta \epsilon + e(w, u^0))^\rho + 2^{1-\rho}(T - h_s)^\rho\right]^{\frac{1}{\rho}} &= u^0 \quad \text{or} \\ e(w, u^0) &= \left[(u^0)^\rho - 2^{1-\rho}(T - h_s)^\rho\right]^{1/\rho} - w h_s^\delta \epsilon. \end{aligned}$$

[26]See, for example, Deaton and Muellbauer (1980).

Applying Shephard's Lemma, the appropriate composite service is the derivative of $e(w, u^0)$ with respect to θ_i (conditional on h_s). We have:

$$-\frac{de}{d\theta_i} = \frac{dw}{d\theta_i} h_s^{\delta} \epsilon. \tag{47}$$

The derivative of w with respect to θ_i is

$$\begin{aligned} \frac{dw}{d\theta_i} &= \frac{d}{d\theta_i} \left(\sum_{j \in \Theta_1} (b_j \theta_1 \alpha_j^0)^{\frac{1}{1-\delta}} + \sum_{j \in \Theta_2} (b_j \theta_2 \alpha_j^0)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_i} (b_j \theta_i \alpha_j^0)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_q} (b_j \theta_q \alpha_j^0)^{\frac{1}{1-\delta}} \right)^{1-\delta} \\ &= \sum_{j \in \Theta_i} b_j \alpha_j^0 \left(\frac{(b_j \alpha_j)^{\frac{1}{1-\delta}}}{\Delta} \right)^{\delta}, \end{aligned}$$

where

$$\begin{aligned} \Delta &= \sum_{j \in \Theta_1} (b_j \theta_1 \alpha_j^0)^{\frac{1}{1-\delta}} + \sum_{j \in \Theta_2} (b_j \theta_2 \alpha_j^0)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_i} (b_j \theta_i \alpha_j^0)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_q} (b_j \theta_q \alpha_j^0)^{\frac{1}{1-\delta}} \\ &= \sum_{j \in \Theta_1} (b_j \alpha_j)^{\frac{1}{1-\delta}} + \sum_{j \in \Theta_2} (b_j \alpha_j)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_i} (b_j \alpha_j)^{\frac{1}{1-\delta}} + ... + \sum_{j \in \Theta_q} (b_j \alpha_j)^{\frac{1}{1-\delta}}. \end{aligned}$$

Substituting into (47), we have:

$$-\frac{de}{d\theta_i} = \sum_{j \in \Theta_i} b_j \alpha_j^0 \left(\frac{(b_j \alpha_j)^{\frac{1}{1-\delta}}}{\Delta} \right)^{\delta} h_s^{\delta} \epsilon.$$

The optimal allocation of hours across services implies

$$h_j = \frac{(b_j \alpha_j)^{\frac{1}{1-\delta}}}{\Delta} h_s.$$

Hence,

$$\begin{aligned} \frac{de}{d\theta_i} &= \sum_{j \in \Theta_i} \alpha_j^0 b_j h_j^{\delta} \epsilon & (48) \\ &= \sum_{j \in \Theta_i} \alpha_j^0 A_j. & (49) \end{aligned}$$

The composite service is total revenue generated from the services in Θ_i during period t, evaluated at base-period prices. The price of the composite service is θ, the percent change in prices over time.

10.1 Aggregation over services with different b's

Let $\mathcal{A}_k$ denote a group of services $A_j, j = \{1, 2, \ldots, J_{\mathcal{A}_k}\}$, within which relative prices are constant across services. Then, in any period t,

$$\alpha_{j,t} = \theta_t \alpha_{j,0} \quad \{j : A_j \in \mathcal{A}_k\},$$

from which it follows that:

$$\alpha_{j,t} = \psi_j \alpha_{1_k,t} \quad \forall t \quad \text{and} \quad j \in \{2, \ldots, J_{\mathcal{A}_k}\}, \quad \text{where} \quad \psi_j = \frac{\alpha_{j,0}}{\alpha_{1_k,0}},$$

which is constant over time.

The earnings of physician k in period t are then given by:

$$\begin{aligned}
\mathcal{E}_{k,t} &= \left[\sum_k \sum_{A_j \in \mathcal{A}_k} \left(\alpha_{j,t} b_j\right)^{\frac{1}{1-\delta}}\right]^{1-\delta} h_s^{\delta} \epsilon & (50)\\
&= \left[\sum_k \sum_{A_j \in \mathcal{A}_k} \alpha_{1_k,t}^{\frac{1}{1-\delta}} \left(b_1{}^{\frac{1}{1-\delta}} + \sum_{j=2}^{J} \psi_j{}^{\frac{1}{1-\delta}} b_j{}^{\frac{1}{1-\delta}}\right)\right]^{1-\delta} h_s^{\delta} \epsilon_t & (51)\\
&= \left\{\sum_k \sum_{A_j \in \mathcal{A}_k} \theta_{k,t}^{\frac{1}{1-\delta}} \left[\left(\alpha_{1_k,0} b_1\right)^{\frac{1}{1-\delta}} + \sum_{j=2}^{J} \left(\alpha_{1_k,0} \psi_j b_j\right)^{\frac{1}{1-\delta}}\right]\right\}^{1-\delta} h_s^{\delta} \epsilon_t & (52)\\
&= \left\{\sum_k \sum_{A_j \in \mathcal{A}_k} \theta_{k,t}^{\frac{1}{1-\delta}} \left[\left(\alpha_{1_k,0} b_{1_k}\right)^{\frac{1}{1-\delta}} + \sum_{j=2}^{J} \left(\alpha_{j_k,0} b_{j_k}\right)^{\frac{1}{1-\delta}}\right]\right\}^{1-\delta} h_s^{\delta} \epsilon_t & (53)\\
&= \left[\sum_k \theta_{k,t}^{\frac{1}{1-\delta}} \tilde{b}_k^{\frac{1}{1-\delta}}\right]^{1-\delta} h_s^{\delta} \epsilon_t, & (54)\\
& & (55)
\end{aligned}$$

where $\alpha_{j_k,0}$ denotes the price of the j^{th} service of group k in the base period 0. In the presence of heterogenous b_js within the aggregated commodity, we estimate a composite parameter

$$\tilde{b}_k = \sum_{j=2}^{J} \left(\alpha_{j_k,0} b_{j_k}\right)^{\frac{1}{1-\delta}}, \tag{56}$$

which is constant over time because the constant bs are weighted by base-level prices through assumption 3. The aggregate service k is given by the volume of services provided within group k, weighted at base level prices $\alpha_{j_k,0}$. The price of the aggregate service $\theta_{k,t}$ is the percentage change in prices of the services in group k, relative to the base period $t = 0$.

Appendix A3: Data

The first group of specialists, which we denote G_2, provided 2 services. It has, in turn, two subgroups. G_{12} is made up of physicians who suppled services 1 and 2. It contains specialities Endocrinology , Otorhinolaryngology, Gastroenterology, and Cardiology. G_{13} is made up of neurologists who supplied services 1 and 3. Earnings for specialist s in G_2 are calculated as

$$E_s = \alpha_1 A_{1s} + \alpha_{2'} A_{2's}, \tag{57}$$

where $\alpha_{2'} = \mathbb{1}_{G_{12}}(s)\alpha_2 + \mathbb{1}_{G_{13}}(s)\alpha_3$ and $A_{2's} = \mathbb{1}_{G_{12}}(s)A_{2s} + \mathbb{1}_{G_{13}}(s)A_{3s}$ with $\mathbb{1}_{G_{ij}}(s) = 1$ if the specialist s belongs to the subgroup G_{ij}; 0 otherwise. A_{js} is the observed quantity of service $j = 1, 2, 3$ provided by specialist s and α_j the fee paid for service j.

For physicians providing 3 services, we have $G_3 = G_{123} \cup G_{125} \cup G_{126}$ where G_{123} , G_{125}, G_{126} are 3 disjoint subsets. G_{123} contains physicians who offered services 1, 2 and 3. It is made up of General surgeons and dermatologists .

The subgroup G_{125} contains physicians who provided services 1, 2 and 5. It is made up of pediatricians. G_{126} represents physicians who offered services 1, 2 and 6. It is made up of internal medicine physicians. Earnings for each specialist s in this case is computed as

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_{3'} A_{3's} \tag{58}$$

where

$$\begin{aligned} \alpha_{3'} &= \alpha_3 \mathbb{1}_{G_{123}}(s) + \alpha_5 \mathbb{1}_{G_{125}}(s) + \alpha_6 \mathbb{1}_{G_{126}}(s) \\ A_{3's} &= A_3 \mathbb{1}_{G_{123}}(s) + A_{5s} \mathbb{1}_{G_{125}}(s) + A_{6s} \mathbb{1}_{G_{126}}(s) \end{aligned}$$

with $\mathbb{1}_{G_{12k}}(s) = 1$ if s belongs to the subgroup G_{12k} $(k = 3, 5, 6)$ and 0 otherwise; A_{js} is the observed quantity of service $j = 1, 2, 3, 5, 6$ provided by specialist s and α_j the fee of service j.

The last case we can find in data is the one in which each specialist supplies 4 services. We denote this group of physicians, G_4. It includes two separate subgroups. G_{1234} contains specialists who provided services 1, 2, 3, and 4. It contains physicians who specialize in Obstetrics and Gynecology. Physicians in the second subgroup G_{1245} provided services 1, 2, 4 and 5. In this set we find only Orthopedic surgeons. Finally, $G_4 = G_{1234} \cup G_{1245}$ and $G_{1234} \cap G_{1245} = \emptyset$. We calculate physician's earning for this group as

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_4 A_{4s} + \alpha_{4'} A_{4's}, \tag{59}$$

where

$$\begin{aligned} \alpha_{4'} &= \alpha_3 \mathbb{1}_{G_{1234}}(s) + \alpha_5 \mathbb{1}_{G_{1245}}(s) \\ A_{4's} &= A_{3s} \mathbb{1}_{G_{1234}}(s) + A_{5s} \mathbb{1}_{G_{1245}}(s) \end{aligned}$$

with $\mathbb{1}_{G_{124k}}(s) = 1$ if s belongs to the subgroup G_{124k} $(k = 3, 5)$ and 0 otherwise; A_{js} is the observed quantity of service $j = 1, 2, 3, 4, 5$ provided by specialist s and α_j the fee of service j.

Table 9: Personal income tax structure in Québec 1996-2002

Year	Bracket Lower Bound	Federal Rate	Provincial Rate	Combined Rates
1996	0	0.17	0.16	0.33
1996	7000	0.17	0.19	0.36
1996	14000	0.17	0.21	0.38
1996	23000	0.17	0.23	0.4
1996	29590	0.26	0.23	0.49
1996	50000	0.26	0.24	0.5
1996	59180	0.29	0.24	0.53
1997	0	0.17	0.16	0.33
1997	7000	0.17	0.19	0.36
1997	14000	0.17	0.21	0.38
1997	23000	0.17	0.23	0.4
1997	29590	0.26	0.23	0.49
1997	50000	0.26	0.24	0.5
1997	59180	0.29	0.24	0.53
1998	0	0.17	0.2	0.37
1998	25000	0.17	0.23	0.4
1998	29590	0.26	0.23	0.49
1998	50000	0.26	0.26	0.52
1998	59180	0.29	0.26	0.55
1999	0	0.17	0.2	0.37
1999	25000	0.17	0.23	0.4
1999	29590	0.26	0.23	0.49
1999	50000	0.26	0.26	0.52
1999	59180	0.29	0.26	0.55
2000	0	0.17	0.19	0.36
2000	26000	0.17	0.225	0.395
2000	30004	0.25	0.225	0.475
2000	52000	0.25	0.25	0.5
2000	60009	0.29	0.25	0.54
2001	0	0.16	0.17	0.33
2001	26000	0.16	0.2125	0.3725
2001	30754	0.22	0.2125	0.4325
2001	52000	0.22	0.245	0.465
2001	61509	0.26	0.245	0.505
2001	100000	0.29	0.245	0.535
2002	0	0.16	0.16	0.32
2002	26700	0.16	0.2	0.36
2002	31677	0.22	0.2	0.42
2002	53405	0.22	0.24	0.46
2002	63354	0.26	0.24	0.5
2002	103000	0.29	0.24	0.53

Source: Milligan (2016)