Measuring Physicians’ Response to Incentives: Labour Supply, Multitasking, and Earnings

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Abstract
Physicians are typically paid for services completed. Yet, they provide different types of services with different prices, introducing a multitasking element to their labour-supply decisions. We show that optimal behaviour generates a maximum earnings function in which earnings depends on prices and total hours worked. Estimation by limited-information methods identifies a lower bound to the own-price substitution effect of a price change. Full-information methods identify the full response to incentives, including income effects. We illustrate these methods on a sample of specialist physicians working in Québec (Canada). Our results suggest that the own-price substitution effects of a price change are both economically and statistically significant. Income effects are present, but are overridden when prices are increased for individual services. In contrast, in the presence of broad-based fee increases, the income effect dominates the substitution effect, which leads physicians to reduce their supply of services.

JEL Classification: I10, J22, J33, J44.

Keywords: Physician labour supply, multitasking, earnings function, the Le Chatelier Principle, incentive pay.

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1 Introduction

Physician labour supply is distinct from many other settings. Physicians are typically paid according to their output, which implies that hours worked are an input into the production of services. Moreover, physicians must allocate their time across different services, introducing a multitasking component to their labour-supply choices.\footnote{Multitasking was introduced to economics by Holmstrom and Milgrom (1991), who analysed workers’ allocation of effort across different tasks within an agency framework.} Within this setting, physicians can alter the supply of services by changing total hours of work or by reallocating a fixed number of hours to different services. Knowledge of the sensitivity of these responses to changes in prices has important policy implications, particularly when health care is provided in the public sector. At least two issues emerge. First, beginning with Feldstein (1970), Rizzo and Blumenthal (1994) and, more recently, Baltagi, Bratberg, and Holmas (2005), Andreassen, Di Tommaso, and Strøm (2013) and Kalb, Kuehnle, Scott, Cheng, and Jeon (2018), much attention has been paid to characterizing the shape of physician labour-supply curves and the resulting implications for policies aimed at increasing the total supply of services (e.g., Sloan, 1975). A second issue is whether a change in the relative fee paid for a particular service leads physicians to increase the supply of that service. An ageing population is likely to increase the demand for services such as cardiovascular treatments, cataract surgeries, and hip replacements. Since training more physicians is costly and takes time, monetary incentives potentially provide the government with a policy tool to meet demand changes.

We address these issues, concentrating on the information that is contained in physician earnings on their labour supply and response to incentives. Earnings are a natural aggregator of services and have been used in different studies of physician behaviour; see, for example, Dumont, Fortin, Jacquemet, and Shearer (2008), Gottlieb, Polyakova, Rinz, Shiplett, and Udalova (2020) and Fortin, Jacquemet, and Shearer (2022). We model physician decisions over hours of work and the allocation of those hours across different services, generating earnings. We show that optimal behaviour gives rise to a conditional earnings function, which returns the maximum earnings a physician can generate for a given number of hours worked.

We formally characterise the properties of the conditional earnings function. It contains information over the response to incentives since physicians can reallocate a fixed number of hours worked across services, substituting towards services whose relative price has risen. We show that the resulting effect identifies a lower bound to the own-price substitution effects of the physicians’ supply of services when it is evaluated at optimal
hours worked. The lower bound results from the fact that changes in hours reinforce the own-price substitution effect, based on the Le Chatelier Principle (Samuelson, 1947; Milgrom and Roberts, 1996). The complete substitution effect involves an adjustment in total hours worked. The reallocation of hours described above affects the marginal return to working, which induces changes in hours worked. Additional hours are then allocated across different services optimally, including the service whose price has changed. Income effects operate through total hours worked since changes in non-labour income do not affect the relative return to any single service.

We illustrate these effects for a specific economic model, in which physicians have Constant Elasticity of Substitution preferences and the production of services is a power function of hours worked. We derive the earnings function for this model and apply it to a sample of physicians working in the province of Québec, Canada. Our data contain information on the number of services completed by individual physicians, along with the fees paid for those services and hours worked. The prices for services are set by the government and apply to all physicians in our sample. In addition, the 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.

We estimate the model using both limited-information and full-information methods. Limited-information methods condition on hours worked and impose fewer restrictions on the data. They amount to non-linear instrumental variables methods, where the instruments control for any endogenous variation in hours worked. Yet they are also less informative over the response to incentives. Identifying the complete reaction to incentives, including the substitution effect and the income effect requires full-information methods which simultaneously model hours of work decisions and earnings.

Our model allows us to analyse the relative importance of income and substitution effects, depending on the specificity of the price change. Our empirical results highlight the importance of these effects in determining physician behaviour. The own-price elasticities are positive and statistically significant for all services. Changes in the fees for individual services have positive effects on the supply of those services as the relative price change creates strong substitution effects which outweigh income effects. However, broad-based fee increases have negative effects on the supply of services as the income effect dominates in this case. 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

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2 Browning and Meghir (1991) use a similar conditional approach to analyse the impact of male and female hours of work on household commodity demands.
the effects of the recent decision of the Québec government to increase all fees by 30%. According to our simulations, this increase leads to a reduction in services by 2.3%.

Our paper is related to the literature studying the manner in which physicians react to monetary incentives. The foundations of this literature are surveyed in McGuire (1990). More recently, a large body of work has sought to measure the supply response of specific services subsequent to changes in relative prices. Examples include (but are not limited to): Gruber and Owings (1996), Keeler and Fok (1996), Gruber, Kim, and Mayzlin (1999), Grant (2009), Hadley, Reschovsky, Corey, , and Zuckerman (2009), Clemens and Gottlieb (2014), Allin, Baker, Isabelle, and Stabile (2015), Coey (2015) and Foo, Lee, and Fong (2017). Our work also concentrates on price changes, but generalizes the setting to multiple services, permitting a more general analysis of the response to incentives. Other work considers the supply of aggregate services and patient access to health care in response to changes in the compensation system (eg. Devlin and Sarma, 2008; Ferrall, Gregory, and Tholl, 1998; Fortin, Jacquemet, and Shearer, 2022), changes in fees paid for services (eg. Hurley and Labelle, 1995), or increases in Medicaid reimbursements (eg. Baker and Royalty, 2000; Buchmueller, Orzol, and Shore-Sheppard, 2015; Alexander and Schnell, 2020). As in Fortin, Jacquemet, and Shearer (2022), our work highlights the importance of income and substitution effects in determining physician responses to incentives. By focusing on price incentives and multitasking, our work allows us to investigate physician reactions to both individual and broad-based price increases, and their implications for the supply of medical services.

Our paper also contributes to the literature on physician labour supply. The classic labour-supply model links hours worked to an exogenous wage. This raises the question of how to define a physician’s wage when he/she is paid per service completed. One possibility is to construct wages by dividing earnings by hours worked; see, for example, Rizzo and Blumenthal (1994); Baltagi, Bratberg, and Holmas (2005); Kalb, Kuehnle, Scott, Cheng, and Jeon (2018). In contrast, our model generates a wage index which measures the marginal return to an hour worked when that hour is optimally allocated across different services. By explicitly modeling the relationship between hours and services and by focusing on how physicians allocate their time across multiple services in response to relative prices, our work provides links between the agency approach to physician behaviour (McGuire, 1990), multitasking (Holmstrom and Milgrom, 1991) and traditional labour supply (Blundell and Macurdy, 1999).

3 Related work considers demand inducement (eg. Evans, 1974; Rice, 1984; Dranove and Wehner., 1994; Yip, 1998) and the adverse consequences of implementing financial incentives (eg. Alexander, 2020).

4 See also Kantarevic, Kralj, and Weinkauf (2008).
The rest of the paper is organized as follows. Section 2 describes the institutional setting related to physician compensation in Québec and the sources of our data. Section 3 develops the properties of the earnings function in the presence of multitasking. Section 4 develops our model. Section 5 derives comparative statics, elasticities and the lower-bound for our model. Section 6 presents the details of our sample used for estimation and the descriptive statistics. Section 7 presents our estimation results, while Section 8 presents the incentive effects and discusses policy simulations. The last section concludes.

2 Data and Institutional Details

The data used for this study contain information on specialist physicians practicing in Québec between 1996 and 2002. These data are derived from two sources: the Québec College of Physicians and the Health Insurance Organization of Québec (RAMQ). During this time, the Québec College of Physicians (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 (yearly) average 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 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 Québec College of Physicians and from RAMQ were matched on the basis of an anonymous payroll number attributed to each physician.

In 2001, the government of Québec changed the prices paid to physicians for completed services, increasing the prices paid for services by up to 25%. Documented evidence suggests the main motivating factor behind the fee change was to narrow the income gap between Québec physicians and other Canadian physicians. In 1998-1999 Québec’s physicians had the lowest average incomes in comparisons across Canadian provinces (Lemieux, Bergeron, Bégin, and Bélanger, 2003). Reducing this income gap was a principal bargaining point of the Québec Federation of Specialist Physicians (FMSQ) in the 2000-2001 bargaining agreement with the government (Hébert, 2016).

We restrict our sample to specialists who were present both before and after 2001, the year in which prices were changed and to those who were paid fee-for-service contracts.5

5In 2000, the government of Québec introduced a mixed remuneration system, under which physicians were paid a reduced (relative to fee-for-service contracts) fee for services completed and a per-diem rewarding hours worked. Extending our model to include these physicians is an important extension that we leave for future work.
This restriction leads us to eliminate 3808 physicians of the 5904 in the initial database. Restricting attention to physicians who remained under the FFS system for the whole sample period eliminates another 590 specialists. Finally, we dropped the following (minor) specialities: electroencephalography, urology, pneumology, rheumatology, physiatry and plastic surgery which represented each between 0.4% and 2% of the sample. This removed another 277 physicians.

These physicians conduct a large number of medical services. Aggregating services based on the composite commodity theorem\(^6\), reduces the number of parameters to estimate and improves tractability of the model.\(^7\) This generated 6 aggregate services, depending on whether the price increased by 0%, 5%, 10%, 15%, 20%, or 25%. These services are denoted 1, 2, 3, 4, 5, and 6, respectively. The quantity of the each aggregate service provided by physician \(i\) in period \(t\) is measured by the weighted volume of the individual services that comprise the aggregate. The weights are provided by the base-period prices of the individual services. The price of the aggregate service is the percentage change in individual prices.\(^8\)

We grouped physicians according to the number of aggregate services that they supplied. This gave three separate groups of physicians: those who provided 2 different aggregate services, those who provided 3 different aggregate services and those who provided 4 different aggregate services. In our empirical application, we treat the change in the prices of services as a natural experiment with which to identify physician reaction to incentives. The validity of this approach, relies on the independence of the price changes from elements that directly affect physician productivity, such as technological change. With this in mind, in our empirical application, we limit our sample to physicians who provided 2 aggregate services. This includes physicians in the following specialties: cardiology, endocrinology, gastroenterology, neurology and otorhinolaryngology (ORL). A list of the services provided, classified by specialty, is given in Table 9 in Appendix A4. It is noteworthy that the vast majority of these services are related to consulting with patients, rather than performing specified medical acts. Of the 90 different services included in the data set, only two relate to specific acts, both performed by endocrinologists: biopsies and endoscopies. Technological change – which is the most likely source

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\(^{6}\) Services whose prices increased by the same proportion over time were grouped into one aggregate service.

\(^{7}\) We dropped 98 medical services which are not present over the whole sample period. We also removed services for which prices increased between the years 1996 and 2000 as we suspect these price changes reflect technological changes and are potentially endogenous. There were 85 such services.

\(^{8}\) See Appendix A2 for the application of the composite commodity theorem for our particular case. The details of the aggregation process and variable construction are given in Appendices A3 and A4.
of endogeneity in price changes – is unlikely to affect patient consultations (as they are largely comprised of interviews). Technological change is therefore unlikely to affect our empirical work, in the selected sample. We note that these physicians do not all provide the same services. In fact, there are two groups of physicians who provide 2 services: those who provide aggregate services 1 and 2, and those who provide aggregate services 1 and 3. There are 242 physicians in our final data set. These data are presented, in detail, in Section 6, below.

3 Multitasking and Earnings

To fix ideas and investigate the general properties of the earnings function, we consider the labour supply problem in the presence of multitasking. Individuals select hours $h_s$, and the manner in which those hours are allocated across tasks $j = 1, 2, \ldots, J$ to produce a quantity of services $A_1, A_2, \ldots, A_J$ via the production functions $f_j(h_j)$, where $h_j$ is the hours devoted to service $j$.

A physician’s preferences are represented by a well-behaved strictly quasi-concave utility function defined over income, $M$, and leisure $\ell = T - h_s$:

$$U(M, T - h_s), \text{ with } \frac{\partial U}{\partial M} > 0, \frac{\partial U}{\partial \ell} > 0,$$

where

$$M = \sum_{j=1}^{J} \alpha_j A_j + y, \quad (1)$$

$$A_j = f_j(h_j), \quad j \in \{1, \ldots, J\}, \quad (2)$$

$$h_s = \sum_{j=1}^{J} h_j, \quad h_j > 0 \quad \forall j, \quad (3)$$

$$f_j'(h_j) > 0, \quad f_j''(h_j) < 0 \quad \forall j. \quad (4)$$

The variable $T$ is time endowment and $h_s$ is total hours worked. The constraint (1) describes income as generated from providing services $j \in \{1, \ldots, J\}$, (we take $J$ as fixed) at prices, $\alpha_j$, and non-labour income $y$. The constraint (2) describes the production of service $A_j$ from the physicians input of time, $h_j$. The constraints (3) specify that total

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9 The process of generating our estimation sample – notably in concentrating on physicians who remained under fee-for-service contracts – may generate sample selection biases to the estimated elasticities if these physicians have different preferences from their colleagues. We return to this issue in the conclusion.
hours of work is allocated across services and we only consider interior solutions. The production functions \( f_j(h_j) \) are increasing and concave in \( h_j, \forall j \) (see (4)).

The physician’s optimization problem can be analysed in two steps. First, conditional on \( h_s \), the physician chooses \( h_1, h_2, \ldots, h_J \) to maximise income \( M \). Second, the physician chooses total hours worked, \( h_s \), to maximise utility. In this section, we focus on the first problem to derive the conditional earnings function and its properties. We show that this function contains economic information over the reaction to incentives.

Maximizing income conditional on \( h_s \) yields \( J - 1 \) first-order conditions

\[
\alpha_j f'_j(h_j) - \alpha_J f'_J(h_s - \sum_{j=1}^{J-1} h_j) = 0, \quad j = 1, \ldots, J - 1.
\] (5)

The optimal solution, denoted \( h^*_j \), \( j \in \{1, 2, J - 1\} \), solves (5). The \( J^{th} \) term comes from the constraint (3). Replacing \( h^*_j \) into (5) gives the identity

\[
\alpha_j f'_j(h^*_j) - \alpha_J f'_J(h^*_J) \equiv 0, \quad j = 1, \ldots, J - 1.
\] (6)

Lemma 1 follows from differentiation of (6).

**Lemma 1:** An increase in \( h_s \) increases hours allocated to all \( J \) services, \( h^*_j \), \( j \in \{1, 2, \ldots, J\} \), with

\[
\frac{\partial h^*_j}{\partial h_s} = \frac{\prod_{k \neq j} \alpha_k f''_k(h^*_k)}{\sum_{j=1}^{J} \left[ \prod_{k \neq j} \alpha_k f''_k(h^*_k) \right]} > 0.
\]

Now, denote \( E \) as the physician’s (labour market) earnings \( (= \sum_{j=1}^{J} \alpha_j A_j) \). The conditional earnings function is defined as

\[
E(\alpha; h_s) = \sum_{j=1}^{J} \alpha_j f_j(h^*_j(\alpha; h_s)),
\]

where \( \alpha \) denotes the vector of prices, \( (\alpha_1, \alpha_2, \ldots, \alpha_J)' \). It represents the maximum value

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10Our model contrasts from much of the theoretical literature on physician labour supply in abstracting from any concerns that physicians have for their patients welfare, or equivalently for the quality of services provided (see McGuire (1990) for a survey). This is due to data limitations. The absence of quality measures in our data, based on patient outcomes for example, precludes identifying preferences over the quality of care. We return to this point in the conclusion.

11All proofs are in Appendix A1.
of earnings from providing services that a physician can generate at prices $\alpha$ for a given number of total hours worked, $h_s$.

The conditional earnings function can be evaluated at any $h_s$. Evaluating it at $h^*_s$, optimal hours worked, generates information over substitution effects as developed in property (4), below. Solving for the utility maximising $h^*_s(\alpha, y)$ as a function of its underlying arguments (prices and non-labour income), and evaluating the earnings function at $h^*_s(\alpha, y)$ gives the unconditional earnings function, which is a function of prices and non-labour income.

### 3.1 Properties of the Conditional Earnings Function

The conditional earnings function has the following properties:

1. The partial derivative of the conditional earnings function with respect to $\alpha_j$ is equal to the conditional supply of service $j$:

$$\frac{\partial \mathcal{E}}{\partial \alpha_j} = A^*_j(\alpha, h_s).$$

2. The second partial derivative of the conditional earnings function with respect to $\alpha_j$ is equal to the slope of the conditional supply of service $j$:

$$\frac{\partial^2 \mathcal{E}}{\partial \alpha_j^2} = \frac{\partial A^*_j}{\partial \alpha_j}.$$

3. The conditional earnings function is convex in prices. Since physicians select $h^*_s$ to maximize earnings, when prices adjust, they can increase their earnings by more than the simple price change by reoptimizing.

4. The second partial derivative of the earnings function with respect to $\alpha_j$, evaluated at $h^*_s$, provides a lower bound to the own-price substitution effect of $\alpha_j$ on $A_j$.

The complete reaction to a change in price $\alpha_j$ involves a substitution effect and an income effect. The income effect operates solely through $h_s$ – changes in non-labour income do not affect the relative return to activity $j$. The partial derivative of the earnings function, holding $h_s$ constant, is therefore independent of the income effect.

The substitution effect also operates, in part, through $h_s$ but this reinforces the direct effect on $A_j$ that is measured in the earnings function. An increase in $\alpha_j$ increases the
return to hours worked $h_s$. The full utility maximization problem implies the substitution effect on $h_s$ is positive. Moreover, any increase in $h_s$ is distributed across all services, $\frac{\partial \bar{c}}{\partial h_s} > 0$ through Lemma 1. This effect is based on the Le Chatelier Principle (Samuelson, 1947; Milgrom and Roberts, 1996), well-known within the analysis of input demands in the presence of fixed factors of production. Here the fixed factor is total hours worked, which are set at their optimal level.\(^{12}\) Allowing hours to vary reinforces and magnifies the conditional price elasticity.

## 4 Empirical Model

To pursue our analysis of physician labour supply we derive the earnings function for a specific empirical model. The production of service $j$ per time unit by physician $i$ is given by the production function

$$A_{ij} = b_j(x_{b,i})h_i^\delta \epsilon_{ij}, \quad \epsilon_{ij} > 0, \ b_j > 0, \quad (7)$$

where $\delta \in (0, 1)$ captures the marginal return to time spent by the physician to provide service $j$. The value of $\delta$ is common across services.\(^{13}\) The production shock captures random elements that are specific to the physician (such as state of health), and affect his/her productivity; they are also common across services i.e. $\epsilon_{ij} = \epsilon_i \ \forall j$. The function $b_j(x_{b,i})$ captures average production when one hour is supplied to the service. Allowing $b_j$ to depend on observable individual characteristics, $x_{b,i}$, captures elements, such as age (or experience) and gender, that can affect the productivity or speed at which a physician completes the service. For example, experienced physicians may perform services more quickly, through learning-by-doing effects. Alternatively, male physicians may work at different speeds than female physicians.\(^{14}\)

Our model specifies a CES utility function for physicians, defined over consumption (which is assumed to be equal to income, $M$) and leisure, denoted by $\ell$. 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

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\(^{12}\)This assumption can be generalized to the case where total hours worked are set at any given level by making use of the concept of virtual prices, that is, the hypothetical prices at which total hours worked correspond to their nonconstrained optimal level.

\(^{13}\)Allowing for heterogeneity in $\delta$ across services would complicate the model’s estimation. We return to this point in Section 4.1, below.

\(^{14}\)For notational simplicity, save for a few exceptions, the index indicating physician $i$ is suppressed until the section (8) on estimation.
incentives, and to identify both income and substitution effects, yet it is parsimonious in
parameters, allowing for simple and direct interpretations of the results:

\[ U(M, \ell_o, \ell_p) = (\gamma(x) M^\rho + 0.5(1 - \gamma(x)) \ell_o^\rho + 0.5(1 - \gamma(x)) \ell_p^\rho)^{1/\rho}, \quad \rho < 1. \quad (8) \]

Here, on the job leisure\(^{16}\) is \( \ell_o = h_T - h_s \), where \( h_T \) is total time worked and \( h_s \), is time spent at work providing services to patients. Traditional leisure is \( \ell_p = T - h_T \), where \( T \) is time endowment. The relative weight a physician places on income and leisure is determined by \( \gamma \). We restrict the relative weight of both types of leisure to be the same.\(^{17}\)

Allowing \( \gamma \) to depend on characteristics, \( x \gamma \), captures observable heterogeneity in preferences for leisure.

Income is given by

\[ M = \sum_{j=1}^{\ell} \alpha_j A_j + y(x), \quad (9) \]

where \( \alpha_j \) represents the fee paid for service \( A_j \) and \( y(x) \) is non-labour income. This can depend on observable factors \( x \gamma \) which are related to asset returns. Labour-market earnings is that part of income that is derived from providing services:

\[ E = \sum_{j=1}^{\ell} \alpha_j A_j. \quad (10) \]

We list the key assumptions that we impose to simplify the model’s resolution and our empirical analysis. We return to a discussion of their importance and possibilities for relaxing them in the conclusion of the paper.

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 of services.

It allows us to search for interior solutions that examine how the supply of those

\(^{15}\)Stern (1986) provides an excellent discussion of the properties of CES and other utility functions and their uses in labour-supply models.

\(^{16}\)This includes nonpaid hours spent performing teaching and administrative duties. Dumont, Fortin, Jacquemet, and Shearer (2008) report that physicians paid fee-for-service contracts spend 5-6 hours per week on such activities. Our interpretation of these activities as on-the-job leisure follows Fortin, Jacquemet, and Shearer (2008).

\(^{17}\)This ensures that optimal \( h_s \) is linear function of \( h_T \), independent of \( \rho \). It simplifies the numerical solution of optimal hours in estimating the model.
services varies as prices change, ignoring services outside of this set. We ignore the decision to provide certain services and not others.\footnote{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.}

A.2 Common Shocks: We assume common shocks across services for a given physician $i$: $\epsilon_{ij} = \epsilon_i$ for $j = \{1, 2, \ldots, J\}$. We therefore interpret the production shock purely in terms of elements that affect the physician’s 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 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. Allowing for demand shocks that vary across services would require numerical solutions for the supply of services and the earnings function.

A.3 Perfectly Elastic Demand for Services and Exogenous Prices: We rule out demand shocks as determinants of the observed number of services provided. This seems reasonable within the context of a publicly provided health-care system, such as Canada. Excess demand and waiting lists for specialist services are prevalent in many publicly provided health-care systems.

A.4 Full Information for physicians: The physician observes $\epsilon$, the price of each service, and the technology parameters, $b_j$, before choosing hours. Given the restriction to common shocks that represent physician health, 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 Exogenous Participation: We assume that participation decisions are independent of potential physician productivity, $\epsilon$. This is consistent with much of the literature on physicians labour supply (e.g. Baltagi, Bratberg, and Holmas, 2005; Crossley,
Hurley, and Jeon, 2009; Kalb, Kuehnle, Scott, Cheng, and Jeon, 2018) and allows us to focus solely on the choice of hours worked and services at the intensive margin.

A.7 Independence: Productivity shocks are independent of personal characteristics, \( x = \{ x_b \cup x_\gamma \cup x_y \} \).

Physicians choose their total time at work, \( h_t \), the amount of time devoted to providing services to patients, \( h_s \), and the manner that those hours are allocated across different services, \( h_j, j = \{1,2,\ldots,J\} \). Substituting (9) and (7) into (8) and taking account of the definition of leisure and that \( h_s = \sum_{j=1}^{J} h_j \), utility is

\[
U = \left\{ \gamma(x_\gamma) \left[ \sum_{j=1}^{J-1} a_j b_j(x_b) h_j^\delta e + a_j b_j(x_b) \left( h_s - \sum_{j=1}^{J-1} h_j \right)^\delta e + y(x_y) \right] \right\}^\rho \\
+ 0.5 (1 - \gamma(x_\gamma)) \left( h_t - h_s \right)^\rho + 0.5 (1 - \gamma(x_\gamma)) \left( T - h_t \right)^\rho \right\}^{\frac{1}{\rho}}.
\]

For notational simplicity, we temporarily suppress dependence of \( \gamma, b \) and \( y \) on \( x \). These will be reintroduced in the empirical section.

4.1 Conditional Earnings

Conditional on clinical hours \( h_s \), the optimal time spent providing service \( j \) is

\[
h_j^*(\alpha, h_s) = \frac{P_j}{\sum_{k=1}^{J} P_k} h_s
\]

where\(^{19}\)

\[
P_j = (a_j b_j)^\frac{1}{\gamma_j}.
\]

Substituting (12) into (7), the optimal number of services of type \( j \) is

\[
A_j(\alpha, h_s) = b_j \left[ \frac{P_j}{\sum_{k=1}^{J} P_k} \right]^\delta \ h_s^\delta e.
\]

\(^{19}\)A closed-form solution for hours allocated to service \( j \) simplifies our empirical work. It relies on \( \delta \) and \( e \) being constant across services. If these elements were heterogeneous, optimal hours to each service would have to be solved numerically.
Substituting into (10) gives the conditional (labour-market) earnings function

$$\mathcal{E}(\alpha, x_b, h_s, \epsilon) = \omega(\alpha, x_b) h_s^\delta \epsilon.$$  

The conditional earnings function can be evaluated at any hours, $h_s$. Taking logarithms, and evaluating at optimal hours, $h_s^*$,

$$\ln \mathcal{E}(\alpha, x_b, h_s^*, \epsilon) = \ln \omega(\alpha, x_b) + \delta \ln h_s^* + \ln \epsilon. \quad (15)$$

The term

$$\omega(\alpha, x_b) = \left( \sum_{j=1}^{l} P_j \right)^{1-\delta}$$

determines the marginal return to an hour worked when that hour is optimally allocated across services, given relative prices. The term $\omega$ 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 exhibit 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 incentive (or substitution) effects, $\delta$, are identified in (15) from two sources. First, exogenous variation in $h_s$ and second, through $\omega$, by measuring the second-order effects of an increase in the price of service $j$ on earnings when total hours are fixed. In the model, $\delta$ captures the sensitivity of the supply of hours to a particular service to changes in the price for that service. If $\delta = 0$, hours and services provided are fixed and outside of the control of physicians. If this were the case, an increase in the price of service $j$ would induce a linear (accounting) increase in earnings with no change in physician behaviour. If physicians react to incentives, $\delta > 0$, then an increase in the price of service $j$ will lead to a change in earnings that is convex in price since both the price of service $j$ and hours devoted to service $j$ increase.²⁰

²⁰This is analogous to the detection of substitution effects from cost functions in the theory of the firm.
4.2 Optimal Hours and the Hours Function

The complete utility maximisation problem solves for optimal hours, $h^*_s$ as a function of prices, $\alpha$ and alternative income $y$. The optimal time spent working, conditional on $h_s$, is

$$h_t(h_s) = \frac{T + h_s}{2}. \quad (16)$$

Substituting from (12) and (16) back into (11) gives indirect utility as a function of $h_s$:

$$V(h_s) = \left[ \gamma(\omega h^*_s \epsilon + y)^\rho + 0.5(1 - \gamma)2^{1 - \rho}(T - h^*_s)^\rho \right]^{\frac{1}{\rho}},$$

The physician’s optimal hours spent seeing patients, $h^*_s$, solves

$$\gamma \omega \delta h^*_s^{\delta - 1} \epsilon (\omega h^*_s \epsilon + y)^{\rho - 1} - 0.5(1 - \gamma)2^{1 - \rho}(T - h^*_s)^{\rho - 1} = 0. \quad (17)$$

We note, $h^*_s$ depends on: prices $\alpha$ through $\omega$, $y$, $x$, through $\gamma(x)$, $x_b$, which enters $\omega$, $x_y$ through $y$, and $\epsilon$. We write

$$h^*_s = h^*_s(\alpha, y, x, \epsilon). \quad (18)$$

The second-order condition is

$$V_{h_s} = \gamma \omega \delta (\delta - 1)h^*_s^{\delta - 2}(\omega h^*_s \epsilon + y)^{\rho - 1} + \gamma(\rho - 1)(\omega \delta h^*_s^{\delta - 1})^2(\omega h^*_s \epsilon + y)^{\rho - 2} + 0.5(1 - \gamma)2^{1 - \rho}(\rho - 1)(T - h^*_s)^{\rho - 2} < 0 \quad (19)$$

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

While (17) does not give rise to an explicit functional form for $h^*_s$, it can be solved numerically. Evaluating (15) using (18) gives the conditional earnings function at $h^*_s$ as solved by our model:

$$\ln E^*(\alpha, x, \epsilon) = \ln \omega(\alpha, x_b) + \delta \ln h^*_s(\alpha, y, x, \epsilon) + \ln \epsilon. \quad (20)$$

---

21 The uniqueness of $h^*$ is ensured by the by the second-order condition, given in equation (19).

22 It will also depend on tax rates (see Section 7.3.1, below).

23 This is the unconditional earnings function since optimal hours are expressed as a function of prices $\alpha$ and non-labour income, $y$. The $h^*$ in (20) solves (17), rather than being pre-allocated at observed hours.
The estimation of (15) and (20) is complicated by three elements. First, they are non-linear functions of $\delta$ since $\omega = \left( \sum_j P_j \right)^{1-\delta}$ and $P_j = (\alpha_j \beta_j)^{1/17}$. Second, $h_s$ is potentially correlated with $\epsilon$, since physician's choose hours worked, implying $h_s^*(\alpha, y, x, \epsilon)$ maximises (8). Finally, individual characteristics can affect both preferences for hours worked and productivity, rendering identification of these different paths problematic. Identification of these separate channels may be through the non-linearities inherent in earnings, exclusion restrictions, and cross-equation restrictions. We return to these points below in discussing the empirical model.

5 Comparative statics and Lower Bound

A physician's reaction to incentives can be analyzed using comparative-static techniques. Price changes imply income and substitution effects for the supply of services. Within the context of our model, these effects operate through multiple channels since physicians choose the number of hours to work and the manner in which those hours are allocated across services. We present the relevant equations in the text, suppressing dependence on $x$.

We make the following definitions:

1. Let
   \[ \tilde{V}(h_s, \alpha, y, \epsilon) = \gamma \omega \delta h_s^{\delta-1} \epsilon \left( \omega h_s^{\delta} \epsilon + y \right)^{\rho-1} - 0.5(1 - \gamma)2^{1-\rho}(T - h_s)^{\rho-1}. \]

2. $h_s^*$ solves
   \[ \tilde{V}(h_s^*, \alpha, y, \epsilon) = 0; \]

3. The second-order condition
   \[ \tilde{V}_{h_s} \equiv \frac{\partial \tilde{V}(h_s^*, \alpha, y, \epsilon)}{\partial h_s} < 0. \]

24Complete derivations are given in Shearer, Somé, and Fortin (2019), Appendix A.2.
5.1 Own-price elasticities

The own-price elasticity of hours devoted to service $j$ is given by

$$\eta_{h_j} = \left[ \sum_{k \neq j} P_k \frac{1}{\sum_{k \neq j} P_k} - \gamma \frac{\alpha_j A_j \delta M^{\rho-1}}{h^2 \bar{V}_{h_j}^{\rho-1}} \right] + \frac{\alpha_j A_j}{y} \eta_{h_j, y},$$  \hspace{1cm} (21)

where:

$$\eta_{h_j, y} = \frac{y}{h_j} \left( \frac{\gamma (1 - \rho) \omega \delta h^{\rho-1} e M^{\rho-2}}{\bar{V}_{h_j}^{\rho-1}} \right)$$

$$\bar{V}_{h_j} = \omega \gamma (\delta - 1) h^{\rho - 2} M^{\rho - 1} + \gamma (\rho - 1) (\omega \delta h^{\rho-1} e)^2 M^{\rho-2} + 0.5 (1 - \gamma) 2^{1-\rho} (\rho - 1) (T - h) \rho^{-2} < 0,$$

$$M = \omega h^{\rho} e + y.$$

From (12),

$$\frac{\alpha_j \partial h_j}{h_j \partial \alpha_j} = \frac{1}{(1 - \delta)} \sum_{k \neq j} P_k > 0,$$

the first term of the substitution effect. This captures physicians reallocating a fixed number of hours towards those services that have higher relative prices in order to maximize earnings. The effect of this reallocation is to increase the wage index $\omega$. The second term of the substitution effect is positive, since $\bar{V}_{h_j}$ is negative from the second-order condition. The increase in $\omega$ leads physicians to work more hours, which are then allocated across all services. The fact that the total substitution effect is positive allows us to state its lower bound as

$$\mathcal{L}_j = \frac{1}{(1 - \delta)} \sum_{k \neq j} P_k,$$

which is independent of $\rho$. Notice that the elasticity for service $j$ is increasing in the terms $P_k = (\alpha_k b_k)^{1/(1-\delta)}$, for $k \neq j$. From (12), the larger are these terms relative to $P_j$, the less time is devoted to $h_j$. Since total hours are fixed, this implies a larger percentage response associated with any price change. Since the values of $b_k$ affect the return to providing service $k$ (and hence $P_k$ through (7)), they affect elasticities in the same manner.

Income effects are also present. The reallocation of services, in response to changes in prices, changes the wage index and the return to hours worked. The resulting change in
hours is then distributed across services in an optimal manner.

5.2 Cross-price elasticities

The cross-price elasticity is

$$
\eta_{h_s, h_j} = \left[ -\frac{1}{1 - \delta} \begin{array}{c} 
P_j \sum_k \frac{P_j}{h^2 V_{h_s}} 
+ \frac{\delta A_k M^{\rho - 1}}{h^2 V_{h_s}} \end{array} \right] + \frac{\alpha_j A_j}{\eta_{h_s, y}}.
$$

Again the substitution effect has two components, but unlike the own-price effect, these components operate in different directions. If the price of service $j$ increases, *ceteris paribus*, the change in relative prices causes physicians to substitute away from services whose relative price has decreased. But the resulting increase in $\omega$ 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. Again, the second term of the substitution effect operates through hours worked and hence depends on $\rho$ which is not identified from the conditional earnings equation.

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.*, Blomquist, 1989). Changes in prices cause first and second-order effects that determine the elasticity of substitution.

5.3 Wage index elasticities

We can also consider the impact of a proportional increase in all prices on physician behaviour. From (17), this can be approximated by the effect of the wage index on clinical hours worked, as given by:

$$
\eta_{h_s, \omega} = \frac{\omega}{h_s} \left[ -\frac{\gamma \delta h^\delta - 1 M^{\rho - 1}}{V_{h_s}} + \frac{(1 - \rho) \gamma \delta h^2 s - 1 e^{2 M^{\rho - 2}}}{V_{h_s}} \right].
$$

(23)

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 (12), the effect of an increase in $\omega$ on hours devoted to a given service can are the same as the effect on total hours

$$\frac{\partial h_j}{\partial \omega} \frac{\omega}{h_j} = \frac{P_j}{\sum_{k=1}^{K} P_k} \frac{\partial h_s}{\partial \omega} \frac{\omega}{h_s} = \frac{P_j}{\sum_{k=1}^{K} P_k} \frac{\partial h_s}{\partial \omega} \frac{\omega}{h_s} = \frac{\partial h_s}{\partial \omega} \frac{\omega}{h_s}. \tag{24}$$

Similarly,

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

6 Descriptive Statistics

Our data contain physicians who provided two aggregate services. This includes physicians who provided services 1 and 2 and physicians who provided services 1 and 3. The raw data are shown in Table 1. It shows summary statistics on the main variables of interest for our model (hours worked, prices and earnings). We provide statistics 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 services 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 for services two and three are evident in years 2001-2002, raising average earnings in the process. The real price of service two increases by 3.7% in 2001 relative to 2000 prices, and by 8.5% in 2002. The real price of service three increases by 8.8% in year 2001 relative to 2000, and by 19% in 2001, raising average earnings in the process. Subsequent to the fee changes, physician incomes increased by 21%. There is a slight decrease in clinical hours worked between the years 2000 and 2002, in the order of 3.5%.

The lower part of Table 1 presents average clinical hours and earnings for different characteristics of physicians. There is little difference between male and female physicians in terms of annual earnings, yet males spend less time seeing patients. This suggests
<table>
<thead>
<tr>
<th>Year</th>
<th>Obs</th>
<th>Service 1</th>
<th>Service 2</th>
<th>Service 3</th>
<th>(000's)</th>
<th>(weekly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>197</td>
<td>1.104</td>
<td>1.104</td>
<td>1.104</td>
<td>96.27</td>
<td>42.02</td>
</tr>
<tr>
<td>1997</td>
<td>201</td>
<td>1.086</td>
<td>1.086</td>
<td>1.086</td>
<td>93.68</td>
<td>46.47</td>
</tr>
<tr>
<td>1998</td>
<td>188</td>
<td>1.057</td>
<td>1.057</td>
<td>1.057</td>
<td>96.55</td>
<td>43.12</td>
</tr>
<tr>
<td>1999</td>
<td>192</td>
<td>1.035</td>
<td>1.035</td>
<td>1.035</td>
<td>95.75</td>
<td>44.74</td>
</tr>
<tr>
<td>2000</td>
<td>189</td>
<td>1.017</td>
<td>1.017</td>
<td>1.017</td>
<td>93.32</td>
<td>44.98</td>
</tr>
<tr>
<td>2001</td>
<td>168</td>
<td>1.005</td>
<td>1.055</td>
<td>1.106</td>
<td>106.94</td>
<td>44.15</td>
</tr>
<tr>
<td>2002</td>
<td>165</td>
<td>1.000</td>
<td>1.103</td>
<td>1.210</td>
<td>112.94</td>
<td>43.39</td>
</tr>
</tbody>
</table>

| Male | 1188 | –       | –       | –       | 99.00   | 43.84    |
| Female | 201  | –       | –       | –       | 97.90   | 47.37    |
| French | 1082 | –       | –       | –       | 99.50   | 44.90    |
| English | 218  | –       | –       | –       | 95.95   | 40.44    |
| Age < 40 | 482  | –       | –       | –       | 87.33   | 44.45    |
| 40 < Age < 60 | 602 | –   | –       | –       | 108.67  | 44.74    |
| 60 < Age | 216  | –       | –       | –       | 97.49   | 41.81    |
that males earn more per hour worked. Physicians whose native language is French work
more and earn more than do those whose native language is English. Middle-aged physi-
cicians, those whose age is between 40 and 60, display no tendency to work more than do
those aged less than 40, but they earn considerably more. This suggests they are more ef-
ficient in their diagnoses and practices. Physicians who are older than 60 spend less time
seeing patients and earn less than middle-aged physicians, but more than their younger
counterparts. We will use these facts in specifying our econometric model.

7 Estimation

Our empirical model consists of three basic equations, explaining for physician \( i \) in period
\( t \): total earnings, (25a), earnings on services \( j \), (25b), and hours worked, (25c):

\[
\ln E_{i,t} = \ln \omega_t + \delta \ln h_{i,t} + \ln \epsilon_{i,t}, \tag{25a}
\]

\[
\ln E_{i,j,t} = \ln (P_{j,t}) - \delta \ln (\sum_j P_{j,t}) + \delta \ln h_{i,t} + \ln \epsilon_{i,t} \quad j = 2, \ldots, J, \tag{25b}
\]

\[
0 = \gamma(x)\omega_t \delta h_{i,t}^{\delta-1} \epsilon_{i,t} (\omega_t h_{i,t}^\delta \epsilon + y(x))^{\rho-1} - 0.5(1 - \gamma(x))2^{1-\rho}(T - h_{i,t})^{\rho-1} \tag{25c}
\]

where \( \omega_t = \left(\sum_{j=1}^J P_{j,t}\right)^{(1-\delta)} \) and \( P_{j,t} = (b_j x_{j,t})^{1/T} \).

7.1 Specification

We allow physician choices to be affected by two sources of exogenous variation: vari-
ables on the personal characteristics of physicians and variables on non-labour income.
We use \( x_\gamma \) to denote personal characteristics which affect preferences for leisure, \( x_b \) to
denote characteristics which affect productivity and \( x_Y \) to denote variables which affect
non-labour income.

The function \( b_j(x_{j,t}) \) includes a service-specific constant term \( b_{0,j} \) as well as terms cap-
turing the effect of personal characteristics (age, and gender) which plausibly affect physi-
cian productivity. Age is included to capture the effect of experience on the ability to
perform diagnoses and perform services. We also experiment with including a trend to
capture changes in productivity through time due, for example, to technological change.

We ensure \( b(x) \) is positive, using the exponential function:

\[
b(x) = \exp(b_{0,j} + x_{j}^T b),
\]
where \( x'_j b \) is independent of \( j \).

The function \( \gamma(x_j) \) is specified as logistic:

\[
\gamma(x_j) = \frac{\exp(x'_j \gamma)}{1 + \exp(x'_j \gamma)},
\]

where \( x_j \) contains age, gender and native language.\(^{25}\) We exclude the middle-age dummy from \( x_j \), forcing their preferences for leisure to be identical to young physicians, since these two groups display no differences in hours worked in Table 1.

The function \( y(x_j) \) is specified to capture non-labour income in year \( t \) that can affect hours choices through income effects. We specify \( y(x_j) \) to be a linear function of the stock market return during the year. Returns are plausibly correlated with asset income, which has often been used to capture non-labour income (e.g., Heckman, 1974).\(^{26}\)

### 7.2 Limited Information Estimation

Limited-information methods estimate the conditional earnings equations (25a) and (25b). Hours, \( h_s \), are taken as given and the model is used to explain how those hours are allocated across different services, given changes in prices. This has certain advantages. Principally, estimation does not require solving for optimal hours through (25c) and is therefore easier. It also relies on fewer restrictions from the model and therefore may provide more robust estimates. Yet there are also costs. Ignoring variation in hours worked precludes the identification of \( \rho \) (which only enters (25c)). Since income effects and part of the substitution effect depend on changes in \( h_s \), these full effects are not identified from limited-information estimation. The limited-information approach does allow us to estimate \( \delta \) and to construct a lower bound to the own-price substitution effect, based on (22). It therefore provides an answer to the question of whether or not physicians respond to monetary incentives.

To estimate the parameters, we treat the earnings of each service as a separate equation and estimate a multivariate non-linear regression model:

\(^{25}\)In practice we restricted \( \gamma(x_j) \in [0, 2/3] \), forcing its value to equal 1/3 when \( x'_j \gamma = 0 \). The latter captures the equal shares case.

\(^{26}\)We have no information on spousal income. Nor was there a major tax reform during the time period under study, another possible instrument for hours worked; see, for example, Blundell, Duncan, and Meghir (1998), and Showalter and Thurston (1997). Also, to be fully consistent with an inter-temporally separable life-cycle model involving a two stage budgeting process, the non-labour income should be net of savings (Blundell and Walker, 1986). Unfortunately, we have no information on physicians’ savings in our data set. Admittedly, this may be a source of measurement errors in our estimates.
\[
\begin{align*}
\ln e_{1,12,t} &= \ln(P_{1,12}) - \delta \ln(P_{1,12} + P_2) + \delta \ln h_{1,t} + \ln \epsilon_{1,t}, \\
\ln e_{1,13,t} &= \ln(P_{1,13}) - \delta \ln(P_{1,13} + P_3) + \delta \ln h_{1,t} + \ln \epsilon_{1,t}, \\
\ln e_{2,t} &= \ln(P_2) - \delta \ln(P_{1,12} + P_2) + \delta \ln h_{1,t} + \ln \epsilon_{2,t}, \\
\ln e_{3,t} &= \ln(P_3) - \delta \ln(P_{1,13} + P_3) + \delta \ln h_{1,t} + \ln \epsilon_{3,t},
\end{align*}
\]

where \( P_j = (b_j, \alpha_j) \). We allow the parameter \( b_1 \) to differ depending on whether the physician provides services 1 and 2 or services 1 and 3. \(^{27}\) \( x_p \) contains a dummy variable for male physicians, a dummy variable for middle aged physicians, a dummy variable for old physicians and a trend term. We define a set of instruments for equation \( \ell \in \{1, 2, 3, 4\} \) in (26) as \( Z_\ell \). \(^{28}\) We include in \( Z_\ell \) the relevant service prices for equation \( \ell, D_{male}, D_{mid}, D_{old}, D_{French} \), the annual market return and its interaction with \( D_{mid} \) and \( D_{old} \). We note that the earnings equations do not include a constant term, hence no constant is included in the instrument set. \(^{29}\)

Equations (26) can then be estimated by minimizing

\[
(\mathbf{E}^o - \mathbf{E}(\beta))' \mathbf{W} (\mathbf{E}^o - \mathbf{E}(\beta)),
\]

where \( \mathbf{E}^o \) represents the stacked vector of observed earnings, \( \mathbf{E}(\beta) \) represents the stacked vector of predicted earnings, from the model, and \( \mathbf{W} \) is a weighting matrix. In the case of non-linear least squares, \( \mathbf{W} \) is set to the identity matrix. These estimates are inconsistent if hours choices are correlated with \( \epsilon \). In that case, instrumental variables will be consistent, even if \( \epsilon \) contains unobserved physician ability \(^{30}\), as long as the instruments are independent of \( \epsilon \). For non-linear instrumental variables estimation, \( \mathbf{W} \) is a block diagonal matrix with block \( \ell \) given by \( P_{Z_\ell} = Z_\ell \left(Z'_\ell Z_\ell\right)^{-1} Z_\ell \).

\(^{27}\) It is possible to allow \( \delta \) to differ depending on whether or not the physician provides services 1 and 2 or 1 and 3. Unfortunately, our estimates of this more general model lacked precision.

\(^{28}\) Valid instruments affect \( h_s \), but are independent of \( \epsilon \). From the model, non-labour market income is correlated with hours through the income effect. Yet, conditional on hours, the earnings function is independent of these effects.

\(^{29}\) Notice that even if \( b_j \) contains a constant, its derivative multiplies the price \( \alpha_j \).

\(^{30}\) Wooldridge (2010) calls such estimators Random Effects Instrumental Variables Estimators.
7.2.1 First-Stage Results

We present first-stage regressions in Table 2. These are regressions of the model’s endogenous variable (ln $h$) on the exogenous prices in equation $\ell$ and the instruments. We present the results from two separate specifications of the model: with and without a trend term among the instruments. These are presented separately for physicians providing services one and two and physicians providing services one and three. The price variables are generally statistically significant, though not always positive. The market return variable is negative and statistically significant in the versions without a trend. It loses its significance when the trend is included. The reported F statistics are for the restriction that all coefficients apart from the prices are equal to zero. These are significant in all cases except for the specification without trend on physicians providing services one and three. This shows that the instruments are correlated with the endogenous variable.

Often tests for weak instruments concentrate on the F statistics for the subset of instruments that are excluded from the equation of interest – in our case the earnings equation. These tests will depend on the specification of the model. Below we estimate two versions of the earnings equation. The first version allows $b(x)$ to depend on observable characteristics: male, Dmid, and Dold. The excluded instruments for this version are: DFrench, Market Return, Market × Dmid and Market × Dold. The F-statistics is 6.88 with 4 and 184 degrees of freedom for the case of physicians providing services one and two; the p-value is essentially zero. It is 2.17 with 4 and 56 degrees of freedom for the case of physicians providing services one and three; the p-value is 0.084. The second version adds a trend term to $b(x)$. Here, the excluded instruments are the same as for the first version. The F-statistics for the case of physicians providing services one and two is 0.92; the p-value is 0.456. For physicians providing services one and three the F-statistic is 1.31 with a p-value of 0.276.

Overall, the evidence for weak instruments is mixed and depends on the version of the model estimated. Some versions (column II) display large F-statistics, suggesting the instruments are not weak. Other versions (column III) display small F-statistics. This reflects the general difficulty of finding suitable instruments for hours of work in our data. Other data sets may be richer in this respect.

7.2.2 Conditional Earnings Equation Estimates

Table 3 provides results for two different specifications of the earnings function. Specification (1) allows $b(x)$ to depend on gender and age, but no trend. Specification (2) adds a
Table 2: First-Stage Estimates  
(Dependent variable: Logarithm of hours worked)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Services 1 and 2</th>
<th>Services 1 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>2.266*** (0.325)</td>
<td>4.920*** (0.325)</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>1.208*** (0.311)</td>
<td>1.690 (0.311)</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.026 (0.109)</td>
<td>0.005 (0.107)</td>
</tr>
<tr>
<td>$DFrench$</td>
<td>0.129* (0.077)</td>
<td>0.102 (0.078)</td>
</tr>
<tr>
<td>$Dmid$</td>
<td>0.005 (0.047)</td>
<td>-0.014 (0.048)</td>
</tr>
<tr>
<td>$Dold$</td>
<td>-0.088 (0.088)</td>
<td>-0.117 (0.088)</td>
</tr>
<tr>
<td>$Market\times Dmid$</td>
<td>-0.295*** (0.086)</td>
<td>0.046 (0.086)</td>
</tr>
<tr>
<td>$Market\times Dold$</td>
<td>-0.049 (0.108)</td>
<td>-0.022 (0.107)</td>
</tr>
<tr>
<td>Trend</td>
<td>-0.158 (0.170)</td>
<td>-0.217 (0.168)</td>
</tr>
<tr>
<td>F-Statistic$^1$</td>
<td>4.70***</td>
<td>30.63***</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>(7, 184)</td>
<td>(8, 184)</td>
</tr>
<tr>
<td>P-Value</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Observations</td>
<td>983</td>
<td>983</td>
</tr>
</tbody>
</table>

1. The reported F-Statistics correspond to the restriction that all coefficients, apart from the $\alpha$s, are equal to zero.
2. Estimated standard errors in parentheses.
3. Standard errors are robust and clustered over individuals.
4. ***, ** and * indicate statistical significance at levels: 0.01, 0.05 and 0.1, respectively.
trend term to service 3.\footnote{Allowing the trend to affect services 1 and 2 did not change the results.} For each specification, we provide least-squares estimates (LS) and generalised method of moments estimates (GMM).

The least-squares estimate of $\delta$ is close to 0.5 in each specification and are statistically significant. The GMM estimate of $\delta$ is close to 0.6 in specification (1), but falls to 0.544 when the trend term is included in specification (2). They are also statistically significant. Of the individual characteristics, only $b_{Dmid}$ is consistently significant. It is also positive, reflecting that physicians in the middle of their careers are more productive and have higher earnings for a given level of hours. This is consistent with the summary statistics presented in Table 1. The trend term is insignificant in both least-squares and GMM estimation.

We test the overidentifying restrictions in the model using a Sargan test, based the value of the objective function. These are given in the last row of the Table. These restrictions are not rejected – the P-values are well above 0.05 in all cases. We also perform a Durbin-Wu-Hausman test on the difference between the least-squares estimates and the GMM estimates.\footnote{The form of the test is given in Davidson and MacKinnon (1993). It is calculated as the F-test for $c = 0$ in the artificial regression

$$y - x(\hat{\beta}) = \hat{\mathbf{x}}b + M_2\hat{\mathbf{x}}^*c + \text{residuals},$$

where $\hat{\mathbf{x}} = \partial x(\hat{\beta}) / \partial \beta$, evaluated at the NLS estimates $\hat{\beta}$, and $\hat{\mathbf{x}}^*$ are the columns of $\hat{\mathbf{x}}$ that are correlated with the error term: $\partial x(\hat{\beta}) / \partial \delta$ in our case. $M_2\hat{\mathbf{x}}^*$ are the residuals from regressing the columns of $\hat{\mathbf{x}}^*$ on the set of instruments.} The p-values are 0.042, and 0.050 for the different specifications, suggesting inconsistency of least-squares estimates.

The estimates of the lower bound to the own-price substitution effect of a price change on service $j$, are presented in Table 4. Column (1) presents the results based on the GMM estimates, without a trend. Column (2) presents the results based on the GMM estimates including a trend. The estimated elasticities are all positive, although they are considerably larger for service 1 than for services 2 and 3. This is due to the large estimated values of $b_2$ and $b_3$ relative to $b_{1,12}$ and $b_{1,13}$, as presented in Table 3. Recall, from (22) and the discussion thereafter, the higher $b_{k \neq j}$ terms reduce the hours devoted to service $j$ and hence increase its price elasticity. The full substitution effects and the income effects of a price change, given in (21), as well as the elasticities of hours worked, depend on the parameter $\rho$ which does not enter the conditional earnings function. We now turn to full-information methods to estimate all parameters and identify these effects.
Table 3: Limited-Information Estimates
(Independent variable: ln $\bar{e}$)

<table>
<thead>
<tr>
<th>Specification</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>LS</td>
<td>GMM</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.505*** (0.075)</td>
<td>0.626*** (0.122)</td>
</tr>
<tr>
<td>$b_{1,12}$</td>
<td>0.784*** (0.127)</td>
<td>0.799*** (0.184)</td>
</tr>
<tr>
<td>$b_{1,13}$</td>
<td>-0.063 (0.138)</td>
<td>-0.004 (0.206)</td>
</tr>
<tr>
<td>$b_2$</td>
<td>2.222*** (0.304)</td>
<td>1.856** (0.487)</td>
</tr>
<tr>
<td>$b_3$</td>
<td>1.268*** (0.305)</td>
<td>0.980* (0.485)</td>
</tr>
<tr>
<td>$b_{\text{Male}}$</td>
<td>0.150 (0.110)</td>
<td>-0.010 (0.143)</td>
</tr>
<tr>
<td>$b_{\text{Dmid}}$</td>
<td>0.177*** (0.068)</td>
<td>0.221*** (0.087)</td>
</tr>
<tr>
<td>$b_{\text{Dold}}$</td>
<td>0.200*** (0.091)</td>
<td>0.060 (0.130)</td>
</tr>
<tr>
<td>$b_{\text{Trend}}$</td>
<td>0.030 (0.033)</td>
<td>0.006 (0.033)</td>
</tr>
<tr>
<td>P-Value Overidentification</td>
<td>0.697</td>
<td>0.622</td>
</tr>
<tr>
<td>P-Value DWH Test</td>
<td>0.042</td>
<td>0.050</td>
</tr>
<tr>
<td>Observations</td>
<td>1,300</td>
<td>1,300</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Table 4: Own-Price Elasticity Lower Bounds

<table>
<thead>
<tr>
<th>Specification</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{1,12}$</td>
<td>1.581</td>
<td>1.235</td>
</tr>
<tr>
<td></td>
<td>[1.360, 1.698]</td>
<td>[1.020, 1.357]</td>
</tr>
<tr>
<td>$\eta_{2,2}$</td>
<td>0.090</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>[0.028, 0.421]</td>
<td>[0.021, 0.363]</td>
</tr>
<tr>
<td>$\eta_{1,13}$</td>
<td>1.566</td>
<td>1.221</td>
</tr>
<tr>
<td></td>
<td>[1.351, 1.694]</td>
<td>[1.013, 1.349]</td>
</tr>
<tr>
<td>$\eta_{3,3}$</td>
<td>0.105</td>
<td>0.085</td>
</tr>
<tr>
<td></td>
<td>[0.034, 0.415]</td>
<td>[0.025, 0.362]</td>
</tr>
</tbody>
</table>

Bootstrapped 95% Confidence Intervals in brackets

7.3 Full-Information Estimation

The full-information model adds the hours equation (25c) and evaluates the conditional earnings equations (25a) and (25b) at optimal hours given by (18). Explaining observed variation in hours worked in each period identifies the parameter $\rho$. The fact that $b(x)$ affects hours choices through $P_j$ generates cross-equation restrictions that can help identify its parameters as well. We denote the parameter vector as

$$\Gamma = (\rho, \delta, b_{1,12}, b_{1,13}, b_2, b_3, b_{x_1}, b_{x_2}, \sigma^2_\epsilon).$$

(27)

We estimate the model using simulated method of moments (SMM), generating $\epsilon$ from a lognormal distribution. Let $h^*_s,t_{i,j} (\Gamma, \alpha_t, X_i, \epsilon_r)$, denote the hours worked that solves (25c), given prices, $\alpha_t$, observed characteristics $X_i$ and a particular draw of $\epsilon_r$. Similarly, let $E^*_{i,j,t} (\Gamma, \alpha_t, X_i, \epsilon_r)$ denote the resulting earnings on service $j$ and $E^*_{i,t} (\Gamma, \alpha_t, X_i, \epsilon_r)$, total earnings. Given $N_t$ repeated draws of $\epsilon_{i,t}$ for observation $i$, we calculate the simulated
expectations, conditional on prices $\alpha_t$, and observable $X_i$, as

$$m^*_{h,t} (\Gamma, \alpha_t, X_i) = \frac{1}{N_r} \sum_{r=1}^{N_r} \ln h^*_{t,i,r} (\Gamma, \alpha_t, X_i, \epsilon_r),$$

$$m^*_{E,t} (\Gamma, \alpha_t, X_i) = \frac{1}{N_r} \sum_{r=1}^{N_r} \ln E^*_{t,i,r} (\Gamma, \alpha_t, X_i, \epsilon_r),$$

$$m^*_{E,ij,t} (\Gamma, \alpha_t, X_i) = \frac{1}{N_r} \sum_{r=1}^{N_r} \ln E^*_{t,ij,r} (\Gamma, \alpha_t, X_i, \epsilon_r),$$

for services $j = 2, 3$.

Recall that physicians provide either services one and two or services one and three. We let $\mathcal{S} \in \{2, 3\}$ denote these two sets of physicians. We match each simulated expectation to its observed counterpart, giving simulated residuals for observation $i, t$

$$m^*_{\mathcal{S},t} (\Gamma)_{i,t} = \begin{bmatrix} \ln h_{t,i} - m^*_{h,t} (\Gamma, \alpha_t, X_i) \\ \ln E_{t,i} - m^*_{E,t} (\Gamma, \alpha_t, X_i) \\ \ln E_{t,ij} - m^*_{E,ij,t} (\Gamma, \alpha_t, X_i) \end{bmatrix} \quad j \in \{2, 3\}.$$

Let $N_\mathcal{S}$ denote the number of observations on physicians of type $\mathcal{S}$ and let $m^*_{\mathcal{S}} (\Gamma)$ denote the $3N_\mathcal{S} \times 1$ vector which stacks the $N_\mathcal{S} \times 1$ vectors: $\ln h_t - m^*_{h,t} (\Gamma, \alpha, X)$, $\ln E_t - m^*_{E,t} (\Gamma, \alpha, X)$ and $\ln E_{t,ij} - m^*_{E,ij,t} (\ln E_{t,ij}; \Gamma, \alpha, X)$. The $N_\mathcal{S} \times k$ instrument matrix, $Z_\mathcal{S}$ is the same for all equations.

We form the objective function for each set of physicians $\mathcal{S} \in \{1, 2\}$

$$m^*_{\mathcal{S}} (\Gamma)' W_\mathcal{S} m^*_{\mathcal{S}} (\Gamma).$$

$W_\mathcal{S}$ is a block diagonal matrix with block $k$ given by $P_{Z_\mathcal{S}} = Z_\mathcal{S} (Z_\mathcal{S}' Z_\mathcal{S})^{-1} Z_\mathcal{S}'$, the projection matrix associated with the instruments of the set $\mathcal{S}$ physicians. Since the error term is common to all equations of the model, the instrument set is the same across equations, within each set of physicians. It includes the relevant prices as well as the elements of $X = \{x_b \cup x_\gamma \cup x_y\}$. To identify the variance of $\epsilon$, which is assumed constant across time and sets of physicians, we add the unconditional second moment of total earnings.

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33 Estimation of (28) is equivalent to the non-linear instrumental variables estimator of Amemiya (1985).
Here we match the simulated second moment of log of total earnings

\[ m^*(\ln \mathcal{E})^2 = \frac{1}{N_r} \frac{1}{N^r} \sum_{i=1}^{N^r} \sum_{r=1}^{N_r} (\ln E_{i,r}^*(\mathbf{I}_r, \mathcal{E}_{i,r}))^2 \]

to the observed second moment of the log of earnings.

\[ \frac{1}{N^r} \sum_{i=1}^{N^r} (\ln \mathcal{E}_{i,t})^2 \]

We weight this moment in the objective function by the inverse of its standard deviation.

Our estimation approach is similar in spirit to a pooled statistical model, in which ignored correlation across periods, due to random effects for example, causes an efficiency loss. In our case, random effects enter \( \mathcal{E} \). The correlation between those random effects and hours worked is captured through (25c), providing consistent estimates of the parameters.

### 7.3.1 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 Shearer, Somé, and Fortin (2019). 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 Quèbec imposed half-yearly billing ceilings\(^{34}\) on physicians. Payment for billed services, beyond the ceiling, was reduced by 75%. Let \( E_{w,c} \) denote the weekly income ceiling.\(^{35}\) The weekly earnings derived from seeing patients, \( \mathcal{E} = \mathcal{E} \delta w_t \mathcal{E} \), allows us to calculate the number of weekly hours needed to obtain \( E_{w,c} \).

\(^{34}\)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.

\(^{35}\)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.
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

$$E = \begin{cases} \quad wh^\delta e & \text{if } h_s \leq \overline{h}_{s,c} \\ \frac{1}{1-\tau_c}wh^\delta e & \text{if } h_s > \overline{h}_{s,c}. \end{cases}$$

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

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

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

where $E$ represents earnings.\(^{36}\) Since the marginal tax rate depends on income, it will depend on hours worked (and $\epsilon$). 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 $\tau_1$. Then, for $h_s > \overline{h}_{s,1}$, we solve for virtual income, $\overline{B}_2$, that equates

$$\overline{B}_2 + (1 - \tau_2)wh_{s,1}^\delta e = (1 - \tau_1)wh_{s,1}^\delta e$$

$$\Leftrightarrow \overline{B}_2 = (\tau_2 - \tau_1)wh_{s,1}^\delta e$$

$$= (\tau_2 - \tau_1)\overline{E}_{w,1}.$$  

\(^{36}\)For the purposes of taxation, we restrict attention to labour-market earnings.
This generalizes easily to find the virtual income that equates earnings at between the \( j \)th and \((j - 1)\)th income-tax bracket:

\[
\bar{B}_j = \sum_{k=1}^{j-1} (\tau_{i+1} - \tau_i) \bar{E}_{i,t}.
\]

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

\[
(1 - \tau_j)(1 - \tau_c) \omega h^d \epsilon,
\]

where \( \tau_j \) is the marginal tax rate at the \( j \)th income-tax bracket. To calculate the optimal hours in this context we proceed piecewise throughout the composite budget constraint following Hausman (1979). Given the kink points, \( h_{s,c} \) depend on \( \epsilon \), the program must be solved for each draw of \( \epsilon \), for each individual.\(^{37}\)

### 7.3.2 Full-Information Results

The results are presented in Table 5. We present two versions of the model. In the first version, \( b(x) \) and \( \gamma(x) \) depend on gender and age. The second version adds a trend term to \( b(x) \) for service 3. One interpretation of this specification is to control for possible endogeneity of the changes to service prices due to technological change that affects the production of type 3 services relative to type 1 and type 2 services. Given the prices of services 3 increase by more that service 1 or 2, one would expect the coefficient on the trend term to be negative if technological change is affecting prices.\(^{38}\) We exclude \( dmid \) from \( \gamma(x) \) since the statistics from Table 1 suggest that middle-aged physicians do not differ in hours worked from young physicians. We also exclude a french-speaking dummy variable from \( \gamma(x) \) as it caused collinearity (and convergence) problems. We specify non-labour income in period \( t \) as a (non stochastic) function of the market return in period \( t \). For the version without a trend we use the same instruments as in the limited-information model: the

\(^{37}\)For a given draw of \( \epsilon \) and given the kink points, \( h(s,c) \) and virtual income \( \bar{B} \), we solve for the optimal hours on the first budget segment. If it is interior to that segment it is the optimal level of hours worked. If optimal hours is a corner solution, at \( h(s,1) \), we calculate optimal hours in the next virtual budget segment. If it is an inferior corner solution, at \( h(s,1) \), then the optimal hours is \( h(s,1) \). Otherwise we repeat the procedure in the second virtual budget segment.

\(^{38}\)The coefficient estimates on the trend terms for services one and two were very close to zero, statistically insignificant and their inclusion led to imprecise estimates of other coefficients in the model. We also exclude the french-language dummy and the interactions between age and the market return from the instrument set as their inclusion caused convergence problems due to multicollinearity.

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relevant prices and $dmale, dfrench, dmid, dold, market, market \ast dmid, market \ast dold$. When the trend is included, the estimation algorithm did not converge with these instruments. We therefore dropped the market interaction terms and dfrench.

The parameter estimates are similar across specifications. The utility function parameters $\delta$ and $\rho$ are precisely estimated, as are the constant terms in $b(x)$. The estimated value of $\delta$ is 0.647 without the trend, and 0.623 with the trend. The value of $\rho$ is somewhat more sensitive to the inclusion of the trend. Its value is $-0.195$ without a trend and $-0.242$ with the trend. The coefficients which determine the dependence of production on characteristics are generally less precisely estimated. There is no evidence that male physicians in this sample differ in productivity from their female counterparts. Middle aged physicians are more productive than young (inexperienced) physicians. This is consistent with learning by doing as experienced physicians are able to perform diagnoses and services more quickly. Older physicians, display no productivity differences from their young counterparts, suggesting that the productivity profile is concave in age (or experience). The preference for leisure displays little variation across gender, although older physicians have a lower value of $\gamma$ which leads to working fewer hours. The p-value on this coefficient is 0.107 for the version without a trend and 0.104 for the version with a trend. The inclusion of the trend does not alter the parameter estimates in sign or the order of magnitude. The market return coefficient is positive and statistically significant, yet it is small. Income is measured in thousands of dollars annually, suggesting that a one percent increase in the stock market return leads to a $20\$ increase in non-labour income. Taken literally, this suggests that physicians had very little money invested in the stock market. An alternative interpretation is that this coefficient reflects perceived income generated in the stock market. Under this interpretation physicians adjust their hours worked in response to stock-market changes as if a one percent increase in the stock market generated $20\$ of income. Inclusion of the trend term nearly doubles the stock market coefficient. Interestingly, the trend term is negative and statistically significant. While its inclusion does not significantly affect our results (or the calculated elasticities), this is consistent with prices being set, at least in part, in response to factors, such as technological change, that affect physician productivity, something that warrants further investigation in future work.

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39 We remind the reader should that our sample is restricted to physicians providing 2 aggregate services. It will be interesting to see if similar results are found on other samples of physicians.
Table 5: Full-Information Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model and Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) No Trend</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.647*** (0.083)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>-0.195*** (0.052)</td>
</tr>
<tr>
<td>$b_{1,12}$</td>
<td>1.316*** (0.211)</td>
</tr>
<tr>
<td>$b_{1,13}$</td>
<td>-0.957*** (0.274)</td>
</tr>
<tr>
<td>$b_2$</td>
<td>1.948*** (0.291)</td>
</tr>
<tr>
<td>$b_3$</td>
<td>0.952*** (0.301)</td>
</tr>
<tr>
<td>$b_{\text{Male}}$</td>
<td>-0.094 (0.155)</td>
</tr>
<tr>
<td>$b_{\text{Dmid}}$</td>
<td>0.199* (0.107)</td>
</tr>
<tr>
<td>$b_{\text{Dold}}$</td>
<td>0.093 (0.151)</td>
</tr>
<tr>
<td>$Y_{\text{Market}}$</td>
<td>0.023*** (0.010)</td>
</tr>
<tr>
<td>$b_{\text{Trend}_3}$</td>
<td>–</td>
</tr>
<tr>
<td>$\Gamma_{\text{Male}}$</td>
<td>0.003 (0.170)</td>
</tr>
<tr>
<td>$\Gamma_{\text{Dold}}$</td>
<td>-0.200 (0.124)</td>
</tr>
<tr>
<td>$\sigma_e$</td>
<td>0.876*** (0.244)</td>
</tr>
</tbody>
</table>

Observations | 1300 | 1300

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
8 Incentive Effects

Estimation of the full-information model allows us to provide a complete characterization of the reaction of physicians to monetary incentives. We use our parameter estimates from the version without a trend to calculate the income and substitution effects of price changes on total hours providing services, $h$, and services supplied. We calculate the effects for each observation in the year 2002 and then average over these observations. In each case, we report the overall effect of the price change, along with its income and substitution effect. Simulated 95% confidence intervals are reported below the calculated estimate.

The own-price elasticities for services are presented in Table 6. The estimated substitution effects are all positive and larger than their corresponding estimated lower bounds from Table 4. The estimated income effects are all negative, indicating that leisure is a normal good. For all cases the overall elasticity is significantly positive, suggesting that the substitution effect dominates the income effect when a single price is changed.

Table 7 presents the cross-price elasticities for services. The overall elasticities are all negative, indicating services are gross substitutes. The lack of symmetry reflects the non-linear effects in the changing prices, noted in Table 7.

Table 8 presents the changes in hours worked, devoted to providing services, due to changes in prices and the wage index. The substitution effects are all positive, but are dominated by negative income effects; Marshallian (uncompensated) hours elasticities with respect to the wage index are small and negative. The point estimates are -0.118, for physicians providing services 1 and 2, and -0.116, for physicians providing services 1 and 3. This result is consistent with the consensus view that physicians’ labour supply is highly inelastic in response to wage changes (for a recent review of the literature, see Lee, Propper, and Stoye, 2019). This should not come as a surprise since physicians are generally at the top level of income and work a large number of hours per week, making the value of additional leisure very high. Therefore it is quite intuitive that there is a large income effect that can cancel out, or even be larger than, the substitution effect, generating a backward-bending labour supply curve (see Feldstein, 1970; Sloan, 1975; Kalb, Kuehnle,

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40The income effects are calculated using the derivative of utility with respect to non-labour income, $y$. If our estimates of $y$ include a preference parameter, capturing perceived income for example, then the elasticity should be interpreted in those terms.

41The bootstrap is parametric. Following Krinsky and Robb (1986) and Krinsky and Robb (1990), we repeatedly draw, parameters from a normal distribution, setting the mean to the estimated parameter vector and using the estimated variance-covariance matrix of the parameter estimates. The reported confidence intervals are based on 999 replications.
Scott, Cheng, and Jeon, 2018). Interestingly, our results are very close to those obtained by Kalb, Kuehnle, Scott, Cheng, and Jeon (2018) who present an econometric analysis of both general practitioners’ and specialists’ labour supplies at the intensive margin in Australia. Their study uses both a structural discrete choice approach and a reduced-form approach. Also, their analysis is done separately for male and female physicians. Their results suggest that the uncompensated wage labour supply elasticities are small and negative both for male specialists: $\eta_m \in [-0.134, -0.023]$, and for female specialists: $\eta_f \in [-0.103, -0.030]$. Moreover, their estimates are robust to the specifications used and to physician gender.

It is more difficult to compare our static elasticity results with those of non-physicians in general. The basic reason is that there does not seem to be a consensus regarding their levels in the literature (see Keane, 2011, for an excellent and comprehensive review). Estimates vary significantly depending on: the income tax treatment (e.g., piecewise linear constraint vs linear constraint), the wage and nonwage definitions, the treatment of fixed costs of working, the econometric approach (e.g., parametric vs nonparametric), whether the model is static or dynamic, and on the gender considered.

However, when focusing only on the static uncompensated labour supply elasticities, one can conclude that they are small, can be positive or negative for men, and are positive and much higher for (married) women (due to a higher substitution between leisure, including work at home, and income). Thus, according to Keane’s Table 6 (based on several empirical studies) the uncompensated static labour supply elasticity for men falls in the following interval: $\eta_m \in [-0.16, 0.19]$ while that for (married) women falls in the following interval: $\eta_f \in [-0.20, 0.89]$ (see Keane’s Table 7). Therefore, one can conclude that our static labour supply elasticities estimates are consistent with those estimated in the literature for non-physicians. Note that a large majority of specialists (74%) working in Quebec in 2000 were men. Therefore one should put much more emphasis on the comparison of our results with $\eta_m$.

8.1 Model Fit

The model fit is presented for the version without trend in Figure 1. 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. In particular, it matches very well the increase in earnings following the rise
Table 6: Own-Price Service Elasticities 2002

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Elasticity</th>
<th>Income Effect</th>
<th>Substitution Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{A_1,P_{12}}$</td>
<td>1.799</td>
<td>[-0.054]</td>
<td>1.852</td>
</tr>
<tr>
<td></td>
<td>[0.889, 3.206]</td>
<td>[-0.080, -0.032]</td>
<td>[0.948, 3.233]</td>
</tr>
<tr>
<td>$\eta_{A_2,P_2}$</td>
<td>0.150</td>
<td>[-0.427]</td>
<td>0.576</td>
</tr>
<tr>
<td></td>
<td>[0.052, 0.313]</td>
<td>[-0.521, -0.336]</td>
<td>[0.416, 0.795]</td>
</tr>
<tr>
<td>$\eta_{A_1,P_{13}}$</td>
<td>1.770</td>
<td>[-0.054]</td>
<td>1.824</td>
</tr>
<tr>
<td></td>
<td>[0.928, 3.112]</td>
<td>[-0.126, -0.015]</td>
<td>[0.973, 3.165]</td>
</tr>
<tr>
<td>$\eta_{A_3,P_3}$</td>
<td>0.179</td>
<td>[-0.410]</td>
<td>0.589</td>
</tr>
<tr>
<td></td>
<td>[-0.025, 0.615]</td>
<td>[-0.515, -0.322]</td>
<td>[0.350, 0.997]</td>
</tr>
</tbody>
</table>

Table 7: Cross-Price Service Elasticities 2002

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Elasticity</th>
<th>Income Effect</th>
<th>Substitution Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{A_1,P_{12}}$</td>
<td>-1.876</td>
<td>[-0.427]</td>
<td>-1.449</td>
</tr>
<tr>
<td></td>
<td>[-3.283, -0.963]</td>
<td>[-0.521, -0.336]</td>
<td>[-2.765, -0.624]</td>
</tr>
<tr>
<td>$\eta_{A_2,P_1}$</td>
<td>-0.227</td>
<td>[-0.054]</td>
<td>-0.173</td>
</tr>
<tr>
<td></td>
<td>[-0.395, -0.126]</td>
<td>[-0.080, -0.032]</td>
<td>[-0.327, -0.087]</td>
</tr>
<tr>
<td>$\eta_{A_1,P_{13}}$</td>
<td>-1.847</td>
<td>[-0.410]</td>
<td>-1.437</td>
</tr>
<tr>
<td></td>
<td>[-3.192, -1.005]</td>
<td>[-0.515, -0.322]</td>
<td>[-2.728, -0.772]</td>
</tr>
<tr>
<td>$\eta_{A_3,P_1}$</td>
<td>-0.256</td>
<td>[-0.054]</td>
<td>-0.201</td>
</tr>
<tr>
<td></td>
<td>[-0.669, -0.057]</td>
<td>[-0.126, -0.015]</td>
<td>[-0.544, -0.041]</td>
</tr>
</tbody>
</table>
in prices. It is notable, however, that there is a tendency to overestimate both hours and earnings in year 4.

8.2 Policy Simulation

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 Québec 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.

To evaluate the effects of this policy, we calculated (23) at the estimated parameter values. The results are presented in bottom two rows of Table 8 for physicians providing services 1 and 2, \( \eta_{h_1, w_{12}} \), and for physicians providing services 1 and 3, \( \eta_{h_1, w_{13}} \). In both cases, hours worked and the volume of all services are predicted to decrease. The hours elasticities are \(-0.118\) and \(-0.116\). Multiplying by 30 and by the estimate of \( \delta \) gives estimates of the percent service response to the 30% increase in all prices. This is \(-2.29\%

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Elasticity</th>
<th>Income Effect</th>
<th>Substitution Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta_{h_1, P_{12}} )</td>
<td>-0.014</td>
<td>-0.085</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>[-0.026, -0.006]</td>
<td>[-0.131, -0.046]</td>
<td>[0.039, 0.107]</td>
</tr>
<tr>
<td>( \eta_{h_1, P_{13}} )</td>
<td>-0.013</td>
<td>-0.083</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>[-0.029, -0.004]</td>
<td>[-0.184, -0.022]</td>
<td>[0.018, 0.159]</td>
</tr>
<tr>
<td>( \eta_{h_1, P_{2}} )</td>
<td>-0.108</td>
<td>-0.660</td>
<td>0.552</td>
</tr>
<tr>
<td></td>
<td>[-0.150, -0.067]</td>
<td>[-0.737, -0.597]</td>
<td>[0.486, 0.629]</td>
</tr>
<tr>
<td>( \eta_{h_1, P_{3}} )</td>
<td>-0.107</td>
<td>-0.636</td>
<td>0.529</td>
</tr>
<tr>
<td></td>
<td>[-0.153, -0.060]</td>
<td>[-0.738, -0.523]</td>
<td>[0.437, 0.625]</td>
</tr>
<tr>
<td>( \eta_{h_1, w_{12}} )</td>
<td>-0.118</td>
<td>-0.722</td>
<td>0.604</td>
</tr>
<tr>
<td></td>
<td>[-0.165, -0.074]</td>
<td>[-0.766, -0.676]</td>
<td>[0.552, 0.656]</td>
</tr>
<tr>
<td>( \eta_{h_1, w_{13}} )</td>
<td>-0.116</td>
<td>-0.692</td>
<td>0.576</td>
</tr>
<tr>
<td></td>
<td>[-0.158, -0.074]</td>
<td>[-0.736, -0.644]</td>
<td>[0.514, 0.638]</td>
</tr>
</tbody>
</table>
for physicians providing services 1 and 2 and $-2.25\%$ for physicians providing services 1 and 3.

These results contrast with those in which the price of single service is increased (see Table 6), which give positive own-price effects. The difference here 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 over all services.\(^{42}\)

\(^{42}\)This result is also consistent with a “target income hypothesis” (see Kantarevic, Kralj, and Weinkauf, 2008; McGuire and Pauly, 1991).
9 Discussion and Conclusion

We have introduced the conditional earnings function and established the information it contains over physicians’ behaviour. Under multitasking, the conditional earnings function is a maximum-value function, returning the maximum earnings a physician can generate for a fixed number of hours worked. It can be estimated using limited or full-information methods. Applying the Le Chatelier Principle, limited information methods identify a lower bound to the own-price substitution effect for medical services. Identifying the complete reaction to incentives, including the income effect, requires full-information estimation methods.

We have estimated the earnings function for a particular economic model. While illustrative, our empirical work contains many noteworthy results. First, income effects are important in determining physicians’ responses to incentives. This is highlighted by different supply reactions to changes in a single price and to broad-based price changes. Changing a single relative price generates a positive response from physicians in our sample as strong substitution effects outweigh the income effect associated with the price change. In contrast, a proportional change in all fees induces a smaller substitution effect and the income effect dominates. These results have policy implications for the provision of health 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. Meanwhile, broad-based price increases induce income effects (with implications for the access to health care) that should be taken into account in government negotiations with physicians. 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 (2019) 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 statics. Yet it is powerful enough to predict physician behaviour, capturing both income and substitution effects. Nevertheless, our model could be extended in various ways to allow for a richer analysis of physician behaviour. Part of the model’s parsimony is due to the aggregation of services, the assumptions of homogeneous marginal return to hours worked across services, and common shocks. Introducing heterogeneity would allow for richer responses to incentives, but would also complicate estimating the model. For example, optimal hours devoted to individual services would require numerical solutions.
and would no longer be proportional to total hours worked. We are also constrained by our data in this respect as we only observe total hours, rather than hours devoted to each service. This may hinder identifying a model with more heterogeneity. Similarly, disaggregating services would allow for the analysis of corner solutions in the supply of particular services, again allowing for a richer analysis of physician behaviour. We have also ruled out demand factors as determinants of the observed observed services and prices. This makes sense within the Canadian health-care system which supplies services in the public sector. Extending the model to account for market-clearing quantities and prices would allow for applications in market-based healthcare systems. We also note the possibility of sample-selection biases. We have estimated our model exclusively on a sample of physicians who are paid fee-for-service contracts. In future work, it will be interesting to investigate whether similar results remain when the model is extended to incorporate physicians under alternative compensation systems.

Another issue is the incorporation of the quality of services into the model. Physician decisions over the supply of services can also affect their quality and social welfare. Clemens and Gottlieb (2014) found that the response to price shocks was greater for elective procedures than for medically necessary ones. They interpreted their result in terms of physicians preferences for patient health and the quality of care. Extending our analysis to account for these elements would require a data set that contains information on the health outcomes of patients and that follows patients through time. More extensive data sets may also contain more information on physician characteristics that can affect labour supply, such as marital status or the presence of young children in the household (e.g., Cheng, Kalb, and Scott, 2018), or a richer set of instruments that allow for more precise estimates of the earnings function. A popular instrument in labour-supply models is based on changes in the tax rate (e.g., Blundell, Duncan, and Meghir, 1998; Showalter and Thurston, 1997). While no tax reform was present in the years covered by our data, recent reforms have taken place in Qu´ebec. It would be interesting to investigate the use of these reforms as instruments for hours worked in the earnings function. Finally, our analysis has concentrated on interior solutions in a static setting. In this regard, we have followed much of the literature in focussing on the intensive margin of physician labour supply (eg. Showalter and Thurston, 1997; Baltagi, Bratberg, and Holmas, 2005; Crossley, Hurley, and Jeon, 2009; Kalb, Kuehnle, Scott, Cheng, and Jeon, 2018). Since physicians belong to high-income groups, participation decisions are generally thought to be of secondary importance.43 Incorporating participation decisions and dynamics into our analysis may

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43 See, for example, Baltagi, Bratberg, and Holmas (2005) and Kalb, Kuehnle, Scott, Cheng, and Jeon (2018).
provide a richer characterisation of the response to incentives and how physician productivity changes due to learning by doing. We leave such extensions for future research.

Note, however, Cheng and Trivedi (2015) found some evidence for attrition bias affecting earnings amongst specialist physicians in Australia.
References


Appendix A1: The Conditional Earnings Function

Proof of Lemma 1.
The proof is by induction. We derive the result for the cases of physicians providing two and three services and then generalize to $J$ services.

With two services, the first-order conditions (5) can be written

$$\alpha_1 f_1'(h_1^*) - \alpha_2 f_2'(h_s - h_1^*) = 0.$$  

Differentiating with respect to $h_s$ gives

$$\alpha_1 f_1''(h_1^*) \frac{\partial h_1^*}{\partial h_s} - \alpha_2 f_2''(h_s - h_1^*) + \alpha_2 f_2'(h_s - h_1^*) \frac{\partial h_1^*}{\partial h_s} = 0,$$

or

$$\frac{\partial h_1^*}{\partial h_s} = \frac{\alpha_2 f_2''(h_s - h_1^*)}{\alpha_1 f_1''(h_1^*) + \alpha_2 f_2''(h_s - h_1^*)} = \frac{\alpha_2 f_2'(h_s - h_1^*)}{\alpha_1 f_1''(h_1^*) + \alpha_2 f_2''(h_s - h_1^*)} > 0,$$

since $f_j'' < 0$, $\alpha_j > 0$, $j = 1, 2$; and $h_2^* = h_s - h_1^*$ from the constraint. Solving from the constraint $h_2^* = h_s - h_1^*$,

$$\frac{\partial h_2^*}{\partial h_s} = 1 - \frac{\partial h_1^*}{\partial h_s} = 1 - \frac{\alpha_2 f_2'(h_s - h_1^*)}{\alpha_1 f_1''(h_1^*) + \alpha_2 f_2''(h_s - h_1^*)} = \frac{\alpha_2 f_2'(h_1^*)}{\alpha_1 f_1''(h_1^*) + \alpha_2 f_2''(h_s - h_1^*)} > 0.$$  

For three services, the first-order conditions (5) can be written

$$\alpha_1 f_1'(h_1^*) - \alpha_3 f_3'(h_s - h_1^* - h_2^*) = 0$$
$$\alpha_2 f_2'(h_2^*) - \alpha_3 f_3'(h_s - h_1^* - h_2^*) = 0.$$  

Differentiating with respect to $h_s$ we have

$$\left[ \alpha_1 f_1''(h_1^*) + \alpha_3 f_3''(h_3^*) \right] \frac{\partial h_1^*}{\partial h_s} + \alpha_3 f_3''(h_3^*) \frac{\partial h_2^*}{\partial h_s} = \alpha_3 f_3''(h_3^*),$$

$$\alpha_3 f_3''(h_3^*) \frac{\partial h_1^*}{\partial h_s} + \left[ \alpha_2 f_2''(h_2^*) + \alpha_3 f_3''(h_3^*) \right] \frac{\partial h_2^*}{\partial h_s} = \alpha_3 f_3''(h_3^*).$$
Solving (32) gives
\[ \frac{\partial h^*_2}{\partial h_s} = \alpha_3 f''_2(h^*_3) \frac{\left(1 - \frac{\partial h^*_3}{\partial h_s}\right)}{[\alpha_2 f''_2(h^*_2) + \alpha_3 f''_3(h^*_3)]}. \] \hspace{1cm} (33)

Substituting into (31) and rearranging, we have
\[ \frac{\partial h^*_1}{\partial h_s} = \frac{\alpha_2 \alpha_3 f''_1(h^*_1) f''_3(h^*_3)}{[\alpha_1 \alpha_2 f''_1(h^*_1) f''_2(h^*_2) + \alpha_1 \alpha_3 f''_1(h^*_1) f''_3(h^*_3) + \alpha_2 \alpha_3 f''_2(h^*_2) f''_3(h^*_3)]} > 0. \]

Substituting back into (33) gives
\[ \frac{\partial h^*_2}{\partial h_s} = \frac{\alpha_1 \alpha_3 f''_1(h^*_1) f''_3(h^*_3)}{[\alpha_1 \alpha_2 f''_1(h^*_1) f''_2(h^*_2) + \alpha_1 \alpha_3 f''_1(h^*_1) f''_3(h^*_3) + \alpha_2 \alpha_3 f''_2(h^*_2) f''_3(h^*_3)]} > 0. \]

Finally, using the constraint, \( h^*_3 = h_s - h^*_1 - h^*_2 \), gives
\[ \frac{\partial h^*_3}{\partial h_s} = \frac{\alpha_1 \alpha_2 f''_1(h^*_1) f''_2(h^*_2)}{[\alpha_1 \alpha_2 f''_1(h^*_1) f''_2(h^*_2) + \alpha_1 \alpha_3 f''_1(h^*_1) f''_3(h^*_3) + \alpha_2 \alpha_3 f''_2(h^*_2) f''_3(h^*_3)]} > 0. \]

With \( J \) services, these formulas generalize to:
\[ \frac{\partial h^*_j}{\partial h_s} = \frac{\prod_{i \neq j} \alpha_k f''_k(h^*_k)}{\sum_{j=1}^{J} \prod_{i \neq j} \alpha_k f''_k(h^*_k)} > 0, \]
which is positive since each term \( \prod_{k \neq j} \alpha_k f''_k(h^*_k) \) has the same sign.
Properties of the Conditional Earnings Function

The conditional earnings function has the following properties.

1. The partial derivative with respect to $\alpha_j$ is equal to $A_j^*(a, h_s)$, the conditional supply of service $j$.

$$
\mathcal{E}(a; h_s) = \sum_{j=1}^J \alpha_j A_j^*(a; h_s)
$$

$$
= \sum_{j=1}^J \alpha_j f_j(h_j^*(a; h_s))
$$

$$
= \alpha_j f_j(h_j^*(a; h_s)) + \sum_{k \neq j}^{l-1} \alpha_k f_k(h_k^*(a; h_s)) + \alpha_j f_j(h_j^*(a; h_s))
$$

$$
= \alpha_j f_j(h_j^*(a; h_s)) + \sum_{k \neq j}^{l-1} \alpha_k f_k(h_k^*(a; h_s)) + \alpha_j f_j(h_j^*(a; h_s)).
$$

Taking the partial derivative with respect to $\alpha_j$ gives

$$
\frac{\partial \mathcal{E}}{\partial \alpha_j} = f_j(h_j^*) + \alpha_j f_j'(h_j^*) \frac{\partial h_j^*}{\partial \alpha_j} + \sum_{k \neq j}^{l-1} \alpha_k f_k'(h_k^*) \frac{\partial h_k^*}{\partial \alpha_j} - \alpha_j f_j'(h_j^*) \frac{\partial h_j^*}{\partial \alpha_j}
$$

$$
= f_j(h_j^*) + \sum_{k=1}^{l-1} \left[ \alpha_k f_k'(h_k^*) - \alpha_j f_j'(h_j^*) \right] \frac{\partial h_k^*}{\partial \alpha_j}
$$

$$
= f_j(h_j^*) = A_j^* \text{ by (6)}.
$$

2. The second partial derivative of the earnings function with respect to $\alpha_j$ is equal to the slope of the conditional supply of service $j$:

$$
\frac{\partial^2 \mathcal{E}}{\partial \alpha_j^2} = \frac{\partial A_j^*}{\partial \alpha_j} = f_j'(h_j^*) \frac{\partial h_j^*}{\partial \alpha_j}.
$$

This follows directly from property 1.

3. Convex in prices. Since physicians select $h_j^*$ to maximize earnings, when prices adjust, they can increase their earnings by more than the simple price change by reoptimizing.

Let $a_1, a_2$ be two price vectors and $a_3 = \theta a_1 + (1 - \theta) a_2$ for $\theta \in (0, 1)$. Let $h_{1,j}, h_{2,j}, h_{3,j}$ denote the optimal hours allocated to service $j$ under price vectors $a_1, a_2, \text{ and } a_3$, respectively. The
earnings function evaluated at $\alpha_3$ is

$$E(\alpha_3; h_s) = \sum_{j=1}^{l} a_{3,j} f_j(h^*_3,j)$$

$$= \sum_{j=1}^{l} (\theta a_{1,j} + (1 - \theta) a_{2,j}) f_j(h^*_3,j). \quad (34)$$

Since $h^*_1,j$ is optimal at $\alpha_1$, and $h^*_2,j$ is optimal at $\alpha_2$ it must be the case that

$$\sum_{j=1}^{l} a_{1,j} f_j(h^*_1,j) \geq \sum_{j=1}^{l} a_{1,j} f_j(h^*_3,j) \quad \forall j \quad \text{and} \quad \sum_{j=1}^{l} a_{2,j} f_j(h^*_2,j) \geq \sum_{j=1}^{l} a_{2,j} f_j(h^*_3,j) \quad \forall j.$$

Substituting into (34) gives

$$E(\alpha_3; h_s) = \sum_{j=1}^{l} (\theta a_{1,j} f_j(h^*_3,j) + (1 - \theta) a_{2,j} f_j(h^*_3,j))$$

$$\leq \sum_{j=1}^{l} \theta a_{1,j} f_j(h^*_1,j) + (1 - \theta) a_{2,j} f_j(h^*_2,j) = \theta E(\alpha_1; h_s) + (1 - \theta) E(\alpha_2; h_s)$$

so:

$$E(\theta a + (1 - \theta) a_2; h_s) \leq \theta E(\alpha_1; h_s) + (1 - \theta) E(\alpha_2; h_s).$$
4. The second derivative of the earnings function with respect to $\alpha_j$ provides a lower bound to the own-price substitution effect of $\alpha_j$ on $A_j$.

Let $\bar{u}$ denote the level of utility attained when supplying optimal hours $h_s^*$. We use $h_s^{*\bar{u}}$ to denote the hicksian supply of hours. We evaluate the conditional supply for service $j$, $h_j^*(\alpha; h_s)$, at $h_s^{*\bar{u}}$. This gives the identity

$$h_j^*(\alpha; h_s^{*\bar{u}}) \equiv h_j^{*\bar{u}}(\alpha; \bar{u}),$$

where $h_j^{*\bar{u}}(\alpha; \bar{u})$ is the hicksian supply of hours to service $j$. Note, given $f_j$ is a monotonic increasing function, the following are implied:

$$A_j^* = f_j(h_j^*(\alpha, h_s^{*\bar{u}})) \equiv f_j(h_j^{*\bar{u}}(\alpha; \bar{u})) = A_j^\bar{u},$$

$$f_j'(h_j^*) = f_j'(h_j^{*\bar{u}}).$$

Differentiating the identity (35) with respect to $\alpha_j$ gives

$$f_j'(h_j^*) \frac{\partial h_j^*}{\partial \alpha_j} + f_j'(h_j^{*\bar{u}}) \frac{\partial h_j^{*\bar{u}}}{\partial \alpha_j} = f_j'(h_j^{*\bar{u}}) \frac{\partial h_j^{*\bar{u}}}{\partial \alpha_j}$$

or

$$f_j'(h_j^*) \frac{\partial h_j^{*\bar{u}}}{\partial \alpha_j} + f_j'(h_j^{*\bar{u}}) \frac{\partial h_j^*}{\partial \alpha_j} = f_j'(h_j^*) \frac{\partial h_j^{*\bar{u}}}{\partial \alpha_j},$$

(36)

since $f_j'(h_j^*) = f_j'(h_j^{*\bar{u}})$. The term on the right-hand side of (36) is the own-price substitution effect of $\alpha_j$ on $A_j$. Rearranging gives

$$f_j'(h_j^*) \frac{\partial h_j^*}{\partial \alpha_j} = f_j'(h_j^{*\bar{u}}) \frac{\partial h_j^{*\bar{u}}}{\partial \alpha_j} - f_j'(h_j^{*\bar{u}}) \frac{\partial h_j^*}{\partial \alpha_j}.$$

The term on the left-hand side is the second partial derivative of the earnings function with respect to $\alpha_j$, from (2). The term

$$\frac{\partial h_j^*}{\partial h_s} \frac{\partial h_s^{*\bar{u}}}{\partial \alpha_j} > 0.$$

Any increase in $\alpha_j$ increases the return to hours worked $h_s$. Hence $\frac{\partial h_s^{*\bar{u}}}{\partial \alpha_j} > 0$ is positive since the substitution effect on hours worked is positive when indifference curves are strictly convex. Moreover, any increase in $h_s$ is distributed across all services, $\frac{\partial h_j^*}{\partial \alpha_j} > 0$ as shown in Lemma 1.
Appendix A2: Composite Services

To aggregate services we use the hicks composite commodity theorem. 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 \( \theta \) with respect to their base-period prices, denoted \( \alpha^0_i, \alpha^0_j \), then we can write

\[
\alpha_k, t = \theta^t \alpha^0_k \quad \text{and} \quad \alpha_j, t = \theta^t \alpha^0_j.
\]

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

\[
\frac{\alpha_i, t}{\alpha_j, t} = \frac{\alpha^0_i}{\alpha^0_j}.
\]

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 \( \Theta_j \) denote the group of services associated with each \( \theta_j, \quad j \in \{1, 2, ..., q\} \).

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

\[
\text{max}_{\{M,h_1,h_2,...,h_n,h_s\}} U = \left[ M^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right]^{\frac{1}{\rho}}
\]

s.t. (i) \( M = \sum_{j=1}^{n} \alpha_j A_j + y \).

(ii) \( A_j = b_j h_j e, \quad j = 1, 2, ..., n. \)

(iii) \( h_s = \sum_{j=1}^{n} h_j. \)

then medical services can be aggregated in \( q < n \) groups of services. The aggregate service vector is \((\sum_{j \in \Theta_1} \alpha^0_j A_j, \sum_{j \in \Theta_2} \alpha^0_j A_j, ..., \sum_{j \in \Theta_q} \alpha^0_j A_j)\) and the associated price vector is \((\theta_1, \theta_2, ..., \theta_q)\).

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

\[
\left[ (wh^\rho e + e(w, u^0))^\rho + 2^{1-\rho}(T - h_s)^\rho \right]^{\frac{1}{\rho}} = u^0 \quad \text{or} \quad e(w, u^0) = \left[ (u^0)^\rho - 2^{1-\rho}(T - h_s)^\rho \right]^{1/\rho} - wh^\rho e.
\]

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

\[
- \frac{de}{d\theta_k} = \frac{dw}{d\theta_k} h_s^\delta \epsilon. \tag{37}
\]

The derivative of \( w \) with respect to \( \theta_k \) is

\[
\frac{dw}{d\theta_k} = \frac{d}{d\theta_k} \left( \sum_{j \in \Theta_1} (b_j \theta_1 a_j^0)^{1-\delta} + \sum_{j \in \Theta_2} (b_j \theta_2 a_j^0)^{1-\delta} + \ldots + \sum_{j \in \Theta_k} (b_j \theta_k a_j^0)^{1-\delta} + \sum_{j \in \Theta_q} (b_j \theta_q a_j^0)^{1-\delta} \right)^{1-\delta}
\]

\[
= \sum_{j \in \Theta_k} b_j a_j^0 \left( \frac{(b_j a_j)^{1-\delta}}{\Delta} \right)^\delta,
\]

where

\[
\Delta = \sum_{j \in \Theta_1} (b_j a_j)^{1-\delta} + \sum_{j \in \Theta_2} (b_j a_j)^{1-\delta} + \ldots + \sum_{j \in \Theta_k} (b_j a_j)^{1-\delta} + \sum_{j \in \Theta_q} (b_j a_j)^{1-\delta}.
\]

Substituting into (37), we have:

\[
- \frac{de}{d\theta_k} = \sum_{j \in \Theta_k} b_j a_j^0 \left( \frac{(b_j a_j)^{1-\delta}}{\Delta} \right)^\delta h_s^\delta \epsilon.
\]

The optimal allocation of hours across services implies

\[
h_j = \frac{(b_j a_j)^{1-\delta}}{\Delta} h_s.
\]

Hence,

\[
\frac{de}{d\theta_k} = \sum_{j \in \Theta_k} a_j^0 b_j h_s^\delta \epsilon = \sum_{j \in \Theta_k} a_j^0 A_j.
\]

The composite service is total revenue from the services in \( \Theta_k \) during period \( t \), evaluated at base-period prices. The price of the composite service is \( \theta \), the percent change in prices over time.

A2.2
Appendix A3: Aggregation and Variable Construction

We aggregate services through the composite-commodity theorem. Our data cover a period during which the Québec 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 by 0, 5, 10, 15, 20 and 25 percent. Let \( \alpha_t^j \) 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 \( \theta \) based on the geometric average growth rate of the price of service \( j \) between \( t = 2000 \) and \( t = 2002 \). Denote this geometric average by \( \lambda \), then

\[
\lambda_j = \text{Round}_{0.05} \left[ \left( \frac{\alpha_{2002}^j}{\alpha_{2000}^j} \right)^{0.5} - 1 \right]
\]

Where \( \text{Round}_{0.05} \) denotes the rounding operator. All services with the same \( \lambda \) were aggregated into the same group. If there are \( m > 2 \) services for with the same \( \lambda \), their composite service volume — provided by physician \( i \) — is calculated as \( \sum_{j=1}^{m} A_{ij} \), where \( A_{ij} \) is the number of services \( j \) performed by physician \( i \) at time \( t \). The nominal price of this composite service is then \( \theta = \lambda + 1 \). We then convert nominal prices to real prices for each period, by dividing by a price index.

---

\(^{44}\)The derivation of the theorem within our context as well as the construction of the data is given in Shearer, Somé, and Fortin (2019).

\(^{45}\)We use the price index of health care services: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ161f-eng.htm.
Appendix A4: 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 supplied 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

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s},$$

where $\alpha_2 = I_{G_{12}}(s) \alpha_2 + I_{G_{13}}(s) \alpha_3$ and $A_{2s} = I_{G_{12}}(s) A_{2s} + I_{G_{13}}(s) A_{3s}$ with $I_{G_{ij}}(s) = 1$ 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 $\alpha_j$ 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

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_3 A_{3s},$$

where

$$\alpha_3 = a_3 I_{G_{123}}(s) + a_3 I_{G_{125}}(s) + a_6 I_{G_{126}}(s)$$

$$A_{3s} = A_3 I_{G_{123}}(s) + A_5 I_{G_{125}}(s) + A_6 I_{G_{126}}(s),$$

with $I_{G_{12k}}(s) = 1$ 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 $\alpha_j$ 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 earnings for this group as

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

A4.1
where

\[
\alpha_4' = \alpha_3 \mathbb{I}_{G_{1234}}(s) + \alpha_5 \mathbb{I}_{G_{1245}}(s)
\]
\[
A_{4's} = A_{3s} \mathbb{I}_{G_{1234}}(s) + A_{5s} \mathbb{I}_{G_{1245}}(s),
\]

with \( \mathbb{I}_{G_{124k}}(s) = 1 \) if \( s \) belongs to the subgroup \( G_{124k} \) \( (k = 3, 5) \) and 0 otherwise; \( A_{jk} \) is the observed quantity of service \( j = 1, 2, 3, 4, 5 \) provided by specialist \( s \) and \( \alpha_j \) the fee of service \( j \).
### Table 9: Service Descriptions

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